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Minerals Yearbook

1987

Volume I

METALS AND MINERALS

Prepared by staff of the

BUREAU OF MINES

UNITED STATES DEPARTMENT OF THE INTERIOR • Manuel J. Lujan, Jr., Secretary

BUREAU OF MINES • T S Ary, Director

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. administration.

U.S. GOVERNMENT PRINTING OFFICE

WASHINGTON : 1989

Foreword

This edition of the Minerals Yearbook discusses the performance of the worldwide minerals industry during 1987 and provides background information to assist in interpreting that performance. Contents of the individual yearbook volumes follow:

Volume I, Metals and Minerals, contains chapters on virtually all metallic and industrial mineral commodities important to the U.S. economy. In addition, it includes a statistical summary chapter, a chapter on mining and quarrying trends, and a chapter discussing the statistical surveying methods used by the Bureau of Mines.

Volume II, Area Reports: Domestic, contains chapters on the minerals 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.

Volume III, Area Reports: International, contains the latest available mineral data on more than 150 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 users. Therefore, constructive comments and suggestions by readers of the Yearbook will be welcomed.

T S Ary, *Director*

Acknowledgments

Volume I, Metals and Minerals, of the Minerals Yearbook, presents data on about 90 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 domestic minerals industries data were performed by the staffs of the Branches of Ferrous Metals, Nonferrous Metals, and Industrial Minerals of the Division of Mineral Commodities. Statistical data were compiled from information supplied by mineral producers and consumers in response to canvasses, and their voluntary response is gratefully appreciated. Information obtained from individual firms by means of Bureau of Mines canvasses has been grouped to provide statistical aggregates. Data on individual firms are presented only if available from published or other nonproprietary sources or when permission of the respondent has been granted.

The chapter "Nonfuel Minerals Survey Methods" discusses in somewhat greater detail procedures for canvassing the minerals industry and the processing and evaluation of these data.

Other material appearing in this volume was obtained from the trade and technical press, industry contacts, and other sources; and this cooperation is gratefully acknowledged.

Statistics on world production were compiled in the Branch of Geographic Data, Division of International Minerals, from numerous sources including reports from the U.S. Department of State. U.S. foreign trade data were obtained from reports of the Bureau of the Census, U.S. Department of Commerce.

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

V. Anthony Cammarota, Jr., *Chief, Division of Mineral Commodities*

Contents

Nonfuel Minerals Survey Methods

By William R. Vogel[1]

The Bureau of Mines Information and Analysis organization collects worldwide data on virtually every commercially important nonfuel mineral commodity. These data form the base for tracking and assessing the health of the minerals sector of the U.S. economy.

This data collection activity was instituted by the 47th Congress in an appropriations act of August 7, 1882 (22 Stat. 329), to place the collection of mineral statistics on an annual basis. The most recent authority for the Bureau of Mines Information and Analysis activity is the National Materials and Minerals Policy, Research and Development Act of 1980 (Public Law 96-479, 96th Congress), which strengthens protection for proprietary data provided to the U.S. Department of the Interior by persons or firms engaged in any phase of mineral or mineral-material production or consumption.

DATA COLLECTION SURVEYS

The Bureau of Mines initiates the collection of domestic nonfuel minerals statistics with an appraisal of the information requirements of Government and private organizations of the United States. Information needs that can be satisfied by data from the minerals industries are formulated as questions on Bureau of Mines survey forms. Figure 1 shows a typical survey form, "Alumina" (6-1013-A). Specific questions pertaining to the production, consumption, shipments, etc., of mineral commodities by industrial establishments are structured to provide data that will be aggregated into meaningful totals. The entire mineral economic cycle from production to trade and consumption is covered by 168 monthly, quarterly, semiannual, and annual surveys.

Once the survey form has been designed, a list of producers or consumers is developed. Many sources are utilized to determine the companies, mines, plants, and other operations that should be included in the survey to produce meaningful national and State totals. Bureau of Mines State Mineral Officers, State geologists, Federal organizations (e.g., Mine Safety and Health Administration), trade associations, and industry publications and directories are some of the sources that are explored to develop and update survey listings. With few exceptions, an attempt is made to canvass the entire population of appropriate establishments. The iron and steel scrap industry is an example of one of the exceptions where a sampling plan is employed rather than a complete canvass of the entire industry.

Prior to mailing, the survey form must be approved by the Office of Management and Budget (OMB). Under the Paperwork Reduction Act of 1980, OMB approves the need or requirement for collecting the data and protects industry from unwarranted Government paperwork.

The Bureau publishes a "Survey Forms Catalog," which describes the content of each survey. Copies of the catalog may be obtained by contacting the Office of Statistical Standards, U.S. Bureau of Mines, 2401 E Street NW., Washington, DC 20241.

Form 6-1013-A
Nonfer. (9-86)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
WASHINGTON, D.C. 20241

ALUMINA

C04

Form Approved
O.M.B. No. 1032-0004.
INDIVIDUAL COMPANY
DATA-PROPRIETARY

Unless authorization is granted in the section above the signature, the data furnished in this report will be treated in confidence by the Department of the Interior, except that they may be disclosed to Federal defense agencies, or to the Congress upon official request for appropriate purposes.

(Please correct if name or address has changed.)

Please reply to the following questions and return this form as promptly as possible in the enclosed envelope.
If exact data are not available, enter your best estimates and mark "estimated". Submit a separate report for each plant.
"Collection of non-fuel minerals information is authorized by Public Law 96-479 and the Defense Production Act. This information is used to support executive policy decisions pertaining to emergency preparedness and defense and analyses for minerals legislation and industrial trends. The Bureau relies on your voluntary and timely response to assure that its information is complete and accurate."

1. Location of plant: Nearest city or town ________ County ________ State ________

2. Production, Consumption, Shipments, and Stocks of Alumina and Primary Alumina Products During the Year.
Report gross weights of each product in Columns 3-7.

Product (1)	Code	Average Al_2O_3 content (Percent) (2)	Stocks beginning of year (Metric tons) (3)	Production during year (Metric tons) (4)	Consumption during year (Metric tons) (5)	Shipments during year: Quantity (Metric tons) (6)	Shipments during year: Value ($000) (7)	Stocks end of year (Metric tons) (8)
Calcined alumina	201							
Commercial alumina trihydrate	202							
Litho or light hydrate	203							
Activated alumina	204							
Tabular alumina	205							
Other (specify)								

3. Shipments of Alumina During Year by Consuming Industries.
The total quantity of shipments reported should equal the total of the shipments reported in Section 2, Column (6).

Product (1)	Code	Quantity (Metric tons): Calcined (2)	Trihydrate (3)	Activated (4)	Tabular (5)	Other (6)
Abrasive	301					
Aluminum	302					
Chemical	303					
Refractory:						
Brick and shapes	305					
Monolithic	306					
Calcium aluminate cement	307					
Other (specify)						

OVER

4. Consumption of Aluminum-Bearing Materials in the Manufacture of Alumina.

Material (1)	Code	Quantity (Metric tons) (2)	Value at Plant (3)
Bauxite, Domestic	401		$
Bauxite, Foreign:			
Jamaica	402		
Guinea	403		
Surinam	404		
Brazil	405		
Guyana	406		
Dominican Republic	407		
Other Countries (specify)			
Total foreign	419		
Other materials (specify)			

5. Consumption and Stocks of Bauxite.
The quantity in Section 5, Column 3, Line 505, should equal the quantity reported in Section 4, Column 2, Line 401.
The quantity in Section 5, Column 3, Line 515, should equal the quantity reported in Section 4, Column 2, Line 419.

Kind of ore (1)	Code	Stocks beginning of year (Metric tons) (2)	Consumption during year (Metric tons) (3)	Stocks end of year (Metric tons) (4)
Domestic:				
Undried	501			
Dried	502			
Activated	503			
Calcined or sintered	504			
Total domestic	505			
Foreign:				
Undried or partially dried	506			
Dried	507			
Other (specify)				
Total foreign	515			

Remarks:

PUBLICATIONS: Annual statistical information is published for aluminum and bauxite. If you desire a copy of one or both of these commodity reports, please check the appropriate box. ☐ (1) Aluminum ☐ (2) Bauxite ☐ (3) Both

Name of person to be contacted regarding this report:	Tel. area code	No.	Ext.
Address No. Street	City	State	Zip

May tabulations be published which could indirectly reveal the data reported above?
Value data ☐ (1) Yes ☐ (2) No Other (including quantity) data ☐ (1) Yes ☐ (2) No

Signature	Title	Date

Figure 1. A typical survey form.

SURVEY PROCESSING

The 168 surveys yield more than 57,000 responses from approximately 26,000 establishments annually. Each of the completed survey forms returned to the Bureau undergoes extensive scrutiny to ensure the highest level of accuracy possible in recording mineral data. Bureau specialists ensure that no error is introduced owing to reporting in units other than those specified on the survey form. Relationships between related measures such as crude ore produced and marketable product are analyzed for consistency. Internal numerical relationships such as column and row totals are checked. The data reported in the current reporting period are checked against prior reports to detect possible errors or omissions.

For automated surveys, the specialist reviews the form for correctness and completeness before the data are entered into the computer. The computer is programmed to conduct a series of automated edit checks to ensure mathematical consistency and to identify any discrepancies between the data reported and logically acceptable responses.

The Bureau of Mines is modernizing and automating all of its survey processing and data dissemination methods. Automation of the commodity data subsystems supports the processing of individual surveys and the preparation of statistical tables for publication. A central data base includes the minerals data gathered through surveys as well as pertinent data from other sources. The data base enables Bureau personnel to retrieve the data required for analysis of minerals problems and for answering specific user questions.

Survey Responses.—To enable the reader to better understand the basis on which the statistics were calculated, each commodity chapter of the "Minerals Yearbook" includes a section entitled "Domestic Data Coverage." This section briefly describes the data sources, the number of establishments surveyed, the response percentage, and the method of estimating the production (or consumption) that is accounted for by nonrespondents.

Although the response to Bureau surveys is generally very good, the Bureau must employ an efficient procedure for handling instances of nonresponse to produce reliable aggregated data. Second mailings of the survey form may be made. Followup by telephone is employed extensively to provide complete data entries on the survey forms, to verify questionable entries, and also to encourage those not reporting to either complete and return survey forms or provide the information orally. Periodic visits to important minerals establishments are also made by Bureau commodity specialists or State Mineral Officers. These visits are made to gather missing data and also to point out the importance of the companies' reporting to the production of accurate national as well as State and county statistics. By showing the use of these statistics and the impact of nonresponse, the Bureau hopes to encourage as complete and accurate a canvass as possible.

The OMB "Guidelines for Reducing Reporting Burden" stipulates that the minimum acceptable response rate shall be 75% of the panel surveyed. In addition, the Bureau strives for a minimum reporting level of 75% of the quantity produced or consumed (depending on the survey) for certain key statistics. Response rates are periodically reviewed, and for those surveys not meeting the minimum reporting level, plans are developed and implemented to improve response rates.

Estimation for Nonresponse.—When efforts to obtain response to a Bureau survey fail, it is necessary to employ estimation or imputation techniques to account for the missing data. These techniques are most effective when the response rate is relatively high. The Bureau is continually striving to develop and make use of the most effective techniques. Some of the imputation methods depend only on knowledge of the prior reporting of the establishment while others rely on external information to estimate the missing data. Survey forms received after publication cutoff dates are edited and necessary imputations are made for missing data. The data base is updated and these revisions will be reflected in subsequent publications.

Protection of Proprietary Data.—The Bureau of Mines relies on the cooperation of the U.S. minerals industry to provide the minerals data that are presented in this and other Bureau publications. Without substantial response to survey requests, the Bureau would not be able to present reliable statistics. The Bureau in turn respects the proprietary nature of the data received from the individual companies and establishments. To ensure that proprietary rights will not be violated, the Bureau analyzes each of the aggregated statistics to ascertain if the statistics of an individual company or establishment can be deduced from the aggregated statistics. For example, if there are only two significant producers of a commodity in a given State, the Bureau will not publish the total for the State since either large producer could readily estimate the production of the other. It is this obligation to protect proprietary information that results in the "Withheld" or "W" entries in "Minerals Yearbook" tables. When the company gives permission in writing, the Bureau may release data otherwise withheld because of proprietary considerations.

INTERNATIONAL DATA

Volume I of the "Minerals Yearbook" contains a "World Review" section in each commodity chapter that usually includes a world production table. These tables are prepared in the Bureau's Division of International Minerals. These data are gathered from various sources including published reports of foreign government mineral and statistical agencies, the U.S. Department of State, and international organizations such as the United Nations and the Organization of Petroleum Exporting Countries. Missing data are estimated by the country specialist based upon information gathered from a variety of sources.

PUBLICATIONS AND DATA SERVICES

In addition to the "Minerals Yearbook," the statistical data collected are published in other reports, the principal series being the "Mineral Industry Surveys." "Mineral Industry Surveys" are concise monthly, quarterly, or annual reports that contain timely statistical and economic data on nonfuel mineral commodities. The surveys are designed to keep Government agencies, the minerals industries, and the business community regularly informed of trends in production, distribution, inventories, and consumption of nonfuel minerals.

One of the earliest publications containing information on mineral production, resources, reserves, imports, exports, uses, recycling, substitution, environmental considerations, and related subjects is "Mineral Commodity Summaries." Published in January, it covers approximately 90 mineral commodities for the previous calendar year.

"Mineral Facts and Problems" is a one-volume reference book containing worldwide production information and demand forecasts for all nonfuel minerals. It is published every 5 years. In the 1985 edition, each commodity chapter covers the structure of the industry, uses of the commodity, reserves and resources, technology, supply-demand relationships, byproducts and coproducts, strategic considerations, economic and operating factors, and forecasts to 1990 and 2000. Each chapter also compares U.S. and world reserves with cumulative demand to appraise the adequacy of world mineral supplies.

The "Mineral Perspectives" series reports on the mineral resources, industries, and related infrastructure of foreign countries or regions of the world that assume major importance to our Nation's mineral needs.

"Minerals and Materials/A Bimonthly Survey" provides timely information on selected commodities. Data and analyses are presented that are germane to policy issues of current interest. Brief narratives are supplemented by statistical graphs and tables. Data are provided for the current month and the previous 17 months.

The "Minerals Yearbook" and "Mineral Facts and Problems" are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. For additional information on the other Bureau publications, contact the Office of Public Information, U.S. Bureau of Mines, 2401 E Street NW., Washington, DC 20241.

Copies of Bureau survey mailing lists are available in printed form. These lists include the company and plant names and the addresses to which the survey forms are mailed. Information on purchasing copies of mailing lists can be obtained from the Office of Statistical Standards, U.S. Bureau of Mines, 2401 E Street NW., Washington, DC 20241.

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[1]Operations research analyst, Office of Statistical Standards.

Mining and Quarrying Trends in the Metals and Industrial Minerals Industries

By Arnold O. Tanner[1]

The recession that took hold of the domestic mining industry in 1981-82 finally abated somewhat in 1987, resulting from increases in many commodity prices, especially in the metals sector, and from continuing success in lowering operating costs. By no means was the work finished; the mining industry was in a sense entering a new era. The struggle for survival was still very evident for many companies and various commodities, but increasing productivity and profits were accompanied by indications that these trends were more long term than short term.

Raw nonfuel minerals produced in the United States during 1987 had an estimated value of $26.3 billion, an increase of $2.9 billion over the 1986 value. This is the fifth consecutive year that the value has increased. Except for a decrease in 1982, the value each year has increased since 1971, or 15 of 16 years. The value of raw metals production increased by an estimated 28%, an impressive improvement since the drastic fall in 1982. Industrial minerals growth was comparatively flat, with an estimated increase in value of 0.1%, continuing a trend of the previous 2 years. Metal mine production dropped considerably in 1982 and maintained its resultant lower level until 1987, when production significantly recovered.

A decrease in imports, low domestic inventories, a decline in the exchange value of the U.S. dollar, and a consistent demand for U.S. goods improved the output and profit picture of mineral and mineral material producers during 1987. Openings and expansions of mines and processing plants well exceeded closings. Real spending for new plant and equipment for primary metal manufacturing increased 21.0%. Total employment in mining fell by 5.2%, but employment at metal mines increased by 5.3%. Prices and output for most mineral commodities in the United States increased in 1987, and the value of raw nonfuel minerals production in the United States increased by 12.3%.

Domestic mine production increased substantially for gold, titanium, copper, iron ore, silver, and bauxite, in descending order. Molybdenum production decreased significantly; lead production was down moderately, and magnesium output fell slightly. Industrial minerals with significantly increased production were boron, lime, phosphate, and potash. Clays, gypsum, soda ash, and crushed stone held fairly even with 1986 production. Small declines occurred for salt and sulfur.

Gold remained the strongest contender among metals in both domestic and international metal mining, as had been the case for a number of years. Gold production continued to be spurred on by the increasing use of heap leaching. This technology made profitable mining ventures out of lower grade ore deposits and even abandoned mine tailings. Gold output in the United States increased from about 3.7 million troy ounces in 1986 to almost 5.0 million ounces in 1987, an impressive 33% rise. This followed the 45-year record increase of 54% in 1986, when the United States overtook Canada as the third largest primary gold producer in the world, behind the Republic of South Africa and the Soviet Union. During

1987, gold bullion imports fell 82% to 2.4 million ounces and exports fell 28% to 2.3 million ounces. The trade deficiency in all precious metals was cut in half, from 137.2 million ounces in 1986 to 67.9 million ounces in 1987. Gold and silver mining, in particular, had a very definite, positive effect on the Nation's economy.[2]

The production of gold bullion and commemorative coins increased worldwide by mining companies, the U.S. Mint, individual States, and a growing number of foreign countries. Demand for gold and silver coins from the U.S. Mint accelerated, with a continuing high demand for American Eagle bullion coins as well as coins commemorating the 200th anniversary of the U.S. Constitution. Additionally, a number of foreign countries, including China and France, produced palladium and platinum coins; Mexico was developing a platinum bullion coin.

Although many metal stocks initially dropped in value by varying amounts following the disruption of the stock market in October, they were not seriously hurt and were identified by some experts as among the bigger winners in the broad market slide.[3] Another positive sign for the year came from a lower 1987 trade deficit for minerals and metals. The deficit for these commodities stood at $23.5 billion, a decrease from the 1986 deficit of $27.6 billion. Total exports increased by 15% to $15.6 billion in 1987, while imports declined 5% to $39.1 billion.[4]

The industry's massive restructurings, imaginative and often bold cost-cutting measures, trend toward teamwork-oriented labor-management relations, use of more-efficient technologies, and application of innovative ideas throughout mining and mineral processing operations appeared to be paying off. Increasing the industry's competitiveness in the world market was the theme of the mining industry and numerous mining conferences throughout the year. Issues that most concerned the industry were regulatory costs and possible tax increases for mining. The regulatory concerns included acid rain, ground water, and mine waste legislation.

Legislation and Government Programs.—Although the mining industry was not ignored by Congress, 1987 was a quiet year for the mining community in terms of legislation that went to the President for his signature.

The National Defense Authorization Act, 1987 (Public Law 100-180), was signed into law by the President in December. The act affirmed the previously authorized stockpile goals, but it also authorized the President to make changes of less than 10% following the submission of the justification to Congress. The change would be made at the beginning of the fiscal year that follows the submission of the justification. Changes greater than 10% would require statutory authorization. The Secretary of Defense was required to send to Congress annually recommendations for stockpile planning, based on mobilization of the United States economy for a global war of not less than 3 years. Additionally, the President, with the consent of the Senate, was to appoint a manager for the National Defense Stockpile.

In the spring, the President signed a bill (Public Law 100-34) that repealed the 2-acre reclamation exemption in the 1977 Surface Mining Control and Reclamation Act (SMCRA). The exemption was intended to protect small privately owned mines but was being technically circumvented. Some mine operators, particularly in the Appalachian Mountains, had divided large mining sites into several small parcels, each one exempt. The bill also revised the rules for the abandoned mine land fund so that States could set aside Federal funds for future reclamation. A State would be able to place into a special trust up to 10% of its annual allocation from the mine land fund. It could use the reserve for future reclamation after the SMCRA payments stopped in 1992.[5]

The Michigan Wilderness Heritage Act, 1987 (Public Law 100-184), became law in December and designated 92,000 acres in Michigan as a Federal wilderness area. The measure shielded 11 areas in 3 national forests from development, which included mineral extraction and logging. At the same time, the bill released for mutiple uses 21,000 additional acres that had been under consideration for designation as wilderness areas.

The U.S. Supreme Court, in *California Coastal Commission* v. *Granite Rock Co.*, upheld a State's right to control mining on Federal lands within its borders. The Court ruled that companies with federally approved mining operations may be required to procure State permits as well. The Court stressed that it was not saying that a State could determine basic uses of Federal land, but that the State could regulate a given mining use so that it would be carried out in an environmentally sensitive and resource-protective fashion. Dissenting Justices noted that the ruling effectively gave the State the power to veto a Federal project. The ruling had broad implications because 6 other States at the time claimed regulatory power over Federal land within their borders, and 13 additional States supported the position of the coastal commission. Also, 700 million acres of land, or about one-third of the United States, was federally owned. The ruling specifically endorsed the commission's right to require that Granite Rock obtain a State permit to mine, by open pit method, chemical-grade limestone in Los Padres National Forest, a scenic and environmentally sensitive area.

In another States rights decision, the Supreme Court upheld an individual State's authority to restrict underground mining in order to protect the land and surface structures. The Court ruled that Pennsylvania could require that 50% of the coal underlying existing housing, public buildings, and cemeteries remain in place to prevent subsidence. In *Keystone Bituminous Coal Association et al.* v. *Duncan*, a group of mine operators had challenged the 1966 Pennsylvania Subsidence and Land Conservation Act, stating that their fifth amendment rights had been violated when they were barred from extracting coal in specified areas. The Court held that Pennsylvania's action did not constitute taking of property without just compensation. The mine operators, it said, had not been denied economically viable use of their lands because only a small percentage of their total coal supplies was affected. The Court said that the protection of the public health and the environment were legitimate State concerns, even though much of the land at issue had been sold at the turn of the century with stipulations releasing mine owners from liability for damage to the surface property. The law mainly affected coal operations, as subsidence was much less common in other types of mining.

In an October ruling, the Supreme Court left intact a lower court ruling that the Federal Government could not be sued by a group of uranium miners who had not been informed of a Federal study on the risks of radiation poisoning in a mine where they worked. The 1980 lawsuit contended that the Federal Government had contributed to the deaths and illnesses of uranium miners who had worked in a privately owned Utah uranium mine since 1950. Those bringing suit said that the Government was aware that radiation was 1,000 times greater than allowable levels and that the Government knew such levels would cause a lung cancer epidemic among the miners.

Exploration.—Mineral exploration in the United States continued to decline in 1987, except in the pursuit of gold and other precious metals. This downtrend had started in 1981. The pace of the decline lessened slightly, probably owing to a midyear rebound in a number of commodity prices, particularly those of copper, lead, and zinc. An estimated 80% of the exploration activities was for gold alone, as was the case in 1986.

Sophisticated remote-sensing instrumentation was fast becoming a valuable tool for mineral exploration, due to new developments in both data processing and sensory technology. Mapping satellites could detect promising mineral classes on the earth's surface. Remote-sensing efforts in the United States mainly relied on two Landsat satellites that had been launched by the Government in 1982 and 1984. Complex scanners aboard the vehicles recorded electronic images of the earth's surface below at seven electromagnetic wavelengths, two of which were sensitive to characteristic reflection "signatures" of mineral classes often found near valuable ores. The recorded data were examined by exploration companies with the help of high-powered computers and specialized software. As they sharpened their data-processing and analytic skills, some companies took second and third looks at prospecting areas they previously had rejected.[6]

Scientists at Homestake Mining Co. (HMC) in California were using the satellite images to find likely areas of gold deposits. They followed up by investigating areas of interest with conventional field techniques. Although many were starting to revive by midyear, the depressed metals prices helped to limit the use of these imaging techniques mostly to gold and petroleum exploration. New satellite construction was planned for the next several years, but governmental budget cutting raised conflicts over apportioning the costs between the Government and the companies licensed to build the satellites.

At the National Aeronautics and Space Administration's Jet Propulsion Laboratory in California, scientists developed an airborne sensor that measured 224 very narrow electromagnetic wavelengths in a continuous range. The Avaris, or Airborne Visible and Infrared Imaging Spectrometer, would provide a precision that was lacking with active satellites' relatively wide-scanning wavelengths. Avaris was successfully tested from a standard, high-altitude U-2 aircraft, where it probably would be initially used, primarily by the scientific community rather than by commercial users. Installation of a similar spectrometer on a space platform was being considered for the mid-1990's.[7]

In a joint venture with three mining companies, the exploration company Earth Search Science Inc. (ESSI) of Salt Lake City, UT, made the data base that it constructed with its Airborne Thematic Mapper (ATM)[8] a key ingredient in the company's recently stepped-up gold prospecting activity in Nevada and Oregon. ESSI used an ATM system that was basically an airborne version of a Landsat scanner. The system was manufactured by Daedalus Enterprises, Ann Arbor, MI. ESSI compiled multispectral scanner imagery of more than 5.5 million acres of Nevada and Oregon terrain, and the company claimed that this was the largest ATM data base produced for exploration in the United States. Two types of multispectral imagery were used. The first was an 11-channel (visible, mid, and thermal infrared) imagery acquired during the daytime to identify mineralized outcrops in mountain ranges. The second type of imagery involved acquiring thermal images before dawn to delineate geological structure and possibly silicification along range front and valley areas. ESSI processed and interpretated all the ATM data. In addition to its own equipment, ESSI used image-processing facilities at the University of Utah.[9]

Exploration core drilling received some assistance from the continued development of polycrystalline diamond (PCD) cutting elements for impregnated-core drill bits. A PCD is formed by the sintering of micrometer-size synthetic diamonds with a catalyzing and binding agent under high pressures. This causes the diamonds to cohere into a composite that doesn't have the natural planes of weakness that natural diamonds have. Under low pressures graphite is formed. The latest impregnated-core bits were made with perfectly formed synthetic diamonds, which were more thermally stable than earlier versions.

One advance included the use of silicon instead of cobalt as a binder in the PCD formation process, because silicon and the silicon carbide resulting from the process are much more compatible with a diamond's thermal properties. The use of cobalt appeared to limit PCD bit drilling to less than 700° C. De Beers Industrial Diamonds Div. of the Republic of South Africa used silicon to produce a high-strength bit that was thermally stable up to 1,200° C. De Beers claimed that the new PCD bits penetrated three or four times as fast as other impregnated bits and lasted as long. The company also reported penetration rates up to 600 millimeters per minute over a 16-meter thickness of hard South African gabbro rock with compressive strengths of about 35,000 pounds per square inch.[10] The improvements in synthetic diamond compounds were increasing total bit life and allowing much faster penetration rates. Some of the new thermally stable bits were made from lower temperature powder matrix alloys sintered in atmospherically controlled furnaces to prevent diamond degradation. When used by a competent driller on high-speed machines, the new bits would often drill more than 100 meters at an average penetration rate of 100 to 150 millimeters per minute in the hardest of Scandinavian rocks. Scandinavia was a likely proving ground for cost-cutting innovations because the region has high labor costs and a broad spectrum of hard and difficult rocks.[11]

The U.S. Geological Survey and the Illinois State Geological Survey made a pilot study on geochemical analyses of insoluble residues from carbonate rocks. The procedure might be useful as a prospecting tool for detecting very small amounts of metals and other minerals, which could indicate the location of such mineral deposits as fluorspar, lead, and zinc. The analyses were done on cores and cuttings from churn- and rotary-drilled wells to assess the resource potential of subsurface carbonate rocks in and on the flanks of the Illinois Basin.[12] The geophysical method of using seismic (sound wave) reflections off subsurface geological structures can help delineate stream channels when exploring for placer gold as well as indicate the direction and extent of gravel, sand, and clay beds. However, reflection surveys very often are too costly for mining operations. Such surveys usually are conducted by the petroleum industry, and these tend to be much deeper than those necessary for a mineral search. The Canadian Geological Survey developed techniques for shallow reflection surveys using small crews, low-priced equipment, and data processing on Apple II personal computers. Where the technique worked, the Canadian geologists reported, their data improved remarkably. Their work progressed as they sought out and identified a number of pertinent formation types, including gold-bearing alluvium.[13]

Development.—Like the slow pace of exploration, the rate of development of new mining properties, especially those involving metals, reflected the low though more stable prices and the competition within the mining community. Expanded operations and modernization of existing properties, reopening of mines closed during the last several years, and redevelopment of previously mined properties took precedence over development of new mines. Gold again was the exception: About 35 new gold mines opened in the United States in 1987. Most mines were in California, Montana, and Nevada, but several came on-line in North Carolina and South Carolina.

In April, Cyprus Minerals Co. commenced construction of its Copperstone gold mine in western Arizona. The mine poured its first gold in November. Copperstone was the largest open pit gold mining and milling operation and the largest producer in the State. It had known open pit reserves of 510,000 ounces of gold. Six million tons of ore grading an average of 0.085 ounce of gold per ton were to be mined over an estimated 6-year mine life. Continued exploration indicated additional surface reserves as well as potentially higher grade reserves that would require future underground mining. The ore was processed by a tank agitation leaching method that incorporated the standard carbon-in-pulp gold-separation technique. This method was more expensive than heap leaching, but it was faster and would yield about 20% higher recoveries.

The Montana Tunnels Mine near Helena, MT, commenced operations in March following its development by Pegasus Gold Inc., Spokane, WA. Montana Tunnels was one of the latest acquisitions of known ore reserves by Pegasus. The company was fairly new in the mining business and growing very quickly by such purchases. Although Montana Tunnels was primarily a gold mine, there were significant quantities of silver, zinc, and lead in the ore. When operated at full capacity, at a rate of 12,500 tons per day, or 4.3 million tons of ore per year, the mine was expected to yield 106,000 ounces of gold, 1.7 million ounces of silver, 26,000 tons of zinc, and 5,700 tons of lead annually.

Owners of new and continuing mine-development projects looked for more ways to cut their costs, following the trend of the rest of the mining industry. Seismic reflection and refraction provided substantial benefits at moderately reasonable costs when used for mine development. With these techniques, drill-hole locations in the ore body could be optimized, and the lateral extent of deposits could be determined, along with information about formation structures between drill holes. For strip mining, seismic surveys helped to estimate costs of removing overburden. For mine safety, seismics could be used to map faults, determine rock quality, locate alluvial intrusions, and estimate pillar diameters. Measurements of seismic velocity could be used to design blasting programs and to measure their effectiveness, reducing the cost of blasting. A possible low-cost alternative to available, state-of-the-art geophysical technologies was the methodology developed by the Canadian Geological Survey, previously cited in the "Exploration" section of this chapter.

Drilling technology for underground development had progressed much in the past 10 years, as evidenced by the latest in powerful and reliable hydraulic drill jumbos. Computer technology took drilling one step further by enhancing drill-cycle performance and reducing excavation costs. Computerized drilling was able to achieve excavation accuracies as close as 5 to 10 centimeters on a tunnel profile. This precision could reduce overbreak by as much as 20% on a theoretical tunnel profile. These advancements decreased machine wear, speeded development, increased safety, and reduced costs. Tamrock of Finland developed its Datamatic 500-series computerized drill jumbo, which incorporated microprocessors to control, among other functions, machine alignment, boom movement, and drilling. The Norwegian Geological Institute tested the machine by developing a 6.0- by 5.5-meter tunnel. The 84-hole round cut, with hole dimensions of 4.3 meters by 45 millimeters, was drilled in less than 2 hours. Using software for three-dimensional drilling, an onboard computer directed the jumbo with a reference laser beam. The unit accurately excavated curves, inclines, and declines. The computer not only controlled drilling sequences and patterns and various other paramaters, but it also monitored drilling functions for efficiency and potential equipment failure. When limit values were exceeded, the computer shut down the machine and revealed the source of the problem. Tamrock said that a correctly trained operator could analyze machine progress and performance and add to the overall cost savings already achieved.[14]

The automatic recording of metal contents and ore grades from a borehole can give the mine planner-developer considerably more flexibility and control of a mining operation. Preussag Aktiengesellschaft of the Federal Republic of Germany reported successful field trials of its automatic borehole logging device, the Slimhole Analyzer, at its Bad Grund lead-zinc mine. Preussag developed the mobile, vehicle-mounted, computerized unit for mine exploration, development, and ore body definition. It was designed for 40-millimeter-diameter holes that are usually produced by standard blasthole drilling equipment, and it was said to supply instant, direct readings of thickness and grade of mineralization. After the system's radiation-inducing probe was hydraulically positioned in front of the borehole, a single keystroke activated the Slimhole's onboard computer for automatic operation. The analyzer inserted the probe and instantly and continuously plotted the metal concentrations detected by X-ray fluorescence. Results were shown on printouts momentarily after the measurements were complete. Cable lengths of 60 meters were used and metallic element detection limits were a function of the speed at which the measurements were made, the slower the better. The Slimhole's modular design allowed different types of ore and elements to be analyzed by adjusting the radiation to fluoresce properties of the materials of interest. The Slimhole was particularly useful at the Bad Grund Mine, where very selective mining was necessary, owing to both irregular mineralization and weak rock conditions.[15]

Underground Mining.—One of many computer-related contributions to operations underground was the Computer Analysis Rock Excavation (CARE) software package. The program simulated rock drilling and blasting and could be used with a personal computer. It produced a considerable amount of useful data within an hour, according to its developer, Atlas Copco MCT AB of Sweden. CARE compared possible excavation systems and their costs, predicted their performance, and identified the best choice. It assessed the fitness of the drilling equipment for specific assignments of different scales ranging from that of an individual face, to a formation, to an entire mine. The program then suggested the best drilling patterns and types and quantities of explosives. Drilling and blasting, two branches of the CARE program, could be used separately or together, but CARE was most effective when both subpackages were used interactively. The system offered mining companies and their suppliers the possibility of eliminating costly full-scale trials of new mining methods and equipment, especially with complex rock formations. CARE was developed by Atlas Copco over 20 years. It was not available for purchase, but Atlas Copco was offering it on a complimentary basis through its local sales organizations.[16]

A good communications system links a mine's functions in a timely manner and improves the productivity, safety, and control of underground transport in a mining operation. A system that combines speech and data radio transmission can provide current information about actual mine traffic, give routing instructions, and make it possible to react immediately to breakdowns or accidents. Obstacles to wide-scale underground radio communication include prohibitive capital costs, inefficient and inadequate performance, and impracticality of installation. These difficulties can be reduced to an acceptable level with medium-wave radio. Without amplification, 300- to 3,000-kilohertz waves can be transmitted on existing cables, pipes, and wires for long distances, thereby avoiding a separately laid-out system. Most currently available systems used AM transmissions that often were severely affected by interference from high-tension cables, electric motors, or rectifiers. FM systems received some increased attention during the year because they were not as badly affected by interference. Montan-Forschung of the Federal Republic of Germany had developed such FM systems for a number of years. One of the company's applications was a combined speech-and-data-transmission network that connected 81 load-haul-dump vehicles (LHD), 12 other vehicles, 6 drill rigs, and 30 handsets. Under development were telediagnostic applications, so that control-room personnel could monitor conditions simultaneously below ground, including equipment oil pressure and temperatures, power currents, and pressures throughout the mine.[17]

Bureau of Mines researchers continued

their efforts with both conventional mining processes and innovative mining systems, but innovation was emphasized in the Bureau's work on mining technology. Research was done with the recognition that mining companies often cannot adopt innovative technology overnight. The Bureau worked with conventional methods in an effort to help companies until they would be able to adopt more radical advancements. Impressive reductions in drilling costs were seen as very possible. Bureau scientists demonstrated that maintaining an electrical balance between the rock and certain drilling fluids could double the drilling rate and drill-bit life over that obtained using plain water. These additives eliminated the need for expensive instruments that are sometimes used to maintain the electrical balance.

Bureau researchers worked on new mine filling technologies to safely and economically support mined-out openings and allow increased extraction of ore, such as from ore bodies previously used as support pillars. They developed a system that uses a special cement pump to push dense pastelike material through pipes to openings underground. There the substance was mixed with large amounts of fine waste rock and forced into voided areas; this mixture provided better support than the loose fill usually used.

At its North River No. 1 Mine, Pittsburgh & Midway Coal Mining Co. continued successful testing of a deep-cut system using continuous miners. The mine's overall productivity increased, and an independent study concluded that deep-cut sections in mines were consistently more productive than regular sections. Three obstacles were overcome. First, with cut depths increased from the standard 6 meters to 12 meters, personnel would be working under unsupported roof. This was solved by using recent advances in remote operation, especially in radio remote controls. The second obstacle, increased methane concentrations, was overcome by using a blowing ventilation system. A blowing system can be more effective than an exhaust system can at greater distances from the face. The system used made it possible to maintain an air-directing face brattice (curtain) at a distance from the working coal face that was sufficient for proper ventilation and yet would not require workers to extend the curtain under unsupported roof as mining advanced. A blowing system, additionally, can be significantly improved by increasing the velocity without increasing air volume. The third difficulty was the quantity of respirable dust that was raised by the blowing system. This problem was overcome by using scrubber systems on the continuous miner. Although scrubbers are approved only for dust control, they also aid the ventilation process during coal extraction.[18]

Technological advancements have spurred significant increases in longwall production figures and efficiency, but often the potential gains are diminished by deficiencies in other aspects of the mine's operation, such as too slow a rate of cutting and panel preparation. CRA Ltd. of Australia found that, because of slow roadway development, conventional continuous miners capable of producing 600 tons of coal per hour (about 10 tons per minute) were mining only 200 to 500 tons for a 7-hour shift. Stop-start actions related to roof support activities were a major factor. CRA's subsidiary, Kembla Coal and Coke Pty. Ltd., after several years of development work, reported successful tests of a prototype "continuous roadway heading machine." The Mark I Kemcol was an adaptation of a continuous miner, which enabled roof-support activities to be completed simultaneously with coal cutting. The prototype, claimed by the company to be the only belt-tracked continuous road-heading machine in the world, was manufactured by another subsidiary, Vale Engineering Pty. Ltd. After some major modifications to the prototype, Vale developed its production model, the refined and more efficient Mark II. The company obtained an Australian patent and sought international patent approval. High sales for the Mark II were anticipated, owing to the successes of the Mark I, but marketing of the revised machine would depend on its actual performance. Field testing was to take place in 1988.[19]

The first self-propelled conveyor was commissioned at a colliery in Australia. The conveyor had been under development over the last decade by Klöckner-Becorit GmbH of the Federal Republic of Germany. It fed coal from a continuous miner working in a room-and-pillar system to the main surface conveyor. A second system was to be installed in a sodium carbonate mine in the United States. The Snake, as it was often called, had the potential for a variety of applications. It generated much lower ground pressure than did trucks, LHD's, or other material-transport systems, making it especially attractive for working on soft ground. The bottom section of the conveyor chain served as the track during tramming. It was steered by hydraulic cylinders between the end pan and the first three line pans. These not only guided the conveyor but also changed the direction of discharge for conveying. Other pneumatic cylinders elevated the belt 100 millimeters off the ground for conveying mined materials. The conveyor was designed so that once it was put on course, following pans proceeded exactly in the same line, enabling the conveyor to safely negotiate the tight corners and confined spaces of a room-and-pillar mine. The initial model had a 600-millimeter-wide conveyor, which ran at a speed of 0.84 meter per second and had a maximum capacity of 800 tons per hour. A side-discharge end unit was optional. The unit could be connected with a low-profile roll crusher, moving parallel to the main belt conveyor.[20]

Although no full-blown system had been developed, the concepts of remote-controlled or automatic LHD vehicles were studied at Lulea University of Technology in Sweden. Researchers there said that the technology was available to automate LHD's using wire-guidance systems. Some Swedish underground mines were evaluating the performance of television systems, which may be necessary for the control of such LHD's underground, but further research in vision systems and position-reference techniques was needed to produce more "intelligent" and automatic vehicles. The major question was whether the expected advantages would justify the costs. The two factors expected to weigh heavily were improving personnel safety and the possible development of new ore bodies where existing mining transport systems would be considered uneconomical and unproductive.[21]

An example of innovative design was the development of "cassette" or "modular" utility equipment systems. These are carrier vehicles that can hold a variety of different front- or back-end attachments, increasing a machine's versatility and overall efficiency. Under this concept, a single machine can fulfill many roles, thus allowing higher vehicle utilization. Overall capital, running, and production costs could be reduced. Units that might otherwise be operating as briefly as 1 or 2 hours each day could be kept at work almost constantly, reducing the overall number of vehicles needed without compromising the mine's level of mechanization.

Orion Corp. of Finland, under its Normet trademark, introduced the NT series, "total utility system" (TUS) carriers to replace its PK line. The Normet system included standard 3- to 12-ton payload chassis with modules that could fulfill a substantial range of underground requirements: personnel or material lifts; explosives handling and charging trucks; and extensively outfitted maintenance trucks. Other cassette units were available for roof consolidation, shotcreting, and various other transportation needs. Normet claimed that the versatility of the cassette system was best shown by the conversion of the basic chassis from personnel carrier to ammonium nitrate-fuel oil charger within minutes. Normet designed the cassettes, but system components, such as shotcrete pumps, came from other suppliers selected in consultation with the customer. Design and marketing efforts were concentrated on hard-rock metal mines and tunneling. Adaptation to soft rock and coal mines was planned; the company recognized that flame-proofed models that conform with more stringent safety regulations would be necessary for these applications.[22]

In the last several decades, the mining industry substantially increased hourly tonnage production through new mining methods, technological advancements, and refinements in excavation, loading, and transportation equipment. This increase was swifter than the increase in overall efficiency. In a study conducted by the Swedish Mining Association, 50% of the work force in Swedish underground mines in the early 1970's was found to be employed in direct mining activities. This proportion had fallen to about 40% by the mid-1980's, while that of the associated service and maintenance workers showed a corresponding increase from 40% to 50%. The proportion involved in supervision, planning, administration, and related functions remained relatively constant at about 10%. NIMICO AB, a Swedish consulting company, called for more research on mining support activities to increase the productivity of employees working in maintenance and other types of indirect tasks. A company that could be more productive in this sense would also increase its own competitiveness, a well-recognized major theme of survival and growth in the mid- to late-1980's for the mining industry as a whole.[23]

Surface Mining.—In recent years, mining companies have returned to previously mined lands. Often these were abandoned mining properties containing relatively low-grade ores, and sometimes the ore was from mine waste piles or tailings of similarly low grades. Hard times made new full-scale exploration too costly for some operators, and the added expenses of mining for increasingly deeper deposits found some looking for less risky ways to bring in needed capital while they worked through difficult or even marginal times at their main properties. Advances in certain processing technologies, especially those of heap leaching, made lower grade properties practicable and often very profitable. The tailings of yesterday's mines were sometimes becoming the valuable land of today.

HMC returned to the mining of its original 1876 gold discovery property, now called the Open Cut, at the Homestake gold mine, Lead, SD. In meeting basic production and profitability requirements, its underground operation faced several obstacles: greater depth of production centers, increased ventilation and cooling requirements, longer lead times for exploration and development, and increased costs of waste handling from newly developed ore trends. Redevelopment of the Open Cut began with a drilling program in 1981, which indicated an ore body made up of broken and caved ground, with solid blocks of pillars and crowns. Several years later the successful Terraville test pit in the northernmost section of the Open Cut yielded more ore than expected. Overall, HMC estimated that the Open Cut contained 7.5 million short tons of gold ore out of 66 million tons of total minable material. The ore graded at about 0.116 troy ounce of gold per ton. Mine plans included both open pit and underground mining methods. Project life was estimated to be 15 years, and work was in the early stages of a 5-year prestripping process. Preproduction waste-to-ore stripping ratios ran about 30:1, and estimated reserve stripping was about 11:1. A 6,700-foot conveyor system replaced road haulage of the crushed ore to HMC's expanded South Mill processing plant. Once loaded, the single-piece belt conveyor was rolled into a pipe shape, which allowed it to make substantial vertical and horizontal curves and climb steep angles without spilling the ore. HMC claimed it was the first such installation in the United States.[24]

One of Pegasus' new projects was the Florida Canyon Mine, an open pit heap-leaching operation of unique design in northwestern Nevada. Florida Canyon produced doré of 65-35 gold to silver, and was significant for its circular heap leach pad and extensive conveyor system. From on-site crushing plants a specially designed conveyor system transported the crushed ore combined with lime, cement, and cyanide solution and deposited it over the leach pad, where a spray leaching system was used. From the "hot" or pivot point at the circle's center extended a 1,500-foot conveyor system made of separate, 150-foot sections. Extension of the perimeter to the full 1,800-foot radius was planned for 1988. Ore was to be deposited over the pad in 90° segments, and by the end of 1987, the pad was in use to one-half of its full design. Completion of the pad foundation was expected to take place in the next couple of years. The first quarter-pad was heaped 40 feet high and the second more than 28 feet high; the entire pad was to be built up to a maximum of 60 feet. The ore was spread out evenly over the pad with a mobile tripper designed by R. A. Hanson Co. Inc., Spokane, WA. Pegasus representatives reported that the Rahco mobile conveyor system was chosen over a standard truck-and-dozer operation because of lower operating costs, reduced compaction of the leach pile, and faster gold recovery. The completed pad was expected to process 24 million tons of ore over the pad's operating life.

Coeur d'Alene Mines Corp.'s Coeur-Rochester Mine in northwestern Nevada was nearing completion of the first of three phases of construction of the largest silver heap-leaching pad in the United States. An additional fourth phase was possible. One of the ore sources of this open pit mine was an adjacent mountain top riddled with old mine shafts from the early 1900's. Initially the peak stood at 7,238 feet; it had been mined in stages down to 7,050 feet by yearend. The most important aspect of this operation was the unique drip-leaching system that management was pioneering. Coeur-Rochester officials claimed that it was easier and less cumbersome than spray systems, which the company used until January 1987. The drip system consisted of an extensive, spaced network of tubing that resembled a grid of large automobile fuel lines. Through this system, cyanide solution was dripped into the crushed ore at specifically spaced intervals. The drip system froze less often and less severely than a spray system, and it lost considerably less water by evaporation. With some help from a well-planned reservoir, officials claimed, the company only used 10% of its budget for water compared with 20% that spray systems customarily demand. The first year was successful, with year-round operation made possible by burying the system in the winter. During the last half of the year, the drip system drew interest not only from U.S. gold and silver producers but also from interested parties from other countries, such as Australia and China. These companies looked into adapting use of the system to their own leaching operations.

Kennecott's open pit copper mine at Bingham Canyon, UT, is the largest copper producer in history. In 1987, it was in the midst of a major modernization project. Three main features of the project were in-pit crushing facilities, a conveyor system including mobile conveyors and a 5-mile ore conveyor, and three pipelines (40 miles of pipe) between the Copperton concentrator plant and the smelter, tailings pond, and water supply. The pipeline and conveyor replaced a complex, combined rail-truck system. Depressed copper prices and rising costs caused the mine to be closed down in early 1985. When copper prices recovered a year and a half later, Bingham Canyon was reopened and its modernization plan set in place. Upon completion in 1988, the new semimobile crusher was to be the largest unit yet constructed. It was part of the transport system being installed by PHB Weserhutte AG of the Federal Republic of Germany. The belt transport system comprised seven conveyors: Six of these spanned a total length of 5.3 miles and the seventh was a single 3.75-mile tunnel conveyor. The in-pit crushing unit and conveyor link replaced a massive 3-tunnel, 150-kilometer rail network, which had 1,000 ore cars loaded by electric shovel. The new crusher, fed by 170-ton dump trucks, was designed to handle about 70,000 tons of ore per day.[25]

For many years surface-mining equipment was made larger and larger in efforts to reduce costs and increase efficiency and production. Many of these machines, however, were beginning to reach the size where the law of diminishing returns took effect. Further improvements would have to involve incorporating new technologies into existing equipment. The purpose of these developments was to improve reliability, availability, and serviceability. Mining experts predicted that the mechanical equipment would change little over the next decade. Microprocessors and onboard computers would be used to control the equipment and reduce operating costs. Some experts believed that surface mines would be sufficiently computerized in the 1990's to substantially reduce the labor force, possibly to one-third of 1987 levels. Microprocessor-based equipment-performance systems were available, such as suspended-load measurement modules for electric cable shovels and draglines. These modules measured and quantified cycle times. On draglines, line-tension control systems protected booms from structural damage. Some monitoring systems provided current, detailed information, including immediate warnings of impending systems failure. The monitors would record performance data, operating time, and machine utilization, and the information would be available for later use by maintenance and operating management. Minewide data-management systems reported equipment performance and condition via VHF radio signals to operations managers. A data console enabled them to oversee all mining operations, including production figures and trends.[26]

Modern pit and quarry operations are much more complex than those of the past. Managers could receive assistance from properly programmed computers when making important equipment-purchase decisions. Fortunately, producers didn't need to be computer-smart to take advantage of such information processing. Many dealers and manufacturers offered these computer software services and could be consulted before any hasty decisions were made. The trend among equipment suppliers was to work closer with individual operators and tailor their products more to the customer's needs.[27]

Innovative thinking rather than technology sometimes assisted companies in becoming more competitive. Battle Mountain Gold Co. of Nevada took a novel approach in cutting its transportation costs. At its Fortitude deposit, truck drivers drove on the left side of their mountainside roads between the mine and the mill. The driver thus could drive more safely and closer to the side of the road without brushing against it. This cut down on tire wear and related maintenance costs. Safety was improved because of the driver's better view of the roadside. Also, more precise driving was possible; what would usually be a road 90 to 100 feet wide was reduced to one 60 feet in width.

Remote Mining.—In situ leach mining was the object of continued interest and research efforts by Federal and State Governments and private mining interests. This method made possible the recovery of a variety of minerals from deposits not susceptible or convenient to mining by conventional means. Other major advantages included lower mining costs, safer and healthier working conditions, and fewer risks to the environment. Bureau of Mines researchers estimated that in situ operations would use 50% less energy than conventional mines and would reduce labor costs by as much as 75%. Also, the new method would require only one-fourth the capital investment required in opening a conventional mine. Much of the Bureau's research centered around developing technology to allow production from remaining large, deep, and low-grade copper oxide deposits in the United States.

At the Bureau of Mines, scientists explored ways to efficiently direct the flow of the leach solution through ore deposits and to contain the solution within the boundaries of the intended mining zone, thereby maximizing mineral recovery and protecting the surrounding geologic environment, especially aquifers. Other work showed that such mining efforts should be concentrated on deposits where copper occurs in highly fractured zones. The Bureau developed a geophysical technique of using sound waves to monitor the solution movement through an ore body and its surrounding rock. With this technique, mining companies could remotely track mining solution movement and modify operating parameters to stop the escape of solution from the mining zone. Such monitoring could ease environmental concerns over lost solution, making it easier for operators to get permits for in situ mines. The method worked best for ore bodies located above the water table. The sound wave data analysis was accomplished with a personal computer. The Bureau assembled a generic manual that provides the technical information needed to develop a commercial in situ leaching operation for any specific copper oxide deposit. A computer program accompanied the manual to help develop design specifications and evaluate the economics of mine design variations.

Leaching Technology Inc. (LTI) was expanding its in situ copper-leaching operation at the old Nacimiento open pit in northern New Mexico. LTI claimed that the mine was a "true" in situ copper-leaching operation, and that no other operation of its kind had yet been successfully conducted by the copper industry. "True" meant that there was an in-place ore body that had not been broken by prior mining activity and was not mechanically or explosively fractured. LTI's first field test well was successful, but the solution moved too fast for good copper recoveries, and some resistance was encountered in the injection wells. The company made adjustments with the help of technology previously used successfully in true in situ uranium-leaching projects, along with some technology from the oil industry. A mine well consisted of a "five-spot pattern" or "cell," which comprised four solution injection wells at the corners of a square and a production or extraction well in the center. Seven new cells were being added, using a smaller square pattern (70 to 80 feet per side) than the initial test cell to attain better copper recoveries; the last cell was expected to be operational by the spring of 1988. A weak solution of sulfuric acid and ferric iron was used to leach the copper. The copper recovery plant on-site was the same solvent-extraction electrowinning facility originally used as the pilot plant at the Bagdad Mine, also in Arizona. Initial production was projected to be 7,000 to 8,000 pounds of copper per day when at full operation, and the project's life was estimated to be 8 to 10 years.[28]

The State of Colorado committed financial support to help establish an advanced mining technology program for small, underground, precious metals deposits. The program included in situ leaching and was a result of discussions between several mining associations, the Governor's office, the Colorado Department of Natural Resources and Local Affairs, and the Bureau of Mines Denver Research Center. Research efforts were to be a cooperative effort between the latter two organizations as part of the Denver Research Center's metal mine productivity program.

Bureau of Mines researchers successfully demonstrated that coal, oil sands, uranium ore, and phosphates could be remotely extracted as a slurry through a borehole. A tool incorporating a water-jet cutting system with a downhole slurry pumping system mined the rock through a single borehole drilled from the surface. The water jets eroded the ore and formed a slurry that flowed into the pump at the base of the tool and was transported to the surface in suitable form for pipeline transfer to a nearby mill or processing plant. Development work for such a project is minimal, so production is almost immediate compared with that of a conventional mining operation. The single machine was remotely operated from the surface, and environmental disturbance was minimal. Crushing and grinding costs were minimized because the ore was already reduced to grain size.

Although interest in seabed mining from governments and mining interests throughout the world was on the rise, several limiting factors were of concern to all. Claims and mining rights received increasing attention. The United Nations Preparatory Committee for International Seabed Authority and for the International Tribunal for the Law of the Sea met twice during the year. In Jamaica, the Committee continued efforts to establish and fine-tune the framework for an international law of the sea administering organization. National representatives worked on such issues as competitive concerns of land-based mineral producers and the rules and regulations that would ultimately constitute the organization's formal mining code. In New York, the Committee registered India as the first "pioneer investor" after the country filed claims to uncontested areas in the Indian Ocean totaling approximately 150,000 square miles. Any country or mining consortium that could fulfill all necessary requirements could be designated as a pioneer investor. Other applicants on the verge of being registered with pioneering status were France, Japan, and the Soviet Union.[29]

The practical accessibility to seabed minerals was of concern, especially in the United States, where the congressional Office of Technology Assessment (OTA) completed a major study of the matter. OTA concluded that prospects for producing commercial quantities of critical minerals within the 200-mile-wide Exclusive Economic Zone off the United States coasts were with some exceptions remote for the foreseeable future. OTA stated that in the current minerals markets most of the country's offshore mineral sources were not economic to mine without active Federal support of ocean exploration and a statutory framework that encouraged private development. A lack of proper processing facilities in the United States for many of the available minerals was also cited as a problem. Two possible exceptions to the downbeat seabed mining forecast were the precious metals, especially gold, and sand and gravel. One land-based mining company was dredging gold off the Alaskan coast, and sand was being mined at the entrance to New York Harbor. Areas that OTA listed as promising for future near-shore mining included Alaska for gold and other precious metals; the east coast between New Jersey and Florida for titanium, and between Georgia and North Carolina for phosphorite, and southern Oregon for chromite sands.

In New Zealand, where gold dredging has been common for more than 100 years, a new technological development was introduced by a joint venture between R. A. Hanson Co. Inc. of the United States and the Australian-based Giant Resources. The venture, Grey River Gold Mining Ltd., will use a continuous bucketline dredge to mine low-grade deposits in the Grey River Valley area of South Island. Conventional technology could not be used to mine the deposit at a profit. Two dredgers would be operated at the same time, one for overburden removal and the other for retrieving the gold ore. All functions of the mining operation would be done by the "dual-dredge" plant, including complete processing of the gold and thorough reclamation of the mined area. The entire "organism," as the company sometimes called the machine, was controlled by a computer and a programmable logic controller system. Sensors were placed in an extensive network over all parts of the operation. Precious metals were the company's first goal, but applications to tin and some other alluvial were anticipated in the near future.[30]

Beneficiation.—The Polycom comminution process was a new approach to ore crushing that was based on the application of high pressures within specially designed grinding-roll circuits. Operation of a successful pilot plant in 1986 led to more than 25 commercial installations by late 1987 in the processing of cement clinker, limestone, coal, copper ore, diamandiferous South African kimberlite, etc.

Krupp Polysius AG of the Federal Republic of Germany produced and marketed the process. The company claimed the Polycom grinding achieved significant reductions in capital costs because of a simple plant structure and a smaller overall system; lower operating costs that included energy savings of about 20%, reduced parts wear, and acceptance of larger material, which eliminated a stage in crushing; capacity increases of up to 100% in existing facilities; and better disintegration results because of the advantages of comminution on a material bed. The basic procedure was to expose a batch or bed of material to pressure that was high enough to break the material. In this batch process, material was loaded into a cylinder and compressed by a piston. Under pressure, the particles were compressed and shifted into the voids before breaking and being further compressed. Under sufficient pressure, the material caked inside the cylinder. The process became continuous when the bed of material was passed between two grinding rollers. The cake or flake discharged from the high-pressure grinding roller was then broken up to release the fines. A larger quantity of fines was produced than is typical from a mechanically similar roll crusher. At a copper ore installation, a Polycom system eliminated the plant's tertiary crushing stage and screens, increased plant capacity from 55,000 to 70,000 tons of ore per day, reduced energy consumption by about 15%, reduced parts wear, and increased the leaching rates.[31]

Advances in biotechnology had been making an impact on the minerals industry for a number of years. Microbial metal recovery was a $450 million business in the United States and was growing at about 12% to 15% annually. One recent study reported that roughly one-fifth of the world's copper production came from microbial methods, with nearly all major copper producers utilizing microbial techniques. Some methods were proving to be more economical, demand less energy, and cause less pollution than the conventional leaching methods. Research centered on finding out which organisms would best carry out the different mineral-recovery processes, and how industry could manipulate the various environmental conditions such as light, oxygen, moisture, and temperature, which were required by the organisms to do their work.

Scientists at the National Bureau of Standards (NBS) studied a number of measurement tools and techniques for biotechnology. They were in the process of establishing certified samples of ores that could standardize tests for identifying preferred strains of organisms and bioprocessing conditions. In cooperation with the American Iron and Steel Institute, NBS investigated types of organisms for the removal of copper from steel scrap and insoluble phosphorous from domestic iron ore. Sulfur removal from coal was another NBS focus of research in work done with the Electric Power Research Institute. The Bureau of Mines emphasized work on the biological dissolution of strategic and critical minerals from low-grade ores and mine wastes that could not be effectively and economically exploited. The Bureau's work on biologically assisted extractive metallurgy focused on enhancing microorganisms' often slow dissolution or leaching rates.[32]

Giant Bay Resources Ltd. of Canada produced what it claimed was the world's first doré gold bar to be produced by biotechnological leaching. The company's bioleach-tank demonstration plant, installed at Giant Yellowknife Mines Ltd.'s Salmita Div. in Canada's Northwest Territories, was used to increase gold recoveries from hard-to-treat refractory ores. The bioleaching was tried as an alternative to roasting or pressure oxidizing the refractory gold prior to cyanidation. In a cost comparison by the company, bioleaching had the lowest capital and operating costs per ton of the three methods. A gold recovery rate of 95.6% achieved during a demonstration run was significantly higher than recovery rates for the company's more conventionally processed refractory ores.[33]

BP Minerals International Ltd. (BP) completed development of a new, patented gold recovery process called Coal Gold Agglomeration (CGA). In a joint venture with two Australian companies, BP successfully used CGA in a pilot plant situated near extensive gold tailings around the historic Australian mining areas of Ballarat and Bendigo. CGA was best suited for the recovery of fine liberated gold in concentrations of less than 10 parts per million. The process could be used on placers, deep leads, tailings, and hard-rock deposits where the gold was liberated by milling. Where deposits contained significant quantities of sulfide materials, gold recoveries were lower.

CGA was based on the capacity of clusters of "oil-bridged" coal particles—coal-oil agglomerates—for carrying fine gold particles. Gold particles are oleophilic, or attracted to oil. Reagents called collectors were added to intensify this attraction, and depressant agents were added to reduce the gangue that also is picked up by the agglomerates. Agglomerates were recycled through the process until they had accumulated the maximum amount of gold, after which they were floated off using conventional flotation. The gold-laden agglomerates, which could carry more than 1,000 grams of gold per ton, were then combusted to burn off the coal and oil. The ashes were smelted to extract the gold. It was a simple, cost-effective process that did not require the use of cyanide and thus reduced waste-disposal problems. Intensive mixing of prepared coal-oil agglomerates with a suitable slurry of gold-base material was necessary. Gold recovery was improved by maximizing free gold through milling the ore and by improving the gold's oleophilic nature through attrition scrubbing to remove any surface films on gold particles.[34]

Another new alternative to cyanide was used by Haber Inc. when it commenced gold production at the company's mill in Tombstone, AZ. The company's new Haber gold process involved only the leaching operation and revolved around the use of a mixture of 21 chemicals that were said to be nontoxic. The company claimed recovery rates were greater and up to four times faster than those of traditional cyanide leaching. Capital costs were calculated as slightly less than those of a cyanide leach plant, and operating costs were similar.[35]

High-Tech Processing Corp. of Pennsylvania completed development of an electrothermal impermeable membrane composition that the company contended could extend refractory brick life up to 15 times longer than was traditionally achieved in metal-producing furnaces and ladles. The membrane prevented contamination of the molten metal and at the same time prevented molten metal from penetrating the refractory brick. It could be used on various porous and nonporous surfaces of heat-affected zones subject to high temperatures and corrosive action. Also, the membrane was resistant to particle bombardment resulting from arc flair. In an electric furnace that produced ferrotitanium, the membrane reportedly had a refractory life more than four times the expected life with no signs of deterioration.[36]

Flotation was still the most widely used procedure for separating desired minerals out of crushed ore grains. Research at the Bureau of Mines focused on two aspects of the procedure: electrochemical control of the crushed ore slurry to reduce reagent consumption and more efficient ways to create the proper size bubbles in column flotation systems. In the flotation process, the desired mineral adsorbs chemicals on its surface, making it water repellant. When bubbles are simultaneously generated, the mineral is stuck at the air-water interface; thus, the mineral floats. In recent years, the adsorption process, particularly with sulfide mineral surfaces, had been recognized to be an electrochemical process. Electrochemical potential (EP), or redox potential, refers to the property of a solution in which a current can flow between an inert electrode and a normal hydrogen electrode in the solution. Bureau research showed that by controlling the degree of EP in a slurry, the desired mineral could be made to float or sink in the presence of the proper collector chemical. The Bureau conducted research aimed at developing reliable electrodes for monitoring and controlling the EP and extending the proper electrochemical conditions to the grinding and conditioning of the ore for greater overall efficiency.

In conventional column flotation the necessary bubbles were generated by pumping air through a porous pipe rather than by traditional mechanical means. The pores clogged periodically, and the column system had to be shut down for cleaning. Bureau researchers designed a bubble generator, an improved gas sparger system that worked outside the column and rarely got clogged, yet also allowed control of the bubble size by adjusting air pressure and water flow rates. Bubble size was poorly controlled in conventional column flotation. The new system could be cleaned without shutting down operations on the rare times that clogging did occur, and it could be retrofitted to existing columns. Seven commercial mills using the system credited it with providing improved recoveries and/or reduced operating costs.[37]

Health and Safety.—Preliminary injury statistics compiled by the Mine Safety and Health Administration showed that mine fatalities in 1987 were about 36% higher than in 1986, with 67 personnel killed in metal and industrial mineral mining operations. This was up from the recent record-low years of 1983 and 1985, each with 56 deaths, and 1986 with a final fatality count of 49. Although employment in mining decreased, employee-hours increased by about 1.5%, reversing a downtrend of recent years. The injury rate in the industry in 1987 was 5.90 per 200,000 employee-hours, increased from a final figure of 4.89 in 1986. All 1987 figures included independent contractors.

A fire protection system for use with any type of diesel-powered equipment was developed by the Mining Div. of Victor Products

PLC of the United Kingdom. It could be set to function automatically when the ignition was switched off and personnel were absent, as well as when the equipment was in operation. The system had a continuous-pressure loop that withstood normal operating temperatures yet would trigger the system upon contact with flame. Then an aqueous, film-forming foam was discharged through high-pressure jet nozzles surrounding the protected area. The company claimed excellent, proven, extinguishing properties, with the ability to seal any flammable materials from the atmosphere. The system also had a cooling effect, which helped prevent re-ignition once the fire was out. The system continued to discharge nitrogen for a period of time after the foam tank was emptied, thereby providing secondary cooling and displacement of oxygen in the affected area. The system was designed to discharge fluid for no less than 2.5 minutes and could easily be adapted to discharge for extended periods.[38]

The Bureau of Mines designed and developed an ultralow-frequency, through-the-earth, electromagnetic, fire-warning alarm system for underground mines. Existing warning systems were usually slow, somewhat unreliable, and often did not achieve total mine coverage. Bureau researchers said the new system was a rapid, reliable means of warning miners underground of a fire or other emergency. The system consisted of a transmitter and a receiver. When triggered by a fire detector, the transmitter established a very large electromagnetic field throughout the mineworkings. The receiving antenna captured and concentrated the magnetic flux to generate a tiny current that would activate a relay, triggering an audible warning. The receiver components easily fit into a modified cap-lamp battery case. When attached to the lamp, the receiver could make the miner's lamp blink in the event of an emergency. The basic components of the system were relatively inexpensive, "low tech," and readily available from commercial manufacturers.

Evaporite formations, such as domal salt and potash, frequently contain methane concentrations that can be encountered unexpectedly and released instantaneously. In an underground setting, the quantities of gas can overwhelm a ventilation system before the danger is spotted. The Bureau of Mines developed two laboratory techniques for detecting the methane. One was a more traditional sample analysis, and the other an unusual, speedy, and inexpensive technique that involved measuring the noise level of gas escaping a sample under one particular condition. Researchers had observed that salt samples containing large amounts of methane emitted a popping sound when immersed in water. A definite correlation existed between the magnitude of these pops and the gas content of the sample. With the help of a small personal computer, readings were possible within 2 to 4 minutes by means of a small, well-insulated, fairly easily transportable sound chamber outfitted with a sound level sensor. The technique was being used in advance of mining to determine gas contents at two domal salt mines in Louisiana, and it proved to be very reliable.

Video systems were playing larger roles in mining operations. ARC Group, a quarry operator in the United Kingdom, reported successful trials of the Backeye reversing video systems on some of its off-highway trucks at the Whatley Quarry in Somersetshire, England. The system consisted of an all-weather camera with a wide-angle lens, a monitor with a 225-millimeter screen, a control box, and camera cable. The driver had a complete view over the blind area from his own rear bumper to a point 15 to 25 meters behind the vehicle. The camera, on standby, would transmit automatically when the reverse gear was engaged, and it could be used effectively at night as well as during the day. The monitor had both a bright-light shield—to ensure a good, readable picture in full daylight—and distance lines that provided a reference to aid precision maneuvering.[39]

Southwest Research Institute (SwRI) engineers developed a large-diameter wire rope fatigue-test machine for the Bureau of Mines Bruceton Research Center in Pittsburgh, PA. The Wire Rope Operating Procedures Evaluation System was installed at the Center for a 10-year program to determine better criteria for removing large-diameter mine hoists from service for both safety and economic considerations. The system was used to evaluate the performance characteristics of wire ropes of diameters of 1 to 2.5 inches. According to SwRI, most wire rope fatigue data available worldwide was for ropes less than 1 inch in diameter. The machine was designed to accommodate 1,000-foot rope specimens on its 10-foot drum and 75-foot structural steel frame. A 1,000-horsepower electric drive was expected to develop the needed testing force of up to 600,000 pounds. Other tests, such as wire-by-wire examinations and metallographic analysis, were to be included in the ongoing studies.[40]

[1]Physical scientist, Branch of Ferrous Metals. Statistical data compiled by Stephen D. Smith, mineral data assistant, Branch of Ferrous Metals. Tables are based on 1986 data that were not available when the 1986 Minerals Yearbook was published; corresponding data for 1987 were not available at publication time.

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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:									
1982	371	677	1,050	60	12	72	431	689	1,120
1983	380	557	938	47	6	53	427	564	991
1984	420	614	1,030	57	10	67	476	624	1,100
1985	411	499	911	48	9	57	459	508	968
1986	418	615	1,030	52	7	59	470	622	1,090
Industrial minerals:									
1982[2]	837	366	1,200	61	2	63	899	368	1,270
1983[3]	1,070	155	1,230	62	1	62	1,130	155	1,290
1984[2]	1,060	286	1,340	40	1	41	1,100	287	1,390
1985[3]	1,260	450	1,710	54	2	56	1,320	452	1,770
1986[2]	1,130	380	1,510	34	1	35	1,160	380	1,540
Total metals and industrial minerals:[1]									
1982	1,210	1,040	2,250	121	14	135	1,330	1,060	2,390
1983	1,450	712	2,160	109	7	116	1,560	719	2,280
1984	1,480	901	2,380	97	11	108	1,570	912	2,490
1985	1,670	950	2,620	102	11	113	1,770	961	2,740
1986	1,550	995	2,540	86	7	93	1,630	1,000	2,630

[1]Data may not add to totals shown because of independent rounding.
[2]Crushed and broken and dimension stone data were not available for 1982, 1984, and 1986 because of biennial canvassing.
[3]Includes industrial sand and gravel. Construction sand and gravel data were not available for 1983 and 1985 because of biennial canvassing.

Table 2.—Material handled at surface and underground mines[1] in the United States in 1986, by commodity

(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	576	W	576	--	--	--	576	W	576
Copper	167,000	325,000	492,000	23,200	541	23,800	190,000	325,000	516,000
Gold:									
Lode	74,000	139,000	213,000	3,280	651	3,930	77,200	139,000	216,000
Placer	8,030	8,200	16,200	--	3	--	8,030	8,200	16,200
Iron ore	133,000	64,400	197,000	1,320	125	1,440	134,000	64,600	199,000
Lead	--	W	W	6,000	2,860	8,860	6,000	2,860	8,860
Silver	5,220	25,500	30,700	4,080	391	4,470	9,310	25,900	35,200
Zinc	--	--	--	4,400	201	4,610	4,400	201	4,610
Other[3]	29,900	54,000	83,900	9,630	1,820	11,400	39,500	55,800	95,300
Total metals[2]	418,000	615,000	1,030,000	51,900	6,590	58,500	470,000	622,000	1,090,000
INDUSTRIAL MINERALS									
Abrasives[4]	92	W	92	W	--	W	92	W	92
Asbestos	57	--	57	--	--	--	57	--	57
Barite	232	--	232	--	--	--	232	--	232
Clays	44,200	[e]38,400	82,700	W	W	W	44,200	[e]38,400	82,700
Diatomite	1,380	6,150	7,530	--	--	--	1,380	6,150	7,530
Feldspar	1,170	796	1,970	--	--	--	1,170	796	1,970
Gypsum	12,700	5,250	18,000	3,010	--	3,010	15,700	5,250	21,000
Mica (scrap)	254	W	254	--	--	--	254	W	254
Perlite	730	907	1,640	5	--	5	735	907	1,640

Phosphate rock	149,000	301,000	450,000	W	W	W	149,000	301,000	450,000
Potassium salts	--	--	--	9,830	W	9,830	9,830	W	9,830
Pumice[5]	1,110	320	1,430	--	--	--	1,110	320	1,430
Salt	342	W	342	13,300	--	13,300	13,700	W	13,700
Sand and gravel	910,000	--	910,000	--	--	--	910,000	--	910,000
Sodium carbonate (natural)	--	--	--	7,360	--	7,360	7,360	--	7,360
Talc, soapstone, pyrophyllite	1,270	8,850	10,100	90	75	166	1,360	8,920	10,300
Other[6]	4,650	17,700	22,400	500	507	1,000	5,150	18,200	23,400
Total industrial minerals[2]	1,130,000	380,000	1,510,000	34,100	583	34,700	1,160,000	380,000	1,540,000
Grand total[2]	1,550,000	995,000	2,540,000	86,100	7,180	93,200	1,630,000	1,000,000	2,630,000

[e]Estimated. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Excludes material from wells, ponds, or pumping operations.
[2]Data may not add to totals shown because of independent rounding.
[3]Includes antimony, beryllium, magnesium, manganiferous ore, mercury, molybdenum, platinum-group metals, rare-earth metals, titanium (ilmenite), tungsten, uranium, and metal items indicated by symbol W.
[4]Includes abrasive stone, emery, garnet, millstones, and tripoli.
[5]Excludes volcanic cinder and scoria.
[6]Includes aplite, boron minerals, fluorspar, iron oxide pigments (crude), kyanite, magnesite, olivine, vermiculite, and industrial mineral data indicated by symbol W.

Table 3.—Material handled at surface and underground mines[1] (including sand and gravel and stone) in the United States in 1986, by State

(Thousand short tons)

State	Surface			Underground			All mines[2]		
	Crude ore	Waste	Total[2]	Crude ore	Waste	Total[2]	Crude ore	Waste	Total[2]
Alabama	13,500	1,920	15,400	--	--	--	13,500	1,920	15,400
Alaska	30,500	8,200	38,700	--	W	W	30,500	8,200	38,700
Arizona	170,000	126,000	296,000	W	304	304	170,000	126,000	296,000
Arkansas	11,100	4,870	16,000	--	--	--	11,100	4,870	16,000
California	152,000	42,500	194,000	61	35	96	152,000	42,500	194,000
Colorado	29,000	12,400	41,400	8,930	180	9,110	37,900	12,500	50,500
Connecticut	7,650	145	7,800	--	--	--	7,650	145	7,800
Delaware	1,550	--	1,550	--	--	--	1,550	--	1,550
Florida	167,000	255,000	422,000	--	--	--	167,000	255,000	422,000
Georgia	18,300	8,250	26,500	9	--	9	18,300	8,250	26,500
Hawaii	617	--	617	--	--	--	617	--	617
Idaho	15,700	44,600	60,300	548	1,700	2,250	16,300	46,300	62,500
Illinois	32,400	410	32,800	W	W	W	32,400	410	32,800
Indiana	20,500	646	21,100	W	--	W	20,500	646	21,100
Iowa	16,300	423	16,700	W	--	W	16,300	423	16,700
Kansas	17,100	786	17,900	1,210	--	1,210	18,300	786	19,100
Kentucky	8,060	749	8,800	--	--	--	8,060	749	8,800
Louisiana	15,000	288	15,200	4,810	--	4,810	19,800	288	20,100
Maine	8,620	W	8,620	--	--	--	8,620	W	8,620
Maryland	15,600	316	18,900	--	--	--	18,600	316	18,900
Massachusetts	19,400	W	19,400	--	--	--	19,400	W	19,400
Michigan	87,000	31,200	118,000	4,660	W	4,660	91,600	31,200	123,000
Minnesota	131,000	39,100	170,000	--	--	--	131,000	39,100	170,000
Mississippi	16,400	1,120	17,500	--	--	--	16,400	1,120	17,500
Missouri	11,800	1,300	13,100	7,090	2,950	10,000	18,900	4,250	23,100
Montana	27,600	23,500	51,100	3,560	61	3,620	31,200	23,500	54,700
Nebraska	9,910	192	10,100	--	--	--	9,910	192	10,100
Nevada	68,100	96,900	165,000	106	62	168	68,200	97,000	165,000
New Hampshire	8,430	W	8,430	--	--	--	8,430	W	8,430
New Jersey	16,500	W	16,500	W	W	W	16,500	W	16,500
New Mexico	44,500	197,000	242,000	10,300	690	11,000	54,800	198,000	253,000

New York	32,000	650	32,600	4,530	W	4,530	36,500	650	37,200
North Carolina	24,200	42,100	66,300	--	--	--	24,200	42,100	66,300
North Dakota	5,210	W	5,210	--	--	--	5,210	W	5,210
Ohio	41,000	2,410	43,400	3,690	W	3,690	44,700	2,410	47,100
Oklahoma	14,300	878	15,200	--	--	--	14,300	878	15,200
Oregon	13,900	178	14,100	([3])	1	1	13,900	178	14,100
Pennsylvania	17,300	1,090	18,400	--	--	--	17,300	1,090	18,400
Rhode Island	2,290	--	2,290	--	--	--	2,290	--	2,290
South Carolina	10,800	1,740	12,600	--	--	--	10,800	1,740	12,600
South Dakota	11,500	17,600	29,100	W	W	W	11,500	17,600	29,100
Tennessee	11,700	5,670	17,300	5,760	194	5,950	17,400	5,870	23,300
Texas	66,100	2,590	68,700	291	--	291	66,400	2,590	69,000
Utah	20,400	16,900	37,300	983	203	1,186	21,400	17,100	38,500
Vermont	5,070	2,220	7,300	W	W	W	5,070	2,220	7,300
Virginia	13,700	1,050	14,800	W	--	W	13,700	1,050	14,800
Washington	27,000	219	27,200	527	W	527	27,500	219	27,700
West Virginia	2,330	W	2,330	--	--	--	2,330	W	2,330
Wisconsin	26,100	--	26,100	--	--	--	26,100	--	26,100
Wyoming	5,800	1,530	7,330	7,360	--	7,360	13,200	1,530	14,700
Undistributed	142	636	778	21,700	793	22,500	21,800	1,430	23,200
Total[2] [4]	1,550,000	995,000	2,540,000	86,100	7,180	93,200	1,630,000	1,000,000	2,630,000

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 1986

(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	$10.01	W	$10.01	--	--	--	$10.01	W	$10.01
Copper	9.22	$0.75	9.98	$2.36	W	$2.36	8.22	$0.75	8.97
Gold:									
Lode	17.76	1.65	19.41	23.86	$4.22	28.08	18.09	1.79	19.88
Placer	3.22	--	3.22	--	--	--	3.22	--	3.22
Iron ore	10.44	--	10.44	21.18	.14	21.32	10.55	--	10.55
Lead	--	--	--	24.47	17.71	42.18	24.47	17.71	42.18
Silver	3.79	1.27	5.06	21.84	8.68	30.52	12.38	4.80	17.17
Zinc	--	--	--	27.81	W	27.81	27.81	W	27.81
Average[1]	10.54	.74	11.28	11.15	2.84	13.99	10.62	.99	11.61
INDUSTRIAL MINERALS									
Abrasives[2]	7.24	--	7.24	10.00	--	10.00	7.83	--	7.83
Asbestos	306.30	--	306.30	--	--	--	306.30	--	306.30
Barite	37.80	W	37.80	--	--	--	37.80	W	37.80
Clays	23.87	.20	24.07	W	--	W	23.87	.20	24.07
Diatomite	76.63	--	76.63	--	--	--	76.63	--	76.63
Feldspar	19.53	58.59	78.12	--	--	--	19.53	58.59	78.12
Gypsum	6.51	--	6.51	6.25	--	6.25	6.46	--	6.46
Mica (scrap)	15.01	--	15.01	--	--	--	15.01	--	15.01
Perlite	16.69	--	16.69	24.45	--	24.45	16.73	--	16.73
Phosphate rock	3.36	--	3.36	W	--	W	3.36	--	3.36
Potassium salts	--	--	--	14.51	--	14.51	14.51	--	14.51
Pumice[3]	9.60	--	9.60	--	--	--	9.60	--	9.60
Salt	W	W	W	13.94	2.82	16.76	13.94	2.82	16.76

Sand and gravel	3.41	W	3.41	--	--	--	3.41	W	3.41
Sodium carbonate (natural)	--	--	--	63.56	--	63.56	63.56	--	63.56
Talc, soapstone, pyrophyllite	18.39	3.34	21.73	30.64	--	30.64	19.18	3.12	22.31
Average[1]	4.72	.07	4.79	24.78	1.2	25.99	5.25	.10	5.35
Average, metals and industrial minerals[1]	6.15	.23	6.39	16.24	2.23	18.47	6.68	.34	7.01
Average, industrial minerals (excluding sand and gravel and stone)[1]	8.34	.26	8.60	24.78	1.22	25.99	9.87	.35	10.22
Average, metals and industrial minerals (excluding sand and gravel)[1]	9.56	.52	10.08	16.24	2.23	18.47	10.29	.71	11.00

W Withheld to avoid disclosing company proprietary data.
[1]Includes unpublished data.
[2]Includes abrasive stone, emery, garnet, millstones, and tripoli.
[3]Excludes volcanic cinder and scoria.

Table 5.—Crude ore and total material handled at surface and underground mines in the United States in 1986, by commodity

(Percent)

Commodity	Crude ore		Total material	
	Surface	Underground	Surface	Underground
METALS				
Bauxite	100.0	--	100.0	--
Copper	87.8	12.2	95.4	4.6
Gold:				
Lode	95.8	4.2	98.2	1.8
Placer	100.0	--	100.0	
Iron ore	99.0	1.0	99.3	.7
Lead	W	[1]100.0	W	[1]100.0
Silver	56.1	43.9	87.3	12.7
Zinc	--	100.0	--	100.0
Average[2]	88.9	11.1	94.6	5.4
INDUSTRIAL MINERALS				
Abrasives[3]	[4]100.0	W	[4]100.0	W
Asbestos	100.0	--	100.0	--
Barite	100.0	--	100.0	--
Clays	[4]100.0	W	[4]100.0	W
Diatomite	100.0	--	100.0	--
Feldspar	100.0	--	100.0	--
Gypsum	80.9	19.1	85.7	14.3
Mica (scrap)	100.0	--	100.0	--
Perlite	99.3	.7	99.7	.3
Phosphate rock	[4]100.0	W	[4]100.0	W
Potassium salts	--	100.0	--	100.0
Pumice[5]	100.0	--	100.0	--
Salt	2.5	97.5	2.5	97.5
Sand and gravel	100.0	--	100.0	--
Sodium carbonate (natural)	--	100.0	--	100.0
Talc, soapstone, pyrophyllite	93.3	6.7	98.4	1.6
Average[2]	97.1	2.9	97.7	2.3
Average, metals and industrial minerals[2]	94.7	5.3	96.5	3.5

W Withheld to avoid disclosing company proprietary data; included with "Surface" or "Underground."
[1]Includes surface; the Bureau of Mines is not at liberty to publish separately.
[2]Includes unpublished data.
[3]Includes abrasive stone, emery, garnet, millstones, and tripoli.
[4]Includes underground; the Bureau of Mines is not at liberty to publish separately.
[5]Excludes volcanic cinder and scoria.

Table 6.—Crude ore and total material handled at surface and underground mines in the United States in 1986, by State

(Percent)

State	Crude ore		Total material	
	Surface	Underground	Surface	Underground
Alabama	100.0	--	100.0	--
Alaska	100.0	--	100.0	--
Arizona	[1]100.0	W	[1]100.0	W
Arkansas	100.0	--	100.0	--
California	100.0	--	100.0	--
Colorado	76.5	23.5	82.0	18.0
Connecticut	100.0	--	100.0	--
Delaware	100.0	--	100.0	--
Florida	100.0	--	100.0	--
Georgia	100.0	--	100.0	--
Hawaii	100.0	--	100.0	--
Idaho	96.6	3.4	96.4	3.6
Illinois	[1]100.0	W	[1]100.0	W
Indiana	[1]100.0	W	[1]100.0	W
Iowa	[1]100.0	W	[1]100.0	W
Kansas	93.4	6.6	93.7	6.3
Kentucky	100.0	--	100.0	--
Louisiana	75.7	24.3	7.6	92.4
Maine	100.0	--	100.0	--
Maryland	100.0	--	100.0	--
Massachusetts	100.0	--	100.0	--
Michigan	94.9	5.1	9.6	90.4
Minnesota	100.0	--	100.0	--
Mississippi	100.0	--	100.0	--
Missouri	62.4	37.6	56.6	43.4
Montana	88.6	11.4	93.4	6.6
Nebraska	100.0	--	100.0	--
Nevada	99.8	.2	99.9	.1
New Hampshire	100.0	--	100.0	--
New Jersey	[1]100.0	W	[1]100.0	W
New Mexico	81.2	18.8	95.7	4.3
New York	87.6	12.4	87.8	12.2
North Carolina	100.0	--	100.0	--
North Dakota	100.0	--	100.0	--
Ohio	91.8	8.2	92.2	7.8
Oklahoma	100.0	--	100.0	--
Oregon	100.0	--	100.0	--
Pennsylvania	100.0	--	100.0	--
Rhode Island	100.0	--	100.0	--
South Carolina	100.0	--	100.0	--
South Dakota	[1]100.0	W	[1]100.0	W
Tennessee	67.0	33.0	74.5	25.5
Texas	99.6	.4	99.6	.4
Utah	95.4	4.6	96.9	3.1
Vermont	[1]100.0	W	[1]100.0	W
Virginia	[1]100.0	W	[1]100.0	W
Washington	98.1	1.9	97.7	2.3
West Virginia	100.0	--	100.0	--
Wisconsin	100.0	--	100.0	--
Wyoming	44.1	55.9	49.9	50.1
Average[2]	94.7	5.3	96.5	3.5

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.
[2]Includes unpublished data.

Table 7.—Number of domestic metal and industrial mineral mines[1] in the United States in 1986, by commodity

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	4	--	--	3	1	--	--
Copper	18	--	--	1	2	7	8
Gold:							
Lode	81	9	9	14	31	17	1
Placer	35	8	8	11	6	2	--
Iron ore	16	--	--	4	--	5	7
Lead	10	2	--	--	5	3	--
Silver	22	5	4	6	4	3	--
Zinc	10	1	--	1	7	1	--
Other[2]	45	14	5	13	7	5	1
Total	241	39	26	53	63	43	17
INDUSTRIAL MINERALS							
Abrasives[3]	5	1	--	4	--	--	--
Asbestos	3	--	1	2	--	--	--
Barite	12	--	7	4	1	--	--
Clays	860	37	187	501	134	1	--
Diatomite	12	--	5	3	4	--	--
Feldspar	17	1	1	10	5	--	--
Gypsum	63	1	2	19	40	1	--
Mica (scrap)	12	2	3	6	1	--	--
Perlite	11	1	2	5	3	--	--
Phosphate rock	37	--	--	3	10	18	6
Potassium salts	6	--	--	--	3	3	--
Pumice[4]	22	3	10	6	3	--	--
Salt	15	--	1	4	4	6	--
Sand and gravel	5,903	87	872	2,848	1,976	119	1
Sodium carbonate (natural)	5	--	--	--	1	4	--
Talc, soapstone, pyrophyllite	36	7	7	16	6	--	--
Other[5]	23	1	4	11	6	1	--
Total	7,042	141	1,102	3,442	2,197	153	7
Grand total	7,283	180	1,128	3,495	2,260	196	24

[1]Excludes wells, ponds, or pumping operations.
[2]Includes antimony, beryllium, manganiferous ore, mercury, molybdenum, nickel, platinum-group metals, rare-earth metals, titanium (ilmenite), tungsten, and uranium.
[3]Includes abrasive stone, emery, garnet, millstones, and tripoli.
[4]Excludes volcanic cinder and scoria.
[5]Includes aplite, boron minerals, fluorspar, greensand marl, iron oxide pigments (crude), kyanite, magnesite, olivine, and vermiculite.

Table 8.—Twenty-five leading metal and industrial mineral[1] mines in the United States in 1986, in order of output of crude ore

Mine	State	Operator	Commodity	Mining method
METALS				
Morenci	Arizona	Phelps Dodge Corp	Copper	Open pit.
San Manuel	do	Magma Copper Co	do	Caving and open pit.
Round Mountain	Nevada	Round Mountain Gold Corp	Lode gold	Open pit.
Empire	Michigan	Empire Iron Mining Co	do	Do.
Pinto Valley	Arizona	Newmont Mining Corp	Copper	Do.
Bagdad	do	Cyprus Bagdad Copper Co	do	Do.
Sierrita	do	Duval Sierrita Corp	do	Do.
Minntac	Minnesota	USX Corp	Iron ore	Do.
Tyrone	New Mexico	Phelps Dodge Corp	Copper	Do.
Hibbing Taconite	Minnesota	Pickands Mather & Co	Iron ore	Do.
Chino	New Mexico	Chino Mines Co	Copper	Do.
Hoyt Lakes	Minnesota	LTV Steel Co. Inc	Iron ore	Do.
Ray Pit	Arizona	Kennecott	do	Do.
Thunderbird	do	Oglebay Norton Co	do	Do.
Tilden	Michigan	Tilden Mining Co	do	Do.
National Pellet Project-St. Louis.	Minnesota	The Hanna Mining Co	do	Do.
Green Cove	Florida	Associated Minerals Corp	Titanium	Dredging.
Henderson	Colorado	Climax Molybdenum Co., a division of AMAX Inc.	Molybdenum	Caving and open pit.
Zortman-Landusky	Montana	Pegasus Gold Inc	Lode gold	Open pit.
Minorca	do	Inland Steel Mining Co	Iron ore	Do.
Continental	Montana	Montana Resources Inc	Copper	Do.
Lisa	California	Yuba Placer Gold Co	Placer gold	Mechanical excavation.
Peter Mitchell	Minnesota	Reserve Mining Co	Iron ore	Open pit.
National Pellet Project-Itasca.	do	The Hanna Mining Co	do	Do.
White Pine	Michigan	Copper Range Co	Copper	Stopes.
INDUSTRIAL MINERALS[2]				
Suwanee	Florida	Occidental Petroleum Corp	Phosphate rock.	Open pit.
Ft. Green	do	Agrico Chemical Co	do	Do.
Swift Creek	do	Occidental Petroleum Corp	do	Do.
Noralyn	do	International Minerals & Chemical Corp.	do	Do.
Kingsford	do	do	do	Do.
Lee Creek	North Carolina	Texasgulf Inc	do	Do.
Haynsworth	Florida	American Cyanamid Co	do	Do.
Lonesome	do	do	do	Do.
Wingate Creek	do	Beker Industries Corp	do	Do.
Ft. Meade	do	Mobil Oil Corp	do	Do.
Rockland	do	USS Agri-Chemicals	do	Do.
Hookers	do	W. R. Grace & Co	do	Do.
Clear Spring	do	International Minerals & Chemical Corp.	do	Do.
Radum	California	Koppers Co., Kaiser Sand and Gravel.	Sand and gravel.	Dredging.
Irwindale	do	Koppers Co., Blue Diamond Materials.	do	Do.
International	New Mexico	International Minerals & Chemical Corp.	Potassium salts.	Stopes.
Sun Valley	California	CalMat Co. of California.	Sand and gravel.	Dredging.
Perkins	do	A. Teichert & Son Inc., Teichert Aggregates.	do	Do.
Watson	Florida	Estech Inc	Phosphate rock.	Open pit.
Hardee	do	C. F. Mining Corp	do	Do.
Steilacoom	Washington	Northwest Aggregates Co	Sand and gravel.	Dredging.
St. Lucie	Florida	General Development Corp	do	Do.
Azusa	California	Owl Rock Products Co	do	Do.
Irwindale	do	Symons Corp., Livingston-Graham Inc.	do	Do.
Dobson	Arizona	Salt River Sand and Rock	do	Do.

[1]Excludes brines and materials from wells.

[2]Crushed and broken and dimension stone were not available in 1986 because of biennial canvassing.

Table 9.—Twenty-five leading metal and industrial mineral[1] mines in the United States in 1986, in order of output of total materials handled

Mine	State	Operator	Commodity	Mining method
		METALS		
Tyrone	New Mexico	Phelps Dodge Corp	Copper	Open pit.
Morenci	Arizona	do	do	Do.
San Manuel	do	Magma Copper Co	do	Caving and open pit.
Chino	New Mexico	Phelps Dodge Corp	do	Open pit.
Pinto Valley	Arizona	Pinto Valley Copper Corp	do	Do.
Empire	Michigan	Empire Iron Mining Co	Iron ore	Do.
Ray Pit	Arizona	Kennecott	Copper	Do.
Hoyt Lakes	Minnesota	LTV Steel Co. Inc	Iron ore	Do.
Round Mountain	Nevada	Round Mountain Gold Co	Lode gold	Do.
Sierrita	Arizona	Duval Sierrita Corp	Copper	Do.
Thompson Creek	Idaho	Cyprus Mines Corp	Molybdenum	Do.
Hibbing Taconite	Minnesota	Pickands Mather & Co	Iron ore	Do.
Bagdad	Arizona	Cyprus Bagdad Copper Co	Copper	Do.
Minntac	Minnesota	USX Corp	Iron ore	Do.
Battle Mountain	Nevada	Battle Mountain Gold Co	Lode gold	Do.
Tilen	Michigan	Tilden Mining Co	Iron ore	Do.
Homestake	South Dakota	Homestake Mining Co	Lode gold	Do.
Candelaria	Nevada	Nerco Minerals Co	Silver	Do.
Thunderbird	Minnesota	Oglebay Norton Co	Iron ore	Do.
Jerritt Canyon	Nevada	Freeport Gold Co	Lode gold	Do.
McLaughlin	California	Homestake Mining Co	do	Do.
National Pellet Projct-Itasca.	Minnesota	The Hanna Mining Co	Iron ore	Do.
McCoy	Nevada	CanAm Gold Corp	Lode gold	Do.
Mercur	Utah	Barrick Mercur Gold Mines Inc	do	Do.
Climax	Colorado	Climax Molybdenum Co., a division of AMAX Inc.	Molybdenum	Do.
		INDUSTRIAL MINERALS[2]		
Lee Creek	North Carolina	Texasgulf Inc	Phosphate rock.	Open pit.
Suwannee	Florida	Occidental Petroleum Corp	do	Do.
Noralyn	do	International Minerals & Chemical Corp.	do	Do.
Kingsford	do	do	do	Do.
Ft. Green	do	Agrico Chemical Co	do	Do.
Lonesome	do	American Cyanamid Co	do	Do.
Clear Spring	do	International Minerals & Chemical Corp.	do	Do.
Haynsworth	do	American Cyanamid Co	do	Do.
Wingate Creek	do	Beker Industries Corp	do	Do.
Gay	Idaho	J. R. Simplot Co	do	Do.
Hookers	Florida	W. R. Grace & Co	do	Do.
Ft. Meade	do	Mobil Oil Corp	do	Do.
Swift Creek	do	Occidental Petroleum Corp	do	Do.
Hardee	do	C. F. Mining Corp	do	Do.
Watson	do	Estech Inc	do	Do.
Ft. Meade	do	Gardinier Inc	do	Do.
4 Corners	do	W. R. Grace & Co	do	Do.
Nichols	do	Mobil Oil Corp	do	Do.
Boron	California	U.S. Borax and Chemical Co	Boron	Do.
Rockland	Florida	USS Agri-Chemicals	Phosphate rock.	Do.
Henry	Idaho	Monsanto Co	do	Do.
Radum	California	Koppers Co., Kaiser Sand and Gravel.	Sand and gravel.	Dredging.
International	New Mexico	International Minerals & Chemical Corp.	Potassium salts.	Stopes.
Saddle Creek	Florida	Agrico Chemical Co	Phosphate rock.	Open pit.
Irwindale	California	Symons Corp., Livingston-Graham Inc.	Sand and gravel.	Dredging.

[1]Excludes brines and materials from wells.
[2]Crushed and broken and dimension stone were not available in 1986 because of biennial canvassing.

Table 10.—Ore treated or sold per unit of marketable product at surface and underground mines[1] in the United States in 1986, by commodity

Commodity	Surface			Underground			Total[2]		
	Ore treated (thousand short tons)	Marketable product (units)	Ratio of units of ore to units of marketable product	Ore treated (thousand short tons)	Marketable product (units)	Ratio of units of ore to units of marketable product	Ore treated (thousand short tons)	Marketable product (units)	Ratio of units of ore to units of marketable product
METALS									
Bauxite ________ thousand long tons	W	502	W	--	--	--	W	502	W
Copper ________ thousand short tons	168,000	1,170	143.3:1	W	W	W	168,000	1,170	143.3:1
Gold:									
Lode ________ thousand troy ounces	64,500	3,110	20.7:1	3,670	238	15.4:1	68,200	3,350	20.4:1
Placer ________ do	8,030	70	114.5:1	--	--	--	8,030	70	114.5:1
Iron ore ________ thousand long tons	134,000	40,500	3.3:1	1,320	803	1.6:1	135,000	41,300	3.3:1
Lead ________ thousand short tons	--	--	--	5,840	324	18.0:1	5,840	324	18.0:1
Silver ________ thousand troy ounces	W	W	W	4,040	16,100	.3:1	4,040	16,100	.3:1
Zinc ________ thousand short tons	--	--	--	W	159	W	W	159	W
INDUSTRIAL MINERALS									
Abrasives[3] ________ do	92	92	1.0:1	W	W	W	92	92	1.0:1
Asbestos ________ do	57	57	1.0:1	--	--	--	57	57	1.0:1
Barite ________ do	317	262	1.2:1	--	--	--	317	262	1.2:1
Clays ________ do	44,200	43,800	1.0:1	W	W	W	44,200	43,800	1.0:1
Diatomite ________ do	1,680	628	2.7:1	--	--	--	1,680	628	2.7:1
Feldspar ________ do	1,220	684	1.8:1	--	--	--	1,220	684	1.8:1
Gypsum ________ do	12,800	12,800	1.0:1	W	W	W	12,800	12,800	1.0:1
Mica (scrap) ________ do	277	90	3.1:1	--	--	--	277	90	3.1:1
Perlite ________ do	898	710	1.3:1	5	5	1.0:1	903	715	1.3:1
Phosphate rock ________ do	260,000	42,500	6.1:1	W	W	W	260,000	42,500	6.1:1
Potassium salts ________ do	--	--	--	9,450	1,220	7.7:1	9,450	1,220	7.7:1
Pumice[4] ________ do	598	554	1.1:1	W	W	W	598	554	1.1:1
Salt ________ do	W	W	W	13,300	12,400	1.1:1	13,300	12,400	1.1:1
Sand and gravel ________ do	910,000	910,000	1.0:1	--	--	--	910,000	910,000	1.0:1
Sodium carbonate (natural) ________ do	--	--	--	7,360	7,360	1.0:1	7,360	7,360	1.0:1
Talc, soapstone, pyrophyllite ________ do	1,310	994	1.3:1	W	W	W	1,310	994	1.3:1

W Withheld to avoid disclosing company proprietary data.
[1]Excludes wells, ponds, and pumping operations.
[2]Data may not add to totals shown because of independent rounding.
[3]Includes abrasive stone, emery, garnet, millstones, and tripoli.
[4]Excludes volcanic cinder and scoria.

Table 11.—Material handled per unit of marketable product at surface and underground mines[1] in the United States in 1986, by commodity

Commodity	Surface: Total material handled[3] (thousand short tons)	Surface: Marketable product (units)	Surface: Ratio of units of material handled to units of marketable product[4]	Underground: Total material handled[3] (thousand short tons)	Underground: Marketable product (units)	Underground: Ratio of units of material handled to units of marketable product[4]	Total[2]: Total material handled[3] (thousand short tons)	Total[2]: Marketable product (units)	Total[2]: Ratio of units of material handled to units of marketable product[4]
METALS									
Bauxite ---- thousand long tons	2,240	502	4.5:1	--	--	--	2,240	502	4.5:1
Copper ---- thousand short tons	385,000	1,170	329.0:1	23,500	51	461.6:1	408,000	1,220	334.5:1
Gold:									
Lode ---- thousand troy ounces	202,000	3,110	64.8:1	3,320	238	14.0:1	205,000	3,350	61.2:1
Placer ---- do	16,200	70	230.5:1	--	--	--	16,200	70	230.5:1
Iron ore ---- thousand long tons	191,000	40,500	4.7:1	1,320	803	1.6:1	192,000	41,300	4.6:1
Lead ---- thousand short tons	--	--	--	6,080	324	18.8:1	6,080	324	18.8:1
Silver ---- thousand troy ounces	21,300	3,080	6.9:1	4,240	16,100	.3:1	25,500	19,200	1.3:1
Zinc ---- thousand short tons	--	--	--	4,430	159	27.8:1	4,430	159	27.8:1
INDUSTRIAL MINERALS									
Abrasives[5] ---- do	137	92	1.5:1	W	W	W	137	92	1.5:1
Asbestos ---- do	57	57	1.0:1	--	--	--	57	57	1.0:1
Barite ---- do	232	262	.9:1	--	--	--	232	262	.9:1
Clays ---- do	82,700	[e]43,800	1.9:1	W	W	W	82,700	[e]43,800	1.9:1
Diatomite ---- do	7,530	628	12.0:1	--	--	--	7,530	628	12.0:1
Feldspar ---- do	1,970	684	2.9:1	--	--	--	1,970	684	2.9:1
Gypsum ---- do	15,700	12,800	1.2:1	3,010	3,010	1.0:1	18,700	15,800	1.2:1
Mica (scrap) ---- do	349	90	3.9:1	--	--	--	349	90	3.9:1
Perlite ---- do	1,640	710	2.3:1	5	5	1.0:1	1,640	715	2.3:1
Phosphate rock ---- do	450,000	42,500	10.6:1	W	W	W	450,000	42,500	10.6:1
Potassium salts ---- do	--	--	--	10,100	1,220	8.2:1	10,100	1,220	8.2:1
Pumice[6] ---- do	1,130	554	2.0:1	--	--	--	1,130	554	2.0:1
Salt ---- do	W	W	W	13,300	12,400	1.1:1	13,300	12,400	1.1:1
Sand and gravel ---- do	910,000	910,000	1.0:1	--	--	--	910,000	910,000	1.0:1
Sodium carbonate (natural) ---- do	--	--	--	7,360	7,360	1.0:1	7,360	7,360	1.0:1
Talc, soapstone, pyrophyllite ---- do	6,030	994	6.1:1	152	91	1.7:1	6,180	1,090	5.7:1

[e]Estimated. W Withheld to avoid disclosing company proprietary data.
[1]Excludes wells, ponds, and pumping operations.
[2]Data may not add to totals shown because of independent rounding.
[3]Includes material from exploration and development activities.
[4]Material from development and exploration activities is excluded from the ratio calculation.
[5]Includes abrasive stone, emery, garnet, millstones, and tripoli.
[6]Excludes volcanic cinder and scoria.

Table 12.—Mining methods used in open pit mining in the United States in 1986, by commodity

(Percent)

Commodity	Total material handled: Preceded by drilling and blasting	Total material handled: Not preceded by drilling and blasting[1]
METALS		
Bauxite	98	2
Beryllium	--	100
Copper	99	1
Gold:		
Lode	98	2
Placer	--	100
Iron ore	99	1
Magnesium	100	--
Manganiferous ore	--	100
Mercury	1	99
Molybdenum	100	--
Rare-earth metals	100	--
Silver	100	--
Titanium (ilmenite)	--	100
INDUSTRIAL MINERALS		
Abrasives[2]	66	34
Aplite	15	85
Asbestos	100	--
Barite	98	2
Boron	--	100
Clays	--	100
Diatomite	--	100
Feldspar	100	--
Fluorspar	100	--
Gypsum	97	3
Iron oxide	91	9
Kyanite	100	--
Magnesite	100	--
Mica (scrap)	25	75
Olivine	100	--
Perlite	57	43
Phosphate rock	5	95
Pumice[3]	24	76
Salt	4	96
Sand and gravel	--	100
Talc, soapstone, pyrophyllite	100	--
Vermiculite	98	2
Average	36	64

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

[2]Includes abrasive stone, emery, garnet, millstones, and tripoli.

[3]Excludes volcanic cinder and scoria.

Table 13.—Exploration and development activity in the United States in 1986, by method

Method	Metals		Industrial minerals		Total[1]	
	Feet	Percent of total[2]	Feet	Percent of total[2]	Feet	Percent of total[2]
EXPLORATION						
Churn drilling	9,690	0.3	--	--	9,690	0.3
Diamond drilling	422,000	12.7	99,500	48.7	522,000	14.8
Percussion drilling	977,000	29.3	--	--	977,000	27.7
Rotary drilling	1,540,000	46.2	54,100	26.5	1,590,000	45.0
Other drilling	319,000	9.6	50,800	24.8	370,000	10.5
Trenching	64,500	1.9	--	--	64,500	1.8
Total[1]	3,330,000	100.0	204,000	100.0	3,540,000	100.0
DEVELOPMENT						
Drifting, crosscutting, or tunneling	496,000	90.0	17,000	91.1	513,000	90.0
Raising	51,900	9.4	652	3.5	52,600	9.2
Shaft and winze sinking	3,360	.6	1,000	5.4	4,360	.8
Solution mining	(3)	--	--	--	--	--
Total[1]	551,000	100.0	18,600	100.0	570,000	100.0
Grand total[1]	3,880,000	XX	223,000	XX	4,104,617	XX

XX Not applicable.
[1]Data may not add to totals shown because of independent rounding.
[2]Based on unrounded footage.
[3]Included with "Drifting, crosscutting, or tunneling" to avoid disclosing company proprietary data.

Table 14.—Exploration and development in the United States in 1986, by commodity

(Feet)

Commodity	Exploration: Churn drilling	Diamond drilling	Percussion drilling	Rotary drilling	Other drilling	Trenching	Total[1]	Development: Drifting, crosscutting, or tunneling	Raising	Shaft and winze sinking	Solution mining	Total[1]
METALS												
Antimony	--	--	--	--	--	--	--	450	--	--	--	450
Cobalt	--	--	245	145	--	--	390	--	--	--	--	--
Copper	--	3,140	W	14,600	--	--	17,800	W	28,000	3	W	28,000
Gold:												
Lode	--	220,000	692,000	449,000	148,000	60,700	1,570,000	74,000	10,800	2,860	--	87,700
Placer	W	2,000	--	W	60,000	877	62,900	W	30	3	W	33
Iron ore	--	W	--	--	--	W	--	4,630	--	--	--	4,630
Lead	W	W	30	W	W	1,650	1,680	59,500	W	5	--	59,500
Mercury	--	--	--	21,500	--	--	21,500	--	--	--	--	--
Molybdenum	--	W	--	--	2,900	--	2,900	W	W	--	--	--
Platinum-group metals	W	57,300	2,400	--	--	1	59,700	W	W	--	--	--
Silver	--	55,000	--	14,000	W	200	69,200	18,400	3,060	W	--	21,500
Tungsten	--	W	25	--	--	20	45	W	W	15	--	15
Zinc	--	W	272,000	--	--	--	272,000	21,600	W	--	--	21,600
Other[2]	9,690	84,500	10,700	1,040,000	108,000	1,050	1,250,000	317,000	10,000	465	([3])	327,000
Total[1]	9,690	422,000	977,000	1,540,000	319,000	64,500	3,330,000	496,000	51,900	3,360	--	551,000
INDUSTRIAL MINERALS												
Phosphate rock	--	W	--	52,300	W	--	52,300	W	--	--	--	--
Other[4]	--	99,500	--	1,840	50,800	--	152,000	17,000	652	1,000	--	18,600
Total[1]	--	99,500	--	54,100	50,800	--	204,000	17,000	652	1,000	--	18,600
Grand total[1]	9,690	522,000	977,000	1,590,000	370,000	64,500	3,540,000	513,000	52,600	4,360	--	570,000

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Data may not add to totals shown because of independent rounding.
[2]Includes bauxite, beryllium, uranium, and metal items indicated by symbol W.
[3]Included with "Drifting, crosscutting, or tunneling" to avoid disclosing company proprietary data.
[4]Includes fluorspar, lime, potassium salts, pumice, talc, soapstone, and pyrophyllite; and mineral items indicated by symbol W.

Table 15.—Exploration and development in the United States in 1986, by State

(Feet)

State	Exploration							Development				
	Churn drilling	Diamond drilling	Percussion drilling	Rotary drilling	Other drilling	Trenching	Total[1]	Drifting, crosscutting, or tunneling	Raising	Shaft and winze sinking	Solution mining	Total[1]
Alaska	W	10,200	--	--	15,000	127	25,300	W	--	--	W	--
Arizona	--	4,120	--	5,000	--	W	9,110	W	W	357	W	357
California	W	12,300	24,100	57,100	45,000	1,560	140,000	3,630	3,210	W	--	6,850
Colorado	--	48,400	32,500	23,100	12,600	1	117,000	30,700	4,550	465	--	35,700
Idaho	--	19,900	--	40,000	44,200	W	104,000	8,830	3,020	33	--	11,900
Missouri	W	W	--	--	W	--	--	57,400	--	--	--	57,400
Montana	--	110,000	2,400	53,100	--	6,040	172,000	W	1,720	3	--	1,730
Nevada	--	82,500	502,000	279,000	79,100	26,200	968,000	8,330	W	12	--	8,330
New Mexico	--	10,500	38,700	66,500	41,100	3,000	160,000	35,400	3,770	20	--	39,200
Oregon	--	50	--	10,800	--	60	10,900	60	30	--	--	90
South Carolina	--	4,000	4,000	--	--	8,000	16,000	--	--	--	--	--
Tennessee	--	W	W	W	W	--	--	20,900	W	--	--	20,900
Utah	--	W	2,370	32,400	30,300	200	65,300	8,630	--	--	--	8,630
Washington	--	37,500	--	W	--	30	37,500	W	W	W	--	--
Undistributed[2]	9,690	182,000	372,000	1,030,000	102,000	19,300	1,710,000	339,000	36,302	3,470	([3])	378,000
Total[1]	9,690	522,000	977,000	1,590,000	370,000	64,500	3,540,000	513,000	52,600	4,360	--	570,000

W Withheld to avoid disclosing company proprietary data; included with "Undistributed."
[1]Data may not add to totals shown because of independent rounding.
[2]Includes Alabama, Arkansas, Florida, Georgia, Illinois, Michigan, Minnesota, New York, North Carolina, Oklahoma, South Dakota, Texas, and items indicated by symbol W.
[3]Included with "Drifting, crosscutting, or tunneling" to avoid disclosing company proprietary data.

Table 16.—Total material (ore and waste) produced by mine development in the United States in 1986, by commodity and State

(Thousand short tons)

	Drifting, crosscutting, or tunneling	Raising	Shaft and winze sinking	Stripping	Total[1]
COMMODITY					
METALS					
Antimony	--	--	1,520	--	1,520
Copper	(2)	51	W	107,000	107,000
Gold:					
Lode	24	38	545	10,900	11,500
Placer	(2)	(2)	W	65	65
Iron ore	--	--	125	6,830	6,960
Lead	(2)	W	2,780	W	2,780
Silver	W	54	180	9,420	9,650
Tungsten	(2)	W	W	--	(2)
Uranium	--	W	113	--	113
Zinc	--	W	173	--	173
Other[3]	1	26	393	2,780	3,200
Total[1]	24	168	5,820	137,000	143,000
INDUSTRIAL MINERALS					
Gypsum	--	--	--	2,250	2,250
Talc, soapstone, pyrophyllite	W	W	W	133	133
Other[4]	7	4	256	315	581
Total[1]	7	4	256	2,700	3,000
Grand total[1]	31	172	6,080	140,000	146,000
STATE					
Arizona	5	W	W	W	5
California	W	9	10	3,170	3,190
Colorado	1	9	117	W	126
Idaho	(2)	54	1,580	--	1,640
Michigan	W	--	W	10	10
Missouri	--	--	2,860	--	2,860
Montana	(2)	5	W	4,200	4,200
Nevada	(2)	1	60	9,890	9,950
New Mexico	(2)	12	412	W	424
Oregon	--	(2)	(2)	W	1
Tennessee	--	W	166	--	166
Utah	--	--	111	W	111
Undistributed[5]	25	82	755	123,000	123,000
Total[1]	31	172	6,080	140,000	146,000

W Withheld to avoid disclosing company proprietary data; included with "Other" or "Undistributed."
[1]Data may not add to totals shown because of independent rounding.
[2]Less than 1/2 unit.
[3]Includes beryllium, molybdenum, platinum-group metals, and metal items indicated by symbol W.
[4]Includes abrasives, fluorspar, phosphate rock, potassium salts, pumice, and mineral items indicated by symbol W.
[5]Includes Alaska, Arkansas, Illinois, Minnesota, New York, North Carolina, Oklahoma, South Dakota, Texas, Washington, and data indicated by symbol W.

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

(Thousand pounds)

Year	Coal mining[1]	Metal mining[1]	Quarrying and industrial mineral mining[1]	Total mineral industry	Construction work and other uses[2]	Total industrial
1982	2,269,565	530,384	423,353	3,223,302	687,189	3,910,491
1983	2,126,263	481,129	467,710	3,075,102	655,150	3,730,252
1984	2,758,659	437,217	479,873	3,675,749	681,109	4,356,858
1985	r2,289,600	382,410	510,500	r3,182,510	666,141	r3,848,651
1986	2,566,337	319,844	585,220	3,471,401	451,435	3,922,836

rRevised.
[1]Some quantities of this use are included with "Construction work and other uses" to avoid disclosing company proprietary data.
[2]Includes some quantities from "Coal mining," "Metal mining," and "Quarrying and industrial mineral mining."

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

(Thousand pounds)

Year	Coal mining	Metal mining	Quarrying and industrial mineral mining	Total
PERMISSIBLE EXPLOSIVES				
1982	43,401	287	1,317	45,005
1983	35,181	311	657	36,149
1984	37,721	195	345	38,261
1985	34,563	117	481	35,161
1986	34,971	7	155	35,133
OTHER HIGH EXPLOSIVES				
1982	19,360	13,108	29,322	61,790
1983	17,964	8,861	31,833	58,658
1984	20,357	7,771	29,658	57,786
1985	21,705	9,466	55,470	86,641
1986	18,004	7,027	63,249	88,280
WATER GELS AND SLURRIES				
1982	104,364	90,738	80,503	275,605
1983	94,578	49,699	94,261	238,538
1984	99,340	78,959	102,849	281,148
1985[1]	133,858	66,653	80,283	280,794
1986[1]	180,201	57,153	128,854	366,208
AMMONIUM NITRATE: FUEL—MIXED AND UNPROCESSED				
1982	2,102,440	426,251	312,211	2,840,902
1983	1,978,540	422,258	340,959	2,741,757
1984	2,601,241	350,292	347,021	3,298,554
1985[1]	r2,099,474	306,174	374,266	r2,779,914
1986[1]	2,333,161	255,657	392,962	2,981,780
TOTAL				
1982	2,269,565	530,384	423,353	3,223,302
1983	2,126,263	481,129	467,710	3,075,102
1984	2,758,659	437,217	479,873	3,675,749
1985	r2,289,600	382,410	510,500	r3,182,510
1986	2,566,337	319,844	585,220	3,471,401

rRevised.
[1]Data for 1985-86 are not comparable to data for prior years. The higher strength blasting agents classification was discontinued. Blasting agents formerly in that classification are now included with "Water gels and slurries."

Statistical Summary

By Stephen D. Smith[1]

This chapter summarizes data on crude nonfuel mineral production for the United States, its island possessions, and the Commonwealth of Puerto Rico. Also included are tables that show the principal nonfuel mineral commodities exported from and imported into the United States and that compare world and U.S. mineral production. 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.

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. For copper, gold, lead, silver, tin, and zinc, 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.

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[1]Mineral data assistant, Section of Ferrous Metals Data. The author was assisted in the preparation of this chapter by Barbara M. Carrico, Chief, Section of Nonferrous Metals Data; Sarah P. Guerrino, Chief, Section of Ferrous Metals Data; Barbara E. Gunn, Chief, Section of Industrial Minerals Data; William L. Zajac, Chief, Branch of Geographic Data.

Table 1.—Nonfuel mineral production[1] in the United States

Mineral	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)
METALS						
Bauxite _____thousand metric tons, dried equivalent__	674	$12,855	510	[r]$10,361	576	$10,871
Copper (recoverable content of ores, etc.) __________metric tons__	1,105,758	1,632,483	1,147,277	1,670,660	1,255,914	2,284,156
Gold (recoverable content of ores, etc.) troy ounces__	2,427,232	771,032	[r]3,739,015	[r]1,376,855	4,966,382	2,224,691
Iron oxide pigments, crude short tons__	46,585	2,826	40,987	2,908	42,773	3,598
Lead (recoverable content of ores, etc.) metric tons__	413,955	174,008	339,793	165,150	311,298	246,654
Magnesium metal[2] ____short tons__	--	--	138,493	423,788	137,123	381,914
Manganiferous ore (5% to 35% Mn) short tons, gross weight__	19,882	W	14,320	W	19,087	W
Mercury _______ 76-pound flasks__	16,530	W	W	W	W	W
Molybdenum (content of ore and concentrate) __ thousand pounds__	111,936	347,812	95,006	240,484	69,868	179,286
Nickel (content of ore and concentrate) short tons__	6,127	W	1,175	W	--	--
Silver (recoverable content of ores, etc.) thousand troy ounces__	39,433	242,205	[r]34,524	[r]188,846	39,790	278,930
Tungsten (content of ore and concentrate) ________metric tons__	983	9,143	817	5,774	W	W
Zinc (recoverable content of ores, etc.) metric tons__	226,545	201,607	202,983	170,050	216,981	200,529
Combined value of antimony (1985-86), beryllium concentrates, iron ore (usable), magnesium chloride for magnesium metal (1985),[3] platinum-group metals (1987), rare-earth metal concentrates, tin, titanium concentrates (ilmenite and rutile), vanadium, zircon concentrates, and values indicated by symbol W ___________	XX	2,234,916	XX	[r]1,562,566	XX	1,636,688
Total[4] _______________	XX	5,629,000	XX	[r]5,817,000	XX	7,447,000
INDUSTRIAL MINERALS (EXCEPT FUELS)						
Abrasives[5] __________short tons__	1,157	515	W	W	12,773	957
Asbestos ___________metric tons__	57,457	20,485	51,437	17,367	50,600	17,198
Barite _____ thousand short tons__	739	21,501	297	12,326	448	15,810
Boron minerals__________do____	1,269	404,775	1,251	426,086	1,385	475,092
Bromine[e] _____ thousand pounds__	320,000	80,000	310,000	93,000	335,000	107,000
Cement:						
Masonry __ thousand short tons__	3,187	213,096	3,525	231,551	3,680	259,926
Portland ____________do____	74,250	3,817,335	75,181	3,759,942	74,868	3,646,561
Clays ______________do____	44,974	1,011,377	44,620	1,095,179	47,657	1,202,284
Diatomite ______________do____	635	127,030	628	128,362	658	134,239
Emery ____________short tons__	W	W	2,878	W	1,945	W
Feldspar ______________do____	700,000	22,800	735,000	26,100	720,000	26,100
Fluorspar _____________do____	66,000	W	[e]78,000	W	68,839	11,725
Garnet (abrasive) ________do____	36,727	2,973	32,296	2,603	42,277	4,350
Gem stones ________________	NA	[e]7,425	NA	9,247	NA	21,389
Gypsum ____ thousand short tons__	[r]14,414	[r]111,785	[r]15,403	[r]99,570	15,612	106,977
Helium:						
Crude _____million cubic feet__	W	W	432	9,504	730	16,068
Grade-A ___________do____	1,865	69,938	1,941	72,788	2,230	82,540
Lime ______ thousand short tons__	15,690	809,000	14,474	757,867	15,733	786,125
Mica (scrap)____________do____	138	6,330	148	7,108	161	8,201
Peat _______________do____	882	21,892	[r]1,038	[r]23,988	958	26,170
Perlite _______________do____	507	17,160	507	15,646	533	16,494
Phosphate rock _______ thousand metric tons__	50,835	[r]1,235,800	[r]40,320	[r]897,131	40,954	793,280
Potassium salts (K_2O equivalent) do____	1,266	178,400	1,147	152,000	1,485	195,700
Pumice_____ thousand short tons__	508	4,553	554	5,756	392	4,493
Salt________________do____	40,067	739,609	36,663	665,400	36,493	684,170
Sand and gravel:						
Construction _________do____	[e]800,100	[e]2,438,000	883,000	2,747,200	896,200	3,002,500
Industrial ___________do____	29,430	374,070	27,420	359,300	28,010	364,100
Sodium carbonate (natural) __do____	W	W	W	W	8,891	593,685
Sodium sulfate (natural) ____do____	389	35,860	396	34,102	382	33,086
Stone:[6]						
Crushed ____________do____	1,000,800	4,053,000	[e]1,023,200	[e]4,255,000	1,200,100	5,248,600
Dimension___________do____	1,104	172,435	[e]1,163	[e]173,269	1,184	190,153
Sulfur, Frasch process thousand metric tons__	4,678	573,570	4,180	508,512	3,610	386,834

See footnotes at end of table.

Table 1.—Nonfuel mineral production[1] in the United States —Continued

Mineral	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)
INDUSTRIAL MINERALS (EXCEPT FUELS) —Continued						
Talc and pyrophyllite thousand short tons	1,269	$29,188	1,302	$31,227	1,349	$28,785
Tripoli short tons	W	W	117,174	918	114,926	975
Vermiculite thousand short tons	314	32,400	317	34,400	303	33,105
Combined value of aplite, asphalt (native, 1985-86), calcium chloride (natural), iodine, kyanite, lithium minerals, magnesite, magnesium compounds,[7] marl (greensand), olivine, pyrites, staurolite, wollastonite, and values indicated by symbol W	XX	1,046,003	XX	r994,446	XX	374,118
Total[4]	XX	r17,678,000	XX	r17,647,000	XX	18,899,000
Grand total[4]	XX	r23,307,000	XX	r23,464,000	XX	26,346,000

eEstimated. rRevised. NA Not available. W Withheld to avoid disclosing company proprietary data; included with "Combined value" figure. XX Not applicable.

[1]Production as measured by mine shipments, sales, or marketable production (including consumption by producers).
[2]Magnesium metal (refinery production) not reported in 1985.
[3]Magnesium chloride for magnesium metal reporting discontinued in 1986.
[4]Data may not add to totals shown because of independent rounding.
[5]Grindstones, pulpstones, and sharpening stones; excludes mill liners and grinding pebbles.
[6]Excludes abrasive stone and bituminous limestone and sandstone; all included elsewhere in table.
[7]Excludes values that must be concealed to avoid disclosing company proprietary data.

Table 2.—Nonfuel minerals produced in the United States and principal producing States in 1987

Mineral	Principal producing States, in order of quantity	Other producing States
Abrasives[1]	OH, AR, IN, WI.	
Antimony (content of ore, etc.)	([2])	
Aplite	VA.	
Asbestos	CA and VT.	
Asphalt (native)	([3])	
Barite	NV, GA, MO, CA	MT, TN.
Bauxite	AR, AL, GA.	
Beryllium concentrate	UT and SD.	
Boron minerals	CA.	
Bromine	AR and MI.	
Calcium chloride (natural)	MI, CA, WA.	
Cement:		
Masonry	IN, PA, FL, AL	All other States except AK, CT, DE, MA, MN, NC, ND, NH, NJ, NV, RI, VT.
Portland	CA, TX, PA, MO	All other States expect CT, DE, MA, MN, NC, ND, NH, NJ, RI, VT.
Clays	GA, TX, NC, OH	All other States except AK, DE, HI, RI, VT, WI.
Copper (content of ores, etc.)	AZ, NM, MI, MT	CO, ID, IL, MO, TN, WA.
Diatomite	CA, NV, WA, OR.	
Emery	NY.	
Feldspar	NC, CT, CA, GA	OK, SD.
Fluorspar	IL and NV.	
Garnet (abrasive)	ID, NY, ME.	
Gold (content of ores, etc.)	NV, CA, SD, UT	AK, AZ, CO, ID, MI, MT, NM, OR, SC, WA.
Gypsum	MI, IA, TX, OK	AR, AZ, CA, CO, IN, KS, LA, MT, NM, NV, NY, OH, SD, UT, VA, WA, WY.
Helium	KS, WY, TX, NM.	
Iodine	OK.	
Iron ore (usable)	MN, MI, MO, UT	CA, MT, NM, TX.
Iron oxide pigments (crude)	MI, GA, MO, VA.	
Kyanite	VA.	
Lead (content of ores, etc.)	MO, CO, ID, MT	IL, NM, NY, TN.
Lime	OH, MO, PA, KY	All other States except AK, CT, DE, FL, GA, KS, ME, MS, NH, NJ, NM, NC, NY, RI, SC, VT.
Lithium minerals	NC and NV.	
Magnesite	NV.	
Magnesium compounds	MI, CA, UT, DE	TX.
Magnesium metal	TX, WA, UT.	
Manganiferous ore	SC.	
Marl (greensand)	DE and NJ.	
Mercury	NV, UT, CA.	
Mica (scrap)	NC, SD, NM, SC	CT, GA, PA.
Molybdenum	CO, ID, AZ, MT	CA, NM, UT.
Nickel	([2])	
Olivine	NC and WA.	
Peat	FL, MI, IL, CA	CO, GA, IA, IN, MA, MD, MN, MT, NC, NJ, NY, ND, OH, PA, SC, WA, WI, WV.
Perlite	NM, AZ, CA, ID	CO, NV.
Phosphate rock	FL, NC, ID, TN	MT, UT.
Platinun-group metals	MT.	
Potassium salts	NM, UT, CA.	
Pumice	OR, NM, CA, ID	AZ, HI, KS.
Pyrites (ore and concentrate)	TN, AZ, CO, NM.	
Rare-earth metal concentrate	CA and FL.	
Salt	LA, TX, NY, OH	AL, AZ, CA, KS, MI, ND, NM, NV, OK, UT, WV.
Sand and gravel:		
Construction	CA, TX, MI, AZ	All other States.
Industrial	IL, MI, CA, NJ, AL	All other States except AK, DE, HI, IA, ME, NH, NM, OR, SD, VT, WY.
Silver (content of ores, etc.)	NV, ID, MT, UT	AK, AZ, CA, CO, IL, MI, MO, NM, NY, OR, SC, SD, TN, WA.
Sodium carbonate (natural)	WY and CA.	
Sodium sulfate (natural)	CA and TX.	
Staurolite	FL.	
Stone:		
Crushed	PA, TX, FL, GA	All other States except DE.
Dimension	IN, GA, VT, MA	All other States except AK, DE, FL, HI, KY, LA, MS, ND, NE, NJ, NV, OR, RI, WV, WY.
Sulfur (Frasch)	TX and LA.	
Talc and pyrophyllite	MT, VT, TX, NY	AR, CA, GA, NC, OR, VA.
Tin	AK.	
Titanium concentrates	FL.	
Tripoli	IL, OK, AR, PA.	
Tungsten (content of ore, etc.)	CA.	
Vanadium (content of ore, etc.)	ID, CO, UT.	
Vermiculite (crude)	SC, MT, VA.	
Wollastonite	NY and CA.	
Zinc (content of ores, etc.)	TN, NY, MO, CO	ID, IL, KY, MT.
Zircon concentrate	FL and NJ.	

[1]Grindstones, pulpstones, and sharpening stones; excludes mill liners and grinding pebbles.
[2]No production reported.
[3]Data no longer available.

Table 3.—Value of nonfuel mineral production in the United States and principal nonfuel minerals produced in 1987

State	Value (thousands)	Rank	Percent of U.S. total	Principal minerals, in order of value
Alabama	$446,643	20	1.70	Cement (portland), stone (crushed), lime, sand and gravel (construction).
Alaska	125,280	40	.48	Sand and gravel (construction), gold, stone (crushed), cement (portland).
Arizona	1,791,043	2	6.80	Copper, sand and gravel (construction), cement (portland), gold, stone (crushed).
Arkansas	264,162	32	1.00	Bromine, stone (crushed), cement (portland), sand and gravel (construction).
California	2,551,285	1	9.68	Cement (portland), sand and gravel (construction), boron minerals, gold.
Colorado	372,990	23	1.42	Sand and gravel (construction), gold, molybdenum, cement (portland).
Connecticut	122,275	41	.46	Stone (crushed), sand and gravel (construction), feldspar, sand and gravel (industrial).
Delaware[1]	6,401	50	.02	Sand and gravel (contruction), magnesium compounds, marl (greensand), gem stones.
Florida	1,346,237	6	5.11	Phosphate rock, stone (crushed), cement (portland), sand and gravel (construction).
Georgia	1,212,370	7	4.60	Clays, stone (crushed), cement (portland), sand and gravel (construction).
Hawaii	73,479	44	.28	Stone (crushed), cement (portland), sand and gravel (construction), cement (masonry).
Idaho	269,373	31	1.02	Silver, phosphate rock, gold, molybdenum.
Illinois	517,206	17	1.96	Stone (crushed), sand and gravel (construction), cement (portland), sand and gravel (industrial).
Indiana	363,865	25	1.38	Stone (crushed), cement (portland), sand and gravel (construction), cement (masonry).
Iowa	305,077	29	1.16	Stone (crushed), cement (portland), sand and gravel (construction), gypsum (crude).
Kansas	319,604	28	1.21	Cement (portland), salt, stone (crushed), sand and gravel (construction).
Kentucky	290,335	30	1.10	Stone (crushed), lime, cement (portland), sand and gravel (construction).
Louisiana	424,221	22	1.61	Sulfur (Frasch), salt, sand and gravel (construction), stone (crushed).
Maine	65,457	46	.25	Cement (portland), sand and gravel (construction), stone (crushed), stone (dimension).
Maryland	345,134	26	1.31	Stone (crushed), sand and gravel (construction), cement (portland), cement (masonry).
Massachusetts	176,522	37	.67	Stone (crushed), sand and gravel (construction), stone (dimension), lime.
Michigan	1,365,610	5	5.18	Iron ore (usable), cement (portland), stone (crushed), sand and gravel (construction).
Minnesota	1,142,749	8	4.34	Iron ore (usable), sand and gravel (construction), stone (crushed), stone (dimension).
Mississippi	110,079	42	.42	Sand and gravel (construction), clays, cement (portland), stone (crushed).
Missouri	863,041	10	3.28	Lead, cement (portland), stone (crushed), lime.
Montana	368,466	24	1.40	Gold, copper, silver, platinum-group metals.
Nebraska	89,748	43	.34	Cement (portland), sand and gravel (construction), stone (crushed), lime.
Nevada	1,446,814	3	5.49	Gold, silver, cement (portland), sand and gravel (construction).
New Hampshire[1]	54,680	47	.21	Sand and gravel (construction), stone (dimension), stone (crushed), gem stones.
New Jersey	214,224	35	.81	Stone (crushed), sand and gravel (construction), sand and gravel (industrial), clays.
New Mexico	737,675	12	2.80	Copper, potassium salts, sand and gravel (construction), cement (portland).
New York	650,380	14	2.47	Stone (crushed), cement (portland), salt, sand and gravel (construction).
North Carolina	476,917	18	1.81	Stone (crushed), phosphate rock, lithium minerals, sand and gravel (construction).
North Dakota	26,311	48	.10	Lime, sand and gravel (construction), salt, stone (crushed).
Ohio	768,781	11	2.92	Stone (crushed), sand and gravel (construction), salt, lime.
Oklahoma	223,219	34	.85	Stone (crushed), cement (portland), sand and gravel (construction), sand and gravel (industrial).
Oregon	160,996	38	.61	Stone (crushed), sand and gravel (construction), cement (portland), lime.
Pennsylvania	1,016,496	9	3.86	Stone (crushed), cement (portland), lime, sand and gravel (construction).
Rhode Island[1]	18,698	49	.07	Sand and gravel (construction), stone (crushed), sand and gravel (industrial), gem stones.
South Carolina	341,325	27	1.30	Cement (portland), stone (crushed), clays, sand and gravel (construction).
South Dakota	262,892	33	1.00	Gold, cement (portland), sand and gravel (construction), stone (crushed).
Tennessee	527,812	16	2.00	Stone (crushed), zinc, cement (portland), sand and gravel (construction).
Texas	1,430,730	4	5.43	Cement (portland), stone (crushed), magnesium metal, sulfur (Frasch).

See footnote at end of table.

Table 3.—Value of nonfuel mineral production in the United States and principal nonfuel minerals produced in 1987 —Continued

State	Value (thousands)	Rank	Percent of U.S. total	Principal minerals, in order of value
Utah	$699,964	13	2.66	Copper, gold, magnesium metal, sand and gravel (construction).
Vermont	72,444	45	.27	Stone (dimension), stone (crushed), sand and gravel (construction), talc.
Virginia	461,442	19	1.75	Stone (crushed), sand and gravel (construction), cement (portland), lime.
Washington	438,362	21	1.66	Magnesium metal, gold, sand and gravel (construction), cement (portland).
West Virginia	144,021	39	.55	Stone (crushed), cement (portland), salt, sand and gravel (construction).
Wisconsin	191,622	36	.73	Stone (crushed), sand and gravel (construction), lime, cement (portland).
Wyoming	645,055	15	2.45	Sodium carbonate (natural), clays, helium (Grade-A), stone (crushed).
Undistributed	6,553	--	.02	
Total[2]	26,346,000	XX	100.00	

XX Not applicable.
[1]Partial total; excludes values that must be concealed to avoid disclosing company proprietary data.
[2]Data may not add to totals shown because of independent rounding.

Table 4.—Value of nonfuel mineral production per capita and per square mile in 1987, by State

State	Area (square miles)	Population (thousands)	Value of mineral production: Total (thousands)	Per square mile: Dollars	Per square mile: Rank	Per capita: Dollars	Per capita: Rank
Alabama	51,705	4,053	$446,643	8,638	25	109	19
Alaska	591,004	525	125,280	212	50	239	10
Arizona	114,000	3,386	1,791,043	15,711	11	529	3
Arkansas	53,187	2,388	264,162	4,967	36	111	18
California	158,706	27,663	2,551,285	16,076	10	92	25
Colorado	104,091	3,296	372,990	3,583	38	113	16
Connecticut	5,018	3,211	122,275	24,367	3	38	45
Delaware	2,044	644	[1]6,401	3,132	43	10	50
Florida	58,664	12,023	1,346,237	22,948	5	112	17
Georgia	58,910	6,222	1,212,370	20,580	8	195	11
Hawaii	6,471	1,083	73,479	11,355	18	68	35
Idaho	83,564	998	269,373	3,226	41	270	6
Illinois	56,345	11,582	517,206	9,179	22	45	41
Indiana	36,185	5,531	363,865	10,056	21	66	36
Iowa	56,275	2,834	305,077	5,421	34	108	21
Kansas	82,277	2,476	319,604	3,884	37	129	15
Kentucky	40,409	3,727	290,335	7,185	28	78	29
Louisiana	47,751	4,461	424,221	8,884	24	95	24
Maine	33,265	1,184	65,457	1,968	46	55	39
Maryland	10,460	4,535	345,134	32,996	1	76	30
Massachusetts	8,284	5,855	176,522	21,309	7	30	47
Michigan	58,527	9,200	1,365,610	23,333	4	148	13
Minnesota	84,402	4,246	1,142,749	13,539	13	269	9
Mississippi	47,689	2,625	110,079	2,308	45	42	42
Missouri	69,697	5,103	863,041	12,383	17	169	12
Montana	147,046	809	368,466	2,506	44	455	5
Nebraska	77,355	1,594	89,748	1,160	48	56	38
Nevada	110,561	1,007	1,446,814	13,086	15	1,437	1
New Hampshire	9,279	1,057	[1]54,680	5,893	33	52	40
New Jersey	7,787	7,672	214,224	27,510	2	28	48
New Mexico	121,593	1,500	737,675	6,067	31	492	4
New York	49,107	17,825	650,380	13,244	14	36	46
North Carolina	52,669	6,413	476,917	9,055	23	74	32
North Dakota	70,703	672	26,311	372	49	39	44
Ohio	41,330	10,784	768,781	18,601	9	71	33
Oklahoma	69,956	3,272	223,219	3,191	42	68	34
Oregon	97,073	2,724	160,996	1,659	47	59	37
Pennsylvania	45,308	11,936	1,016,496	22,435	6	85	26
Rhode Island	1,212	986	[1]18,698	15,427	12	16	49
South Carolina	31,113	3,425	341,325	10,970	20	100	22
South Dakota	77,116	709	262,892	3,409	40	371	7
Tennessee	42,144	4,855	527,812	12,524	16	109	20
Texas	266,807	16,789	1,430,730	5,359	35	85	27
Utah	84,899	1,680	699,964	8,243	26	417	6
Vermont	9,614	548	72,444	7,535	27	132	14

See footnote at end of table.

Table 4.—Value of nonfuel mineral production per capita and per square mile in 1987, by State —Continued

State	Area (square miles)	Population (thousands)	Value of mineral production: Total (thousands)	Per square mile: Dollars	Per square mile: Rank	Per capita: Dollars	Per capita: Rank
Virginia	40,767	5,904	$461,442	11,319	19	78	28
Washington	68,138	4,538	438,362	6,433	30	97	23
West Virginia	24,231	1,897	144,021	5,944	32	76	31
Wisconsin	56,153	4,807	191,622	3,412	39	40	43
Wyoming	97,809	490	645,055	6,595	29	1,316	2
Undistributed	XX	XX	6,553	XX	XX	XX	XX
Total[2] or average	3,618,700	242,744	[3]26,346,000	7,280	XX	109	XX

XX Not applicable.

[1]Partial total, excludes values that must be concealed to avoid disclosing company proprietary data. Concealed values included with "Undistributed" figure.

[2]Excludes Washington, DC (which has no mineral production), with an area of 69 square miles and a population of 626,000.

[3]Data do not add to total shown because of independent rounding.

Table 5.—Nonfuel mineral production[1] in the United States, by State

Mineral	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)
ALABAMA						
Cement:						
Masonry ____ thousand short tons__	268	$18,113	267	$18,165	291	$17,626
Portland ____do____	3,721	165,972	3,477	153,629	3,600	160,878
Clays[2] ____do____	1,873	13,139	2,077	14,828	2,239	16,217
Gem stones____	NA	e1	NA	1	NA	7
Lime ____ thousand short tons__	1,216	52,295	1,180	50,377	1,232	52,200
Sand and gravel:						
Construction ____do____	e11,000	e32,000	10,781	30,807	e10,300	e35,600
Industrial ____do____	524	4,533	433	3,388	580	5,025
Stone:						
Crushed ____do____	25,853	109,176	e24,000	e120,500	30,018	146,247
Dimension ____do____	10	2,661	e8	e968	W	W
Combined value of bauxite, clays (bentonite), salt, and value indicated by symbol W ___	XX	8,719	XX	12,553	XX	12,843
Total____	XX	406,609	XX	405,216	XX	446,643
ALASKA						
Gem stones____	NA	e$60	NA	$25	NA	$86
Gold (recoverable content of ores, etc.) troy ounces__	44,733	14,210	48,271	17,775	86,548	38,769
Sand and gravel (construction) thousand short tons__	e29,000	e63,000	27,762	61,954	e27,200	e73,400
Silver (recoverable content of ores, etc.) thousand troy ounces__	W	W	W	W	10	70
Stone (crushed) ___ thousand short tons__	1,907	8,535	e2,000	e8,500	2,033	8,945
Combined value of cement (portland), tin, and values indicated by symbol W ____	XX	4,164	XX	3,226	XX	4,010
Total____	XX	89,969	XX	91,480	XX	125,280
ARIZONA						
Clays ____ thousand short tons__	186	$1,503	201	$1,366	218	$1,905
Copper (recoverable content of ores, etc.) metric tons__	796,556	1,175,995	789,175	1,149,193	764,148	1,389,771
Gem stones____	NA	e2,700	NA	2,533	NA	3,000
Gold (recoverable content of ores, etc.) troy ounces__	52,053	16,535	W	W	95,240	42,663
Gypsum ____ thousand short tons__	251	1,926	260	1,820	W	W
Lead (recoverable content of ores, etc.) metric tons__	581	244	W	W	--	--
Lime ____ thousand short tons__	476	21,226	505	21,016	546	21,932
Molybdenum ____ thousand pounds__	24,125	63,389	29,382	75,607	W	W
Perlite ____ short tons__	W	W	W	W	49	1,361
Pumice ____ thousand short tons__	W	2	2	30	1	7
Sand and gravel (construction) ____do____	e37,000	e118,000	40,468	140,004	e38,100	e141,300

See footnotes at end of table.

Table 5.—Nonfuel mineral production[1] in the United States, by State —Continued

Mineral	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)
ARIZONA—Continued						
Silver (recoverable content of ores, etc.) thousand troy ounces	4,885	$30,007	[r]4,506	[r]$24,649	3,667	$25,706
Stone (crushed) thousand short tons	5,929	23,111	[e]5,600	[e]25,100	7,712	33,999
Combined value of cement, pyrites (1985, 1987), salt (1986-87), sand and gravel (industrial), stone (dimension), and values indicated by symbol W	XX	95,447	XX	[r]118,505	XX	129,399
Total	XX	1,550,085	XX	[r]1,559,823	XX	1,791,043
ARKANSAS						
Clays thousand short tons	1,052	$10,769	[2]974	[2]$8,998	908	$8,651
Gem stones	NA	[e]200	NA	522	NA	1,800
Sand and gravel:						
Construction thousand short tons	[e]8,500	[e]24,400	8,571	26,999	[e]7,200	[e]23,900
Industrial do	412	5,414	400	3,975	505	5,147
Stone:						
Crushed do	14,815	60,874	[e]15,500	[e]58,500	15,234	63,847
Dimension do	5	305	[e]5	[e]305	11	629
Combined value of abrasives,[3] bauxite, bromine, cement, clays (fire clay, 1986), gypsum, lime, talc, tripoli (1986-87), and vanadium (1985)	XX	168,290	XX	[r]163,703	XX	160,188
Total	XX	270,252	XX	[r]263,002	XX	264,162
CALIFORNIA						
Boron minerals thousand short tons	1,269	$404,775	1,251	$426,086	1,385	$475,092
Cement (portland) do	9,462	601,506	9,490	578,502	9,937	593,859
Clays do	[2]2,203	[2]26,600	[2]2,449	[2]33,289	2,296	33,045
Gem stones	NA	[e]550	NA	418	NA	3,367
Gold (recoverable content of ores, etc.) troy ounces	187,813	59,660	425,617	156,729	602,605	269,937
Gypsum thousand short tons	1,332	12,201	1,378	10,777	1,468	11,719
Lime do	367	24,733	371	24,187	465	25,745
Mercury 76-pound flasks	--	--	--	--	(4)	(4)
Pumice thousand short tons	78	1,491	46	1,263	42	1,539
Sand and gravel:						
Construction do	[e]112,800	[e]430,000	128,407	498,456	[e]141,600	[e]561,300
Industrial do	2,255	37,434	2,364	44,813	2,241	41,472
Silver (recoverable content of ores, etc.) thousand troy ounces	115	709	155	849	122	854
Stone:						
Crushed thousand short tons	41,199	174,395	[e]38,500	[e]159,300	44,315	186,504
Dimension do	23	2,449	[e]23	[e]2,582	33	4,554
Talc and pyrophyllite do	100	2,493	64	1,528	W	W
Combined value of asbestos, barite (1987), calcium chloride (natural), cement (masonry), clays (ball clay, 1986, and fire clay, 1985), copper, diatomite, feldspar, iron ore (usable), magnesium compounds, molybdenum, peat, perlite, potassium salts, rare-earth metal concentrates, salt, sodium carbonate (natural), sodium sulfate (natural), tungsten ore and concentrate, wollastonite (1986-87), and value indicated by symbol W	XX	333,014	XX	330,638	XX	342,298
Total	XX	2,112,010	XX	2,269,417	XX	2,551,285

See footnotes at end of table.

Table 5.—Nonfuel mineral production[1] in the United States, by State —Continued

Mineral	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)
COLORADO						
Clays ---------- thousand short tons--	303	$1,743	242	$1,523	292	$1,763
Gem stones----------------------	NA	[e]80	NA	100	NA	100
Gold (recoverable content of ores, etc.) troy ounces--	43,301	13,755	120,347	44,317	178,795	80,091
Gypsum-------- thousand short tons--	233	1,800	W	W	W	W
Sand and gravel (construction) ----do----	[e]27,500	[e]88,000	23,233	70,095	[e]22,800	[e]84,300
Silver (recoverable content of ores, etc.) thousand troy ounces--	549	3,370	645	3,526	861	6,033
Stone:						
Crushed------ thousand short tons--	7,037	25,930	[e]8,000	[e]30,700	8,045	33,465
Dimension --------------do----	2	204	[e]4	[e]255	3	133
Combined value of cement, copper, iron ore (usable, 1985), lead, lime, molybdenum, peat, perlite, pyrites (1985, 1987), sand and gravel (industrial), tin (1985), tungsten ore and concentrate (1985-86), vanadium, zinc, and values indicated by symbol W------	XX	273,611	XX	219,492	XX	167,104
Total--------------------	XX	408,493	XX	370,008	XX	372,989
CONNECTICUT						
Clays ---------- thousand short tons--	106	$632	157	$975	W	W
Gem stones----------------------	NA	W	NA	2	NA	$2
Sand and gravel (construction) thousand short tons--	[e]6,000	[e]21,000	7,254	25,984	[e]8,400	[e]37,000
Stone:						
Crushed----------------do----	7,277	43,937	[e]7,700	[e]45,800	11,412	76,668
Dimension --------------do----	20	1,285	[e]24	[e]1,653	18	1,646
Combined value of feldspar, mica (scrap), sand and gravel (industrial), and values indicated by symbol W ------------	XX	5,532	XX	6,040	XX	6,959
Total--------------------	XX	72,386	XX	80,454	XX	122,275
DELAWARE						
Gem stones----------------------	--	--	NA	$1	NA	$1
Marl (greensand) -- thousand short tons--	2	$29	1	12	W	W
Sand and gravel (construction) ----do----	[e]1,300	[e]4,000	1,547	4,156	[e]2,300	[e]6,400
Total[5] --------------------	XX	4,029	XX	4,169	XX	6,401
FLORIDA						
Cement:						
Masonry ----- thousand short tons--	316	$17,137	352	$21,269	390	$24,069
Portland ----------------do----	3,282	148,908	3,189	147,643	3,565	165,944
Clays ------------------do----	672	33,074	726	43,261	598	39,496
Gem stones----------------------	NA	[e]6	NA	W	NA	W
Peat---------- thousand short tons--	243	5,333	365	5,743	363	6,068
Sand and gravel:						
Construction--------------do----	[e]22,500	[e]49,500	28,233	67,898	[e]30,000	[e]74,900
Industrial --------------do----	2,123	12,642	1,467	14,930	1,884	19,713
Stone (crushed) --------------do----	69,266	287,237	[e]69,000	[e]288,200	[6]78,992	[6]350,537
Combined value of lime (1985-86), phosphate rock, rare-earth metal concentrates, staurolite, stone (crushed marl, 1987), titanium concentrates (ilmenite and rutile), zircon concentrates, and values indicated by symbol W----------------------	XX	1,007,899	XX	[r]700,919	XX	665,510
Total--------------------	XX	1,561,736	XX	[r]1,289,863	XX	1,346,237
GEORGIA						
Clays ---------- thousand short tons--	8,671	$575,097	9,827	$669,200	10,455	$756,093
Gem stones----------------------	NA	[e]20	NA	20	NA	20

See footnotes at end of table.

Table 5.—Nonfuel mineral production[1] in the United States, by State —Continued

Mineral	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)
GEORGIA—Continued						
Sand and gravel:						
Construction thousand short tons	e5,000	e$13,400	8,126	$23,222	e9,000	e$26,900
Industrial do	571	6,675	W	W	W	W
Stone:						
Crushed do	52,062	256,588	e56,700	e293,100	60,834	318,903
Dimension do	183	19,466	e199	e20,678	179	21,683
Talc do	16	111	9	61	20	286
Combined value of barite, bauxite (1987), cement, feldspar, iron oxide pigments (crude), kyanite (1985-86), mica (scrap), peat, and values indicated by symbol W	XX	74,718	XX	85,174	XX	88,485
Total	XX	946,075	XX	1,091,455	XX	1,212,370
HAWAII						
Cement:						
Masonry thousand short tons	7	$588	7	$1,078	10	$1,559
Portland do	215	16,050	287	24,253	324	26,550
Gem stones	NA	e25	NA	25	NA	25
Lime thousand short tons	W	W	3	W	3	W
Sand and gravel (construction) do	e500	e2,100	605	2,666	e700	e3,500
Stone (crushed) do	5,627	34,183	e7,100	e42,100	5,732	41,548
Combined value of other industrial minerals and values indicated by symbol W	XX	326	XX	290	XX	297
Total	XX	53,272	XX	70,412	XX	73,479
IDAHO						
Clays[2] thousand short tons	2	W	2	W	22	$230
Copper (recoverable content of ores, etc.) metric tons	3,551	$5,242	W	W	W	W
Gem stones	NA	e175	NA	$305	NA	507
Gold (recoverable content of ores, etc.) troy ounces	44,306	14,074	70,440	25,938	97,773	43,797
Lead (recoverable content of ores, etc.) metric tons	33,707	14,169	9,951	4,836	W	W
Lime thousand short tons	93	5,803	89	4,729	97	5,149
Phosphate rock thousand metric tons	3,784	104,000	r4,235	r82,332	3,411	47,072
Sand and gravel (construction) thousand short tons	e4,000	e11,400	5,708	14,830	e7,200	e28,000
Silver (recoverable content of ores, etc.) thousand troy ounces	18,828	115,645	11,207	61,301	W	W
Stone (crushed) thousand short tons	2,019	6,977	e3,700	e12,700	3,852	15,346
Zinc (recoverable content of ores, etc.) metric tons	W	W	351	294	W	W
Combined value of antimony (1985-86), cement, clays (bentonite, common clay, fire clay, and kaolin (1985-86)), garnet (abrasive), molybdenum, perlite, pumice, sand and gravel (industrial), stone (dimension), vanadium, and values indicated by symbol W	XX	81,181	XX	66,783	XX	129,272
Total	XX	358,666	XX	r274,048	XX	269,373
ILLINOIS						
Cement (portland) thousand short tons	2,101	$86,211	2,118	$83,783	2,119	$86,210
Clays[2] do	265	876	283	1,092	233	977
Gem stones	NA	e15	NA	15	NA	15
Sand and gravel:						
Construction thousand short tons	e26,600	e77,000	27,867	82,523	e28,300	e93,300
Industrial do	4,056	56,915	4,039	52,133	4,346	45,547
Stone:						
Crushed do	41,044	164,117	e44,200	e179,600	52,102	216,212
Dimension do	2	107	e2	e107	W	W
Combined value of barite (1985), cement (masonry), clays (fuller's earth), copper, fluorspar, lead, lime, peat, silver, tripoli, zinc, and value indicated by symbol W	XX	74,679	XX	70,272	XX	74,945
Total	XX	459,920	XX	469,525	XX	517,206

See footnotes at end of table.

Table 5.—Nonfuel mineral production[1] in the United States, by State —Continued

Mineral	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)
INDIANA						
Cement:						
Masonry ----- thousand short tons--	W	W	395	$22,936	422	$32,299
Portland ---------------do----	W	W	2,136	92,327	2,320	103,177
Clays ------------------do----	740	$2,776	744	3,044	[2]1,037	[2]4,056
Gem stones---------------------	NA	[e]1	NA	1	NA	10
Peat ---------- thousand short tons--	54	W	79	W	44	W
Sand and gravel:						
Construction-------------do----	[e]18,600	[e]55,800	19,642	61,232	[e]18,900	[e]65,200
Industrial --------------do----	182	1,209	193	1,490	230	1,357
Stone:						
Crushed-----------------do----	[6]23,384	[6]81,119	[e] [6]22,600	[e] [6]76,500	31,067	106,770
Dimension --------------do----	169	20,186	[e]191	[e]20,252	184	23,115
Combined value of abrasives, clays (fire clay, 1987), gypsum, lime, stone (crushed marl, 1985-86), and values indicated by symbol W	XX	141,863	XX	27,566	XX	27,881
Total--------------------	XX	302,954	XX	305,348	XX	363,865
IOWA						
Cement:						
Masonry ----- thousand short tons--	39	$3,372	48	$3,199	W	W
Portland ---------------do----	1,618	77,890	1,819	86,984	2,139	$104,457
Clays ------------------do----	503	2,450	486	1,421	473	1,495
Gem stones---------------------	NA	[e]1	NA	20	NA	W
Gypsum-------- thousand short tons--	1,639	13,682	1,826	12,602	1,874	12,887
Peat -------------------do----	11	415	14	381	24	W
Sand and gravel (construction)----do----	[e]12,000	[e]30,500	14,511	40,418	[e]19,000	[e]63,800
Stone (crushed) -------------do----	23,657	94,496	[e]23,400	[e]98,000	25,991	110,106
Combined values of other industrial minerals and values indicated by symbol W------	XX	5,211	XX	5,707	XX	12,332
Total--------------------	XX	228,017	XX	248,732	XX	305,077
KANSAS						
Cement:						
Masonry ----- thousand short tons--	W	W	51	$3,264	52	$3,150
Portland ---------------do----	W	W	1,763	91,110	1,697	81,045
Clays ------------------do----	878	$5,326	903	5,295	[2]604	[2]2,576
Gem stones---------------------	NA	[e]1	NA	3	NA	3
Salt[3]---------- thousand short tons--	1,790	71,970	1,656	68,887	1,689	70,148
Sand and gravel:						
Construction-------------do----	[e]13,200	[e]31,800	15,609	33,721	[e]15,600	[e]37,800
Industrial --------------do----	134	1,124	132	1,155	127	1,400
Stone:						
Crushed-----------------do----	15,653	57,155	[e]16,600	[e]60,300	19,319	69,628
Dimension --------------do----	W	W	W	W	11	445
Combined value of clays (bentonite, 1987), gypsum, helium (crude and Grade-A), pumice, salt (brine), and values indicated by symbol W -------------------	XX	154,793	XX	53,910	XX	53,409
Total--------------------	XX	322,169	XX	317,645	XX	319,604
KENTUCKY						
Clays --------- thousand short tons--	775	$6,487	[2]721	[2]$3,450	1,031	$8,821
Gem stones---------------------	NA	[e]1	NA	3	NA	3
Sand and gravel (construction) thousand short tons--	[e]7,600	[e]19,000	7,194	16,986	[e]7,100	[e]15,200
Stone (crushed) -------------do----	[6]38,022	[6]134,978	[e] [6]38,400	[e] [6]137,000	43,330	173,222
Zinc --------------- metric tons--	W	W	W	W	10	9
Combined value of cement, clays (ball clay and fire clay, 1986), lime, sand and gravel (industrial), stone (crushed sandstone, 1985-86), and values indicated by symbol W --------------------	XX	107,092	XX	109,826	XX	93,080
Total--------------------	XX	267,558	XX	267,265	XX	290,335

See footnotes at end of table.

Table 5.—Nonfuel mineral production[1] in the United States, by State —Continued

Mineral	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)
LOUISIANA						
Clays ---------- thousand short tons--	334	$7,017	332	$7,670	357	$9,192
Gem stones----------------------	NA	[e]1	NA	1	NA	1
Salt ---------- thousand short tons--	12,271	137,273	11,608	103,611	12,498	108,999
Sand and gravel:						
Construction--------------do----	[e]15,000	[e]48,000	14,292	46,134	[e]12,200	[e]43,600
Industrial --------------do----	267	3,838	256	4,225	289	3,997
Stone (crushed)[6]--------------do----	4,820	25,956	[e]5,400	[e]25,300	4,390	36,514
Sulfur (Frasch) -- thousand metric tons--	1,698	W	1,602	W	1,458	W
Combined value of cement (masonry (1985, 1987), and portland), gypsum (1985, 1987), lime, stone (crushed miscellaneous), and values indicated by symbol W --------	XX	298,501	XX	259,857	XX	221,918
Total--------------------	XX	520,586	XX	446,798	XX	424,221
MAINE						
Clays ---------- thousand short tons--	50	$100	46	$90	W	W
Gem stones----------------------	NA	[e]400	NA	200	NA	$1,172
Sand and gravel (construction) thousand short tons--	[e]7,200	[e]18,000	8,572	22,843	[e]8,600	[e]22,100
Stone:						
Crushed----------------do----	1,459	5,114	[e]1,600	[e]4,400	2,010	7,532
Dimension ----------------do----	W	W	W	W	8	5,924
Combined value of cement, garnet (abrasive), peat (1986), and values indicated by symbol W----------------------	XX	17,494	XX	25,326	XX	28,729
Total--------------------	XX	41,108	XX	52,859	XX	65,457
MARYLAND						
Cement (portland) - thousand short tons--	W	W	1,785	$89,799	1,829	$90,020
Clays --------------------do----	[2]336	[2]$1,647	[2]362	[2]1,757	383	1,940
Gem stones----------------------	NA	[e]2	NA	5	NA	5
Lime ---------- thousand short tons--	10	608	10	546	9	486
Sand and gravel (construction)----do----	[e]17,000	[e]58,000	18,173	86,925	[e]19,600	[e]92,900
Stone:						
Crushed----------------do----	24,406	98,584	[e]26,400	[e]126,000	30,136	151,579
Dimension ----------------do----	18	1,218	[e]21	[e]1,286	23	1,516
Combined value of cement (masonry), clays (ball clay, 1985-86), peat, sand and gravel (industrial), and value indicated by symbol W----------------------	XX	98,215	XX	7,027	XX	6,688
Total--------------------	XX	258,274	XX	313,345	XX	345,134
MASSACHUSETTS						
Clays ---------- thousand short tons--	265	$1,388	140	$871	W	W
Gem stones----------------------	NA	W	NA	W	NA	$1
Lime --------------------do----	159	10,935	W	W	W	W
Sand and gravel:						
Construction--------------do----	[e]14,900	[e]47,500	19,200	60,464	[e]21,800	[e]75,300
Industrial --------------do----	W	W	45	739	56	922
Stone:						
Crushed----------------do----	9,354	42,881	[e]10,000	[e]50,000	14,907	78,969
Dimension ----------------do----	73	13,724	[e]79	[e]14,928	77	12,747
Combined value of peat and values indicated by symbol W ------------------	XX	777	XX	7,395	XX	8,583
Total--------------------	XX	117,205	XX	134,397	XX	176,522
MICHIGAN						
Cement:						
Masonry ----- thousand short tons--	W	W	257	$17,026	263	$23,004
Portland ----------------do----	W	W	4,713	216,120	4,755	207,332
Clays --------------------do----	1,477	$5,514	1,402	5,684	1,333	5,338
Gem stones----------------------	NA	[e]15	NA	25	NA	25
Gypsum-------- thousand short tons--	1,772	11,883	1,979	11,052	1,977	12,190
Iron ore (usable) thousand long tons, gross weight--	12,629	W	10,957	W	12,312	W

See footnotes at end of table.

Table 5.—Nonfuel mineral production[1] in the United States, by State —Continued

Mineral	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)
MICHIGAN—Continued						
Lime thousand short tons	535	$24,790	556	$27,257	569	$30,320
Peat do	282	5,414	[r]324	[r]6,599	281	5,290
Salt do	927	71,224	W	W	W	W
Sand and gravel:						
Construction do	[e]38,000	[e]93,000	42,514	91,886	[e]42,800	[e]105,300
Industrial do	3,345	25,469	3,343	29,493	2,792	22,451
Stone:						
Crushed do	30,685	95,953	[e]27,800	[e]83,900	37,909	109,514
Dimension do	4	113	[e]6	[e]148	W	W
Combined value of bromine, calcium chloride (natural), copper, gold, iodine (1985), iron oxide pigments (crude), magnesium compounds, silver, and values indicated by symbol W	XX	1,053,672	XX	[r]750,393	XX	844,846
Total	XX	1,387,047	XX	[r]1,239,583	XX	1,365,610
MINNESOTA						
Gem stones	NA	[e]$5	NA	$5	NA	$40
Iron ore (usable) thousand long tons, gross weight	34,977	1,430,353	28,779	1,017,261	33,654	1,012,788
Peat thousand short tons	34	1,720	W	W	30	W
Sand and gravel:						
Construction do	[e]25,000	[e]55,500	24,055	53,116	[e]25,200	[e]67,400
Industrial do	884	16,910	W	W	W	W
Stone:						
Crushed do	7,756	22,601	[e]8,300	[e]26,300	8,995	29,246
Dimension do	37	13,598	[e]28	[e]10,507	41	12,967
Combined value of clays, lime, and values indicated by symbol W	XX	[r]7,272	XX	20,438	XX	20,308
Total	XX	[r]1,547,959	XX	1,127,627	XX	1,142,749
MISSISSIPPI						
Clays thousand short tons	1,558	$34,864	[2]928	[2]$13,538	1,123	$26,933
Gem stones	--	--	NA	1	NA	1
Sand and gravel (construction) thousand short tons	[e]13,400	[e]42,000	15,080	42,809	[e]14,700	[e]47,000
Stone (crushed) do	1,582	4,282	[e]1,600	[e]4,400	1,492	9,621
Combined value of cement, clays (ball clay and fuller's earth, 1986), and sand and gravel (industrial)	XX	21,647	XX	40,347	XX	26,524
Total	XX	102,793	XX	101,095	XX	110,079
MISSOURI						
Barite thousand short tons	47	$2,791	W	W	27	$2,030
Cement:						
Masonry do	139	6,630	167	$7,816	167	10,027
Portland do	3,669	159,757	4,642	179,184	5,110	185,317
Clays[2] do	1,545	10,271	1,321	6,650	1,476	10,415
Copper (recoverable content of ores, etc.) metric tons	13,410	19,797	W	W	W	W
Gem stones	NA	[e]10	NA	W	NA	W
Iron ore (usable) thousand long tons, gross weight	1,110	W	803	W	744	W
Lead (recoverable content of ores, etc.) metric tons	371,008	155,955	319,900	155,481	W	W
Sand and gravel:						
Construction thousand short tons	[e]7,500	[e]20,000	9,746	24,065	[e]10,900	[e]30,400
Industrial do	535	7,330	517	6,230	622	7,786
Silver (recoverable content of ores, etc.) thousand troy ounces	1,635	10,044	1,459	7,982	1,181	8,276
Stone:						
Crushed thousand short tons	50,646	162,097	[e]51,200	[e]170,500	54,910	184,824
Dimension do	W	W	W	W	3	454
Zinc (recoverable content of ores, etc.) metric tons	49,340	43,908	37,919	31,767	34,956	32,306
Combined value of clays (fuller's earth), iron oxide pigments (crude), lime, and values indicated by symbol W	XX	136,370	XX	158,910	XX	391,206
Total	XX	734,960	XX	748,585	XX	863,041

See footnotes at end of table.

Table 5.—Nonfuel mineral production[1] in the United States, by State —Continued

Mineral	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)
MONTANA						
Clays ---------- thousand short tons--	279	$8,296	222	$5,882	[2]29	[2]$98
Copper (recoverable content of ores, etc.) metric tons--	15,092	22,281	W	W	W	W
Gem stones----------------------	NA	400	NA	480	NA	1,302
Gold (recoverable content of ores, etc.) troy ounces--	160,262	50,909	W	W	234,365	104,984
Gypsum-------- thousand short tons--	W	W	W	W	24	W
Lead (recoverable content of ores, etc.) metric tons--	846	356	W	W	W	W
Sand and gravel (construction) thousand short tons--	[e]9,000	[e]26,000	8,066	19,391	[e]6,800	[e]18,800
Silver (recoverable content of ores, etc.) thousand troy ounces--	4,010	24,630	4,773	26,110	5,837	40,920
Stone (crushed) --- thousand short tons--	[6]1,730	[6]5,044	[e] [6]2,200	[e] [6]6,200	1,463	3,585
Talc ---------------------do----	W	W	W	W	386	12,321
Combined value of barite (1985, 1987), cement, clays (fire clay, 1987), iron ore (usable), lime, molybdenum (1986-87), peat, phosphate rock, platinum-group metals (1987), sand and gravel (industrial), stone (crushed traprock, 1985-86, and, dimension), vermiculite, zinc (1987), and values indicated by symbol W ----------	XX	[r]62,366	XX	[r]179,870	XX	186,456
Total----------------------	XX	[r]200,282	XX	[r]237,933	XX	368,466
NEBRASKA						
Clays ---------- thousand short tons--	244	$718	221	$668	224	$721
Gem stones----------------------	NA	[e]10	NA	10	NA	10
Sand and gravel (construction) thousand short tons--	[e]11,600	[e]28,800	9,675	23,912	[e]10,300	[e]26,300
Stone (crushed) -------------do----	4,175	19,134	[e]4,000	[e]17,900	4,316	19,461
Combined value of cement, lime, and sand and gravel (industrial)-------------	XX	51,308	XX	51,598	XX	43,256
Total----------------------	XX	99,970	XX	94,088	XX	89,748
NEVADA						
Barite---------- thousand short tons--	590	$10,904	184	$3,005	308	$4,778
Clays ---------------------do----	[2]80	[2]3,776	[2]10	[2]584	65	2,468
Gem stones----------------------	NA	[e]1,300	NA	213	NA	280
Gold (recoverable content of ores, etc.) troy ounces--	1,276,114	405,369	[r]2,098,980	[r]772,909	2,679,470	1,200,269
Gypsum-------- thousand short tons--	1,207	8,942	1,236	8,221	W	W
Lead (recoverable content of ores, etc.) metric tons--	(4)	(4)	--	--	--	--
Mercury ----------- 76-pound flasks--	16,530	W	W	W	W	W
Perlite ----------------short tons--	W	W	4	122	W	W
Sand and gravel:						
Construction--- thousand short tons--	[e]9,500	[e]24,880	12,197	35,692	[e]10,600	[e]30,700
Industrial ----------------do----	479	W	518	W	578	W
Silver (recoverable content of ores, etc.) thousand troy ounces--	4,947	30,383	6,409	35,056	12,190	85,451
Stone (crushed) --- thousand short tons--	1,334	6,218	[e]1,500	[e]7,000	[6]1,264	[6]5,700
Combined value of cement (portland), clays (fuller's earth and kaolin, 1985-86), copper (1985-86), diatomite, fluorspar, iron ore (usable, 1985-86), lime, lithium minerals, magnesite, molybdenum (1985), salt, stone (crushed dolomite, 1987), and values indicated by symbol W --------------	XX	139,201	XX	114,529	XX	117,168
Total----------------------	XX	630,973	XX	[r]977,350	XX	1,446,814
NEW HAMPSHIRE						
Gem stones----------------------	NA	W	NA	W	NA	$310
Sand and gravel (construction) thousand short tons--	[e]6,300	[e]$19,800	8,418	$26,089	[e]9,100	[e]33,300
Stone:						
Crushed-----------------do----	1,612	6,434	[e]1,800	[e]5,900	2,479	10,386
Dimension ---------------do----	80	6,625	[e]82	[e]6,451	67	10,684
Combined value of other industrial minerals and values indicated by symbol W------	XX	134	XX	137	XX	(7)
Total----------------------	XX	32,993	XX	38,577	XX	[5]54,680

See footnotes at end of table.

Table 5.—Nonfuel mineral production[1] in the United States, by State —Continued

Mineral	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)
NEW JERSEY						
Clays ---------- thousand short tons--	130	$2,050	133	$2,066	[2]6	[2]$140
Gem stones----------------------	NA	[e]1	NA	3	NA	3
Peat ---------- thousand short tons--	W	311	W	542	32	614
Sand and gravel:						
Construction --------------do----	[e]10,600	[e]36,700	13,999	53,746	[e]15,200	[e]61,200
Industrial --------------do----	2,820	31,119	2,341	29,878	2,112	27,872
Stone (crushed) ------------do----	15,692	94,339	[e]15,300	[e]95,400	[6]17,576	[6]111,951
Combined value of other industrial minerals	XX	13,056	XX	4,613	XX	12,444
Total----------------------	XX	177,576	XX	186,248	XX	214,224
NEW MEXICO						
Clays ---------- thousand short tons--	60	$161	60	$170	51	$141
Gem stones----------------------	NA	[e]200	NA	200	NA	200
Gold (recoverable content of ores, etc.) troy ounces--	45,045	14,309	39,856	14,677	W	W
Gypsum--------- thousand short tons--	350	1,570	W	W	W	W
Lead (recoverable content of ores, etc.) metric tons--	W	W	10	5	W	W
Perlite --------- thousand short tons--	430	14,896	433	13,727	437	13,611
Potassium salts -- thousand metric tons--	1,120	156,000	987	[r]132,900	1,323	174,200
Pumice --------- thousand short tons--	152	1,114	255	2,370	87	991
Sand and gravel (construction) ----do----	[e]8,400	[e]22,800	8,471	25,862	[e]8,600	[e]31,000
Stone:						
Crushed----------------do----	3,641	15,232	[e]3,900	[e]15,300	4,503	15,919
Dimension --------------do----	20	277	[e]22	[e]378	22	626
Combined value of cement, copper, helium (Grade-A), iron ore (usable, 1986-87), mica (scrap), molybdenum, pyrites (1987), salt, silver, and values indicated by symbol W --	XX	430,705	XX	406,586	XX	500,987
Total----------------------	XX	657,264	XX	[r]612,175	XX	737,675
NEW YORK						
Clays ---------- thousand short tons--	700	$3,129	619	$3,075	673	$3,562
Emery ----------------short tons--	W	W	2,878	W	1,945	W
Gem stones----------------------	NA	[e]30	NA	100	NA	135
Peat ---------- thousand short tons--	W	W	W	W	1	34
Salt ----------------------do----	7,044	142,318	5,071	122,601	4,918	119,962
Sand and gravel:						
Construction --------------do----	[e]28,000	[e]88,500	31,172	103,748	[e]31,400	[e]112,900
Industrial --------------do----	W	W	59	1,164	58	651
Stone:						
Crushed----------------do----	35,139	165,136	[e]40,600	[e]196,600	38,103	188,694
Dimension --------------do----	16	3,666	[e]16	[e]3,002	39	5,822
Combined value of cement, garnet (abrasive), gypsum, lead, lime (1985), silver, talc, wollastonite, zinc, and values indicated by symbol W -------------------	XX	254,529	XX	247,272	XX	218,620
Total----------------------	XX	657,308	XX	677,562	XX	650,380
NORTH CAROLINA						
Clays ---------- thousand short tons--	2,688	$10,477	2,658	$10,970	3,229	$15,282
Feldspar --------------short tons--	490,993	13,351	526,672	15,568	512,386	15,562
Gem stones----------------------	NA	[e]50	NA	551	NA	550
Gold (recoverable content of ores, etc.) troy ounces--	--	--	12	4	--	--
Mica (scrap) ----- thousand short tons--	80	3,726	89	4,641	100	5,607
Peat --------------------do----	W	W	15	W	W	W
Sand and gravel:						
Construction --------------do----	[e]6,100	[e]19,500	7,543	23,127	[e]8,600	[e]30,100
Industrial --------------do----	1,294	13,086	1,464	16,656	1,184	15,329
Stone:						
Crushed----------------do----	41,771	194,818	[e]43,500	[e]206,500	48,847	237,181
Dimension --------------do----	35	6,132	[e]41	[e]6,633	33	5,128

See footnotes at end of table.

Table 5.—Nonfuel mineral production[1] in the United States, by State —Continued

Mineral	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)
NORTH CAROLINA—Continued						
Talc and pyrophyllite thousand short tons	885	$1,604	83	$1,552	W	W
Combined value of lithium minerals, olivine, phosphate rock, and values indicated by symbol W	XX	[r]203,442	XX	[r]180,528	XX	$152,178
Total	XX	[r]466,186	XX	[r]466,730	XX	476,917
NORTH DAKOTA						
Clays thousand short tons	W	W	W	W	50	$100
Gem stones	NA	[e]$2	NA	$2	NA	2
Lime thousand short tons	56	5,562	74	7,359	127	11,912
Sand and gravel (construction) do	[e]6,900	[e]13,800	5,135	10,741	[e]4,900	[e]10,200
Combined value of peat, salt, sand and gravel (industrial, 1986-87), stone (crushed miscellaneous), and values indicated by symbol W	XX	4,820	XX	2,700	XX	4,097
Total	XX	24,184	XX	20,802	XX	26,311
OHIO						
Cement:						
Masonry thousand short tons	110	$10,412	138	$11,540	139	$11,964
Portland do	1,769	84,929	1,706	79,383	1,748	83,661
Clays do	2,114	10,581	2,833	11,515	3,187	12,714
Gem stones	NA	[e]10	NA	10	NA	10
Lime thousand short tons	1,730	84,142	1,648	81,103	1,926	93,108
Peat do	16	413	6	W	W	W
Salt do	4,329	130,964	4,115	126,757	3,276	104,099
Sand and gravel:						
Construction do	[e]33,000	[e]109,000	36,806	126,747	[e]36,400	[e]136,900
Industrial do	1,312	21,945	1,221	21,183	1,249	21,292
Stone:						
Crushed do	38,310	136,544	[e]39,300	[e]147,300	51,590	300,096
Dimension do	53	3,661	[e]36	[e]2,708	48	2,427
Combined value of abrasives, gypsum, and values indicated by symbol W	XX	1,541	XX	1,738	XX	2,510
Total	XX	594,142	XX	609,984	XX	768,781
OKLAHOMA						
Cement:						
Masonry thousand short tons	43	$2,854	50	$3,198	41	$2,436
Portland do	1,589	72,583	1,579	69,075	1,415	54,870
Clays do	997	2,338	993	2,329	797	1,783
Gem stones	NA	[e]2	NA	2	NA	8
Gypsum thousand short tons	1,595	12,548	1,683	9,855	1,828	13,336
Sand and gravel:						
Construction do	[e]12,600	[e]32,300	10,366	24,585	[e]10,500	[e]24,200
Industrial do	W	W	1,203	16,454	1,243	17,078
Stone:						
Crushed do	31,173	98,811	[e]30,900	[e]102,100	[e]25,155	[e]83,732
Dimension do	11	836	[e]19	[e]913	8	861
Combined value of feldspar, iodine, lime, pumice (1985-86), salt, stone (crushed dolomite, 1987), tripoli, and value indicated by symbol W	XX	29,335	XX	18,504	XX	24,915
Total	XX	251,607	XX	247,015	XX	223,219
OREGON						
Clays thousand short tons	188	$285	204	$289	268	$986
Gem stones	NA	[e]350	NA	350	NA	350
Nickel (content of ore and concentrate) short tons	6,127	W	1,175	W	--	--
Sand and gravel (construction) thousand short tons	[e]12,500	[e]36,800	13,441	42,597	[e]13,000	[e]42,200
Stone (crushed) do	15,336	54,244	[e]15,100	[e]53,400	20,663	73,902
Talc (soapstone) do	[4]	30	[4]	41	[4]	14
Combined value of cement, diatomite, gold, lime, pumice, silver (1987), stone (dimension, 1985-86), and values indicated by symbol W	XX	38,587	XX	29,755	XX	43,544
Total	XX	130,296	XX	126,432	XX	160,996

See footnotes at end of table.

Table 5.—Nonfuel mineral production[1] in the United States, by State —Continued

Mineral	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)
PENNSYLVANIA						
Cement:						
Masonry ----- thousand short tons--	303	$20,970	391	$26,683	397	$30,464
Portland ----------------do----	5,535	288,036	6,290	324,187	6,325	334,709
Clays[2] ----------------do----	1,142	5,293	1,234	5,061	1,206	4,751
Gem stones----------------------	NA	[e]5	NA	5	NA	5
Lime --------- thousand short tons--	1,492	85,269	1,417	81,234	1,574	93,430
Peat -------------------do----	21	602	19	532	18	513
Sand and gravel:						
Construction -------------do----	[e]17,000	[e]74,000	15,373	68,880	[e]14,800	[e]72,900
Industrial --------------do----	693	9,846	688	10,091	W	W
Stone:						
Crushed ----------------do----	64,765	310,859	[e]63,700	[e]317,100	97,213	458,676
Dimension --------------do----	51	8,214	[e]72	[e]8,100	60	10,177
Combined value of clays (kaolin), mica (scrap), tripoli (1986-87), and value indicated by symbol W ---------------	XX	1,380	XX	1,185	XX	10,871
Total ---------------------	XX	804,474	XX	843,058	XX	1,016,496
RHODE ISLAND						
Gem stones----------------------	NA	W	NA	W	NA	$1
Sand and gravel:						
Construction --- thousand short tons--	[e]1,200	[e]$4,600	2,269	$8,252	[e]2,700	[e]10,900
Industrial --------------do----	W	W	22	143	W	W
Stone (crushed) -------------do----	[6]1,135	[6]7,016	[e] [6]1,000	[e] [6]5,700	1,228	7,797
Combined value of other industrial minerals and values indicated by symbol W------	XX	576	XX	101	XX	([7])
Total ---------------------	XX	12,192	XX	14,196	XX	[5]18,698
SOUTH CAROLINA						
Cement (portland) - thousand short tons--	2,207	$104,705	2,306	$109,529	2,567	$117,878
Clays[2] ----------------do----	1,896	37,695	1,986	37,980	2,193	38,244
Gem stones----------------------	NA	[e]10	NA	10	NA	10
Manganiferous ore ---------short tons--	19,882	W	14,320	W	19,087	W
Peat ---------- thousand short tons--	W	173	W	W	W	W
Sand and gravel:						
Construction -------------do----	[e]4,900	[e]14,000	7,200	19,783	[e]7,500	[e]19,500
Industrial --------------do----	794	14,092	800	14,081	844	15,188
Stone:						
Crushed ----------------do----	17,079	72,520	[e]18,200	[e]76,700	[6]24,278	[6]105,387
Dimension --------------do----	8	541	[e]8	[e]533	2	312
Combined value of cement (masonry), clays (fuller's earth), gold, mica (scrap), silver, stone (crushed shell, 1987), vermiculite, and values indicated by symbol W --------	XX	32,193	XX	37,273	XX	44,806
Total ---------------------	XX	275,929	XX	295,889	XX	341,325
SOUTH DAKOTA						
Cement:						
Masonry ----- thousand short tons--	4	W	4	W	4	W
Portland ----------------do----	655	W	635	W	519	W
Clays[2] ----------------do----	117	$309	119	$375	W	W
Feldspar --------------short tons--	13,721	W	W	W	W	W
Gem stones----------------------	NA	[e]70	NA	100	NA	$100
Gold (recoverable content of ores, etc.) troy ounces--	356,103	113,119	W	W	W	W
Gypsum-------- thousand short tons--	34	269	31	268	W	W
Sand and gravel (construction) ----do----	[e]6,400	[e]16,000	9,713	19,853	[e]9,600	[e]19,100
Silver (recoverable content of ores, etc.) thousand troy ounces--	63	388	W	W	W	W
Stone:						
Crushed------ thousand short tons--	4,071	14,412	[e]3,600	[e]12,600	5,070	18,515
Dimension --------------do----	51	18,336	[e]55	[e]18,399	51	18,209
Combined value of beryllium concentrates, clays (bentonite, 1985-86; common, 1987), lime, mica (scrap), and values indicated by symbol W --------------------	XX	44,800	XX	181,291	XX	206,968
Total ---------------------	XX	207,703	XX	232,886	XX	262,892

See footnotes at end of table.

Table 5.—Nonfuel mineral production[1] in the United States, by State —Continued

Mineral	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)
TENNESSEE						
Clays[2] ---------- thousand short tons--	1,244	$25,913	1,164	$25,228	1,261	$25,480
Gem stones----------------------	NA	[e]5	NA	W	NA	W
Phosphate rock -- thousand metric tons--	1,233	27,000	[r]1,231	[r]21,191	W	W
Sand and gravel:						
Construction--- thousand short tons--	[e]7,200	[e]22,000	7,360	24,592	[e]7,900	[e]28,900
Industrial ---------------do----	569	6,156	488	5,523	W	W
Stone:						
Crushed----------------do----	[6]37,939	[6]155,760	[e] [6]40,700	[e] [6]175,600	51,406	227,263
Dimension ---------------do----	6	1,856	[e]6	[e]1,553	3	573
Zinc (recoverable content of ores, etc.) metric tons--	104,471	92,971	102,118	85,550	115,699	106,926
Combined value of barite, cement, clays (fuller's earth), copper, lead (1985, 1987), lime, pyrites, silver, stone (crushed granite, 1985-86), and values indicated by symbol W	XX	141,109	XX	136,610	XX	138,670
Total---------------------	XX	[r]473,270	XX	[r]475,847	XX	527,812
TEXAS						
Cement:						
Masonry ----- thousand short tons--	263	$22,114	209	$15,790	172	$11,283
Portland ----------------do----	10,242	532,494	8,883	412,697	7,318	319,996
Clays ------------------do----	4,107	28,059	[2]2,515	[2]11,724	3,475	25,959
Gem stones---------------------	NA	[e]175	NA	297	NA	345
Gypsum-------- thousand short tons--	1,981	17,299	2,131	14,982	1,874	14,254
Lime -------------------do----	1,192	65,927	1,173	62,670	1,140	59,027
Salt -------------------do----	8,390	84,249	8,520	62,996	7,810	60,857
Sand and gravel:						
Construction--------------do----	[e]57,800	[e]198,000	59,562	209,855	[e]48,200	[e]178,600
Industrial ---------------do----	1,968	29,095	1,302	18,274	1,509	22,843
Stone:						
Crushed----------------do----	85,764	306,821	[e]84,200	[e]301,500	84,347	276,477
Dimension ---------------do----	36	11,209	[e]49	[e]15,407	75	10,030
Sulfur (Frasch) -- thousand metric tons--	2,979	W	2,506	W	2,152	W
Talc ---------- thousand short tons--	261	5,245	283	6,456	255	4,380
Combined value of asphalt (native, 1985-86), clays (ball clay, fuller's earth, and kaolin, 1986), fluorspar (1985-86), helium (crude and Grade-A), iron ore (usable), magnesium chloride (1985), magnesium compounds, magnesium metal (1986-87), mica (scrap, 1985), sodium sulfate (natural), and values indicated by symbol W ------------	XX	435,936	XX	579,340	XX	446,679
Total---------------------	XX	1,736,623	XX	1,711,988	XX	1,430,730
UTAH						
Beryllium concentrates -----short tons--	5,738	$6	6,533	$7	6,062	$6
Cement (portland) - thousand short tons--	W	W	1,014	58,431	935	50,565
Clays -------------------do----	332	2,509	305	2,048	315	1,959
Gem stones---------------------	NA	[e]80	NA	96	NA	105
Gold (recoverable content of ores, etc.) troy ounces--	135,489	43,039	W	W	W	W
Gypsum-------- thousand short tons--	[r]274	[r]2,942	[r]284	[r]2,478	W	W
Lime -------------------do----	225	11,912	232	13,079	562	17,894
Salt -------------------do----	1,057	30,013	1,112	31,830	1,108	34,264
Sand and gravel:						
Construction--------------do----	[e]14,000	[e]36,400	16,452	39,763	[e]21,000	[e]56,700
Industrial ---------------do----	W	W	6	123	6	11
Stone:						
Crushed----------------do----	4,657	14,180	[e]4,500	[e]14,100	7,989	23,606
Dimension ---------------do----	W	W	W	W	2	93
Vermiculite ---------------do----	--	--	W	153	--	--
Combined value of asphalt (native, 1985-86), cement (masonry), copper, iron ore (usable, 1986-87), magnesium compounds, magnesium metal (1986-87), mercury (1986-87), molybdenum (1985, 1987), phosphate rock, potassium salts, silver, sodium sulfate (natural, 1985-86), vanadium (1986-87), and values indicated by symbol W ----------	XX	171,792	XX	[r]212,330	XX	514,661
Total---------------------	XX	[r]312,873	XX	[r]374,438	XX	699,864

See footnotes at end of table.

Table 5.—Nonfuel mineral production[1] in the United States, by State —Continued

Mineral	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)
VERMONT						
Gem stones	NA	W	NA	W	NA	$10
Sand and gravel (construction) thousand short tons	e2,700	e$7,000	4,834	$11,226	e4,700	e10,800
Stone:						
Crushed do	1,689	7,468	e1,600	e7,600	62,159	620,400
Dimension do	116	26,346	e105	e27,075	104	30,074
Combined value of asbestos, stone (crushed granite, 1987), talc, and values indicated by symbol W	XX	9,040	XX	9,310	XX	11,160
Total	XX	49,854	XX	55,211	XX	72,444
VIRGINIA						
Clays thousand short tons	814	$6,977	890	$7,700	21,171	2$6,291
Gem stones	NA	e20	NA	20	NA	20
Iron oxide pigments (crude) short tons	2,280	W	W	W	W	W
Lime thousand short tons	633	28,103	624	27,362	699	29,435
Sand and gravel (construction) do	e10,200	e42,000	11,670	46,488	e12,100	e43,400
Stone:						
Crushed do	51,686	221,900	e52,000	e224,700	60,376	295,903
Dimension do	10	3,136	e10	e3,128	9	2,720
Combined value of aplite, cement, clays (fuller's earth, 1987), gypsum, kyanite, sand and gravel (industrial), talc (soapstone, 1985, 1987), vermiculite, and values indicated by symbol W	XX	79,140	XX	83,639	XX	83,673
Total	XX	381,276	XX	393,037	XX	461,442
WASHINGTON						
Cement:						
Masonry thousand short tons	W	W	6	$530	W	W
Portland do	W	W	1,212	59,091	1,282	$63,600
Clays do	243	$1,402	252	1,560	416	2,356
Gem stones	NA	e200	NA	200	NA	200
Peat thousand short tons	12	292	W	W	7	191
Sand and gravel:						
Construction do	e22,700	e62,300	26,342	76,387	e25,300	e78,900
Industrial do	322	5,589	W	W	294	5,186
Stone:						
Crushed do	9,543	31,052	e9,000	e34,100	14,754	49,618
Dimension do	1	53	e1	e69	(4)	42
Combined value of barite (1985), calcium chloride (natural), copper (1987), diatomite, gold, gypsum, lime, magnesium metal (1986-87), olivine, silver, and values indicated by symbol W	XX	120,719	XX	204,688	XX	238,269
Total	XX	221,607	XX	376,625	XX	438,362
WEST VIRGINIA						
Clays thousand short tons	331	$3,342	215	$470	266	$565
Gem stones	--	--	NA	1	NA	1
Salt thousand short tons	895	W	W	W	W	W
Sand and gravel (construction) do	e900	e3,000	1,501	5,365	e1,000	e3,200
Stone (crushed) do	9,393	38,348	e9,800	e37,500	12,458	50,947
Combined value of cement, lime (1985, 1987), peat, sand and gravel (industrial), and values indicated by symbol W	XX	60,719	XX	86,473	XX	89,308
Total	XX	105,409	XX	129,809	XX	144,021
WISCONSIN						
Gem stones	--	--	NA	$15	NA	$15
Lime thousand short tons	341	$19,001	350	19,715	393	21,733
Peat do	10	W	9	W	9	W
Sand and gravel:						
Construction do	e16,000	e36,000	24,913	59,325	e23,900	e57,000
Industrial do	1,197	14,624	1,194	12,399	1,314	15,168

See footnotes at end of table.

Table 5.—Nonfuel mineral production[1] in the United States, by State —Continued

Mineral	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)
WISCONSIN—Continued						
Stone:						
Crushed thousand short tons	14,496	$42,380	e18,700	e$57,600	622,757	6$71,776
Dimension do	22	2,733	e23	e2,878	37	3,697
Combined value of abrasives, cement, stone (crushed traprock, 1987), and values indicated by symbol W	XX	10,372	XX	12,600	XX	22,233
Total	XX	125,110	XX	164,532	XX	191,622
WYOMING						
Clays thousand short tons	2,302	$64,146	1,762	$51,823	22,128	2$62,031
Gem stones	NA	225	NA	225	NA	150
Gypsum thousand short tons	r404	r3,135	W	W	W	W
Lime do	W	W	25	1,689	29	1,560
Sand and gravel (construction) do	e3,500	e11,000	3,377	10,977	e2,600	e9,000
Stone (crushed) do	62,030	67,329	e 61,700	e 65,900	3,171	15,049
Combined value of beryllium concentrates (1986), cement (masonry, 1986-87, and portland), clays (common, 1987), helium (Grade-A, 1986-87), sodium carbonate (natural), stone (crushed granite, 1985-86), and values indicated by symbol W	XX	465,275	XX	r484,196	XX	557,265
Total	XX	r551,110	XX	r554,810	XX	645,055

eEstimated. rRevised. NA Not available. W Withheld to avoid disclosing company proprietary data, value included with "Combined value" figure. XX Not applicable.
[1]Production as measured by mine shipments, sales, or marketable production (including consumption by producers).
[2]Excludes certain clays; kind and value included with "Combined value" figure.
[3]Grindstones, pulpstones, and sharpening stones; excludes mill liners and grinding pebbles.
[4]Less than 1/2 unit.
[5]Partial total; excludes values that must be concealed to avoid disclosing company proprietary data.
[6]Excludes certain stones; value included with "Combined value" figure.
[7]Value excluded to avoid disclosing company proprietary data.

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

(Thousand short tons and thousand dollars)

Area and mineral	1985 Quantity	1985 Value	1986e Quantity	1986e Value	1987 Quantity	1987 Value
American Samoa: Stone	(2)	1	(2)	400	W	W
Guam: Stone	548	3,731	700	3,300	354	2,289
Virgin Islands: Stone	214	2,405	200	1,500	345	2,741

eEstimated. W Withheld to avoid disclosing company proprietary data.
[1]Production as measured by mine shipments, sales, or marketable production (including consumption by producers).
[2]Less than 1/2 unit.

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

(Thousand short tons and thousand dollars)

Mineral	1985 Quantity	1985 Value	1986 Quantity	1986 Value	1987 Quantity	1987 Value
Cement (portland)	962	$72,602	W	W	1,296	$106,185
Clays	118	264	111	$223	148	318
Lime	23	3,249	24	3,291	25	3,558
Salt	35	735	40	880	40	900
Sand and gravel (industrial)	--	--	31	624	67	W
Stone:						
Crushed	5,493	25,799	e5,400	e26,000	8,480	41,299
Dimension	W	W	--	--	--	--
Total[2]	XX	102,649	XX	r31,018	XX	152,260

eEstimated. rRevised. W Withheld to avoid disclosing company proprietary data; not included in "Total." 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 not available or withheld.

Table 8.—U.S. exports of principal minerals and products, excluding mineral fuels

Mineral	1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)
METALS				
Aluminum:				
Ingots, slabs, crude ---- metric tons	209,794	$282,958	281,163	$415,003
Scrap ---- do	350,858	333,187	368,492	409,686
Plates, sheets, bars, etc ---- do	180,057	442,681	251,572	647,890
Castings and forgings ---- do	6,902	59,979	6,902	65,504
Aluminum sulfate ---- do	2,749	1,180	1,857	1,535
Other aluminum compounds ---- do	29,486	28,847	46,419	40,587
Antimony, metals and alloys, crude ---- short tons	595	1,210	876	2,817
Bauxite including bauxite concentrate thousand metric tons	69	12,946	201	15,232
Beryllium ---- pounds	79,556	7,394	170,408	5,013
Bismuth, metals and alloys ---- do	92,906	415	83,685	641
Cadmium metal ---- metric tons	38	188	241	660
Chromium:				
Ore and concentrate:				
Exports ---- thousand short tons	92	4,143	1	707
Reexports ---- do	1	511	5	352
Ferrochromium ---- do	6	5,693	5	5,730
Cobalt (content) ---- thousand pounds	631	4,726	806	7,007
Copper:				
Ore, concentrate, composition metal, unrefined (copper content) ---- metric tons	194,137	215,931	149,082	195,785
Scrap ---- do	136,422	123,138	108,535	104,920
Refined copper and semimanufactures ---- do	86,645	427,359	114,721	427,843
Other copper manufactures ---- do	9,583	20,799	3,723	9,511
Ferroalloys not elsewhere listed:				
Ferrophosphorous ---- short tons	38,377	4,393	34,699	4,334
Ferroalloys, n.e.c ---- do	10,029	11,561	19,073	14,938
Gold:				
Ore and base bullion ---- troy ounces	1,440,680	512,065	1,557,794	674,658
Bullion, refined ---- do	r3,554,411	r1,306,958	2,288,404	1,304,186
Iron ore ---- thousand long tons	4,482	204,738	5,013	198,254
Iron and steel:				
Pig iron ---- short tons	r47,051	r5,271	50,072	4,897
Iron and steel products (major):				
Steel mill products ---- do	r926,521	r858,386	1,093,982	949,597
Other steel products ---- do	r168,444	r444,053	225,587	482,464
Iron and steel scrap: Ferrous scrap including rerolling materials, ships, boats, other vessels for scrapping thousand short tons	11,994	1,081,626	10,670	996,145
Lead:				
Ore and concentrates ---- metric tons	4,380	1,491	8,764	3,333
Pigs, bars, cathodes, sheets, etc ---- do	12,601	13,997	10,116	11,945
Scrap ---- do	58,998	14,921	52,823	15,670
Magnesium, metal and alloys, scrap, semimanufactured forms, n.e.c. ---- short tons	43,992	122,378	48,677	130,672
Manganese:				
Ore and concentrates ---- do	41,966	3,278	63,270	4,225
Ferromanganese ---- do	4,323	2,650	2,851	2,144
Silicomanganese ---- do	2,004	687	697	493
Metal ---- do	5,146	7,892	5,775	9,748
Molybdenum:				
Ore and concentrate (molybdenum content) thousand pounds	49,153	136,006	40,514	98,381
Metal and alloys, crude and scrap ---- do	1,000	3,111	513	3,504
Wire ---- do	494	7,671	573	9,043
Semimanufactured forms, n.e.c ---- do	486	9,119	282	8,167
Powder ---- do	854	2,821	2,145	8,866
Ferromolybdenum ---- do	332	929	161	605
Compounds ---- do	17,063	24,997	2,696	11,146
Nickel:[1]				
Primary (unwrought commercially pure, cathodes, anodes, ferronickel, powder and flakes) ---- short tons	3,083	19,416	2,507	19,165
Wrought (bars, rods, angles, shapes, sections; plates, sheets, strip; tubes, pipes, blanks, fittings, hollow bar, wire) do	7,443	69,836	9,887	87,595
Compound catalysts and waste and scrap ---- do	12,743	25,643	15,525	34,213
Platinum-group metals:				
Ore and scrap ---- troy ounces	368,748	103,332	276,727	84,578
Palladium, rhodium, iridium, osmiridium, ruthenium, osmium (metal and alloys including scrap) ---- do	277,772	56,753	341,362	93,626
Platinum (metal and alloys) ---- do	104,155	41,722	90,208	46,765
Rare-earth metals: Ferrocerium and alloys ---- metric tons	29	319	82	653
Selenium ---- kilograms	161,007	1,452	162,217	1,686
Silicon:				
Ferrosilicon ---- short tons	11,331	8,306	15,049	11,647
Silicon carbide, crude and in grains (including reexports) do	4,254	7,197	5,254	7,825

See footnote at end of table.

Table 8.—U.S. exports of principal minerals and products, excluding mineral fuels —Continued

Mineral	1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)
METALS —Continued				
Silver:				
Ore, concentrates, waste, sweepings thousand troy ounces	15,002	$85,795	15,853	$113,182
Bullion, refined do	10,109	56,785	11,240	79,123
Tantalum:				
Ore, metal, other forms thousand pounds	463	15,792	416	18,665
Powder do	160	14,172	193	16,129
Tin:				
Ingots, pigs, bars, etc.: Exports metric tons	1,547	9,742	1,318	9,456
Tinplate and terneplate do	219,074	91,793	209,526	106,156
Titanium:				
Ore and concentrate short tons	5,314	1,414	4,435	1,395
Unwrought and scrap metal do	6,679	12,870	5,922	12,721
Intermediate mill shapes and mill products, n.e.c do	3,251	70,167	4,704	84,737
Pigments and oxides do	115,447	156,335	133,057	210,185
Tungsten (tungsten content):				
Ore and concentrate metric tons	34	242	2	31
Carbide powder do	349	9,268	383	9,063
Alloy powder do	951	19,779	669	13,319
Vanadium:				
Ore and concentrate (vanadium content) thousand pounds	177	772	--	--
Pentoxide, etc do	3,088	6,810	2,922	5,566
Ferrovanadium do	1,025	4,647	872	4,081
Zinc:				
Slabs, pigs, or blocks metric tons	1,938	3,533	1,082	2,114
Sheets, plates, strips, other forms, n.e.c do	721	1,513	1,732	2,337
Waste, scrap, dust (zinc content) do	70,211	34,907	90,204	49,482
Semifabricated forms, n.e.c do	r3,141	3,356	7,096	12,534
Ore and concentrates do	3,269	1,590	16,921	8,304
Zirconium:				
Ore and concentrate do	15,852	4,567	20,054	6,802
Oxide do	1,647	4,010	1,206	3,948
Metals, alloys, other forms do	1,079	63,134	1,225	62,892
INDUSTRIAL MINERALS				
Abrasives (includes reexports):				
Industrial diamond, natural or synthetic:				
Powder or dust thousand carats	51,163	89,812	56,792	92,858
Other do	3,564	30,313	2,542	27,592
Diamond grinding wheels do	464	5,597	493	5,964
Other natural and artificial metallic abrasives and products	XX	r [2]101,207	XX	[2]124,984
Asbestos:				
Exports:				
Unmanufactured metric tons	46,897	14,401	59,136	15,818
Products	XX	162,851	XX	178,953
Reexports:				
Unmanufactured metric tons	384	119	948	331
Products	XX	1,045	XX	1,649
Barite: Natural barium sulfate short tons	6,969	1,021	9,083	716
Boron:				
Boric acid do	42,178	23,562	66,614	34,180
Sodium borates, refined do	624,057	161,000	608,893	243,600
Bromine compounds thousand pounds	28,000	23,900	48,300	18,000
Calcium:				
Other calcium compounds including precipitated calcium carbonate short tons	26,833	15,000	49,978	40,705
Chloride do	18,168	3,962	34,718	6,657
Dicalcium phosphate do	51,113	42,000	83,362	53,456
Cement: Hydraulic and clinker do	58,556	9,024	52,009	9,563
Clays:				
Kaolin or china clay thousand short tons	1,583	213,373	2,026	340,475
Bentonite do	581	44,607	539	40,596
Other do	749	93,182	761	131,897
Diatomite do	131	32,180	139	33,075
Feldspar, leucite, nepheline syenite short tons	12,000	1,024	9,634	691
Fluorspar do	16,215	1,801	2,860	340,315
Gem stones (including reexports):				
Diamond thousand carats	2,527	787,700	2,530	968,100
Pearls	XX	2,600	XX	1,860
Other	XX	111,700	XX	140,300
Graphite, natural short tons	7,754	3,416	12,897	6,218
Gypsum:				
Crude, crushed or calcined thousand short tons	155	15,481	127	15,629
Manufactured, wallboard and plaster articles	XX	13,324	XX	16,432
Helium million cubic feet	432	16,200	494	18,278

See footnotes at end of table.

Table 8.—U.S. exports of principal minerals and products, excluding mineral fuels —Continued

Mineral	1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)
INDUSTRIAL MINERALS —Continued				
Lime short tons	16,448	$4,500	12,644	$2,971
Lithium compounds:				
Lithium carbonate thousand pounds	11,579	15,978	12,750	16,751
Lithium hydroxide do	6,388	11,141	6,930	11,033
Other lithium compounds do	3,092	8,060	2,688	7,062
Magnesium compounds:				
Magnesite, dead-burned short tons	23,746	5,488	14,131	3,240
Magnesite, crude, caustic-calcined, lump or ground do	22,801	13,295	22,396	14,167
Mica:				
Waste, scrap, ground thousand pounds	14,892	2,230	11,154	1,534
Block, film, splittings do	98	196	170	145
Manufactured, cut or stamped, built-up do	NA	4,502	NA	4,748
Mineral-earth pigments, iron oxide, natural and synthetic short tons	28,841	30,830	22,249	31,689
Nitrogen compounds (major) thousand short tons	7,754	NA	10,901	NA
Phosphate rock thousand metric tons	7,848	211,701	8,454	194,691
Phosphatic fertilizers:				
Phosphoric acid do	700	110,010	500	85,912
Superphosphates do	r1,233	r155,774	1,160	192,308
Diammonium phosphates do	4,120	641,385	5,647	890,801
Elemental phosphorus metric tons	20,266	33,310	20,302	30,796
Pigments and compounds: Zinc oxide (metal content) do	791	1,124	265	531
Potash:				
Potassium chloride do	708,357	NA	511,590	NA
Potassium sulfate do	155,608	NA	230,899	NA
Quartz, crystal:				
Cultured thousand pounds	324	5,686	448	6,954
Natural do	74	411	139	708
Salt:				
Crude and refined thousand short tons	1,165	16,928	541	8,217
Shipments to noncontiguous territories do	24	6,725	NA	NA
Sand and gravel:				
Construction:				
Sand do	674	5,446	593	7,610
Gravel do	492	2,392	544	2,923
Industrial sand do	849	20,363	758	21,253
Sodium compounds:				
Sodium carbonate do	2,049	241,238	2,224	253,200
Sodium sulfate do	111	10,183	122	10,554
Stone:				
Crushed do	2,921	36,957	3,320	26,063
Dimension do	NA	14,623	NA	20,470
Sulfur, crude thousand metric tons	1,895	251,664	1,242	139,431
Talc, crude and ground thousand short tons	234	16,302	318	21,040
Total	XX	11,661,097	XX	13,439,507

rRevised. NA Not available. XX Not applicable.

[1]Not comparable to prior years owing to regrouping of nickel forms.

[2]Silicon carbide (crude or in gains) has been deducted and is shown separately elsewhere in this table.

Table 9.—U.S. imports for consumption of principal minerals and products, excluding mineral fuels

Mineral	1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)
METALS				
Aluminum:				
Metal ---- metric tons	1,348,816	$1,682,907	1,245,510	$1,852,152
Scrap ---- do	162,317	141,702	188,612	202,292
Plates, sheets, bars, etc ---- do	455,531	914,305	415,211	840,409
Aluminum oxide (alumina) thousand metric tons	3,603	574,210	4,068	581,864
Antimony:				
Ore and concentrate (antimony content) short tons	5,855	5,892	5,634	5,732
Sulfide including needle or liquated ---- do	576	596	102	112
Metal ---- do	7,940	15,242	9,701	18,171
Oxide ---- do	13,521	21,529	13,645	20,024
Arsenic:				
White (As_2O_3 content) ---- metric tons	25,728	16,347	26,843	16,800
Metallic ---- do	395	2,649	631	3,471
Bauxite, crude ---- thousand metric tons	6,456	NA	9,156	NA
Beryllium ore ---- short tons	1,510	1,324	2,302	1,944
Bismuth, metals and alloys (gross weight) ---- pounds	2,489,634	6,895	3,484,713	8,769
Cadmium metal ---- metric tons	3,174	6,208	2,701	7,818
Calcium metal ---- pounds	566,170	1,310	776,225	1,918
Cesium compounds and chloride ---- do	37,487	1,161	73,892	4,033
Chromium:				
Ore and concentrate (Cr_2O_3 content) thousand short tons	214	21,657	229	23,774
Ferrochromium (gross weight) ---- do	388	172,694	326	150,269
Ferrochromium-silicon ---- do	9	5,743	8	4,920
Metal ---- do	4	21,647	4	24,096
Cobalt:				
Metal ---- thousand pounds	11,669	83,295	18,612	122,791
Oxide (gross weight) ---- do	511	4,202	795	5,293
Salts and compounds (gross weight) ---- do	805	2,669	903	2,004
Columbium ore ---- do	2,854	4,541	4,581	6,612
Copper (copper content):				
Ore and concentrate ---- metric tons	4,232	2,593	2,339	2,013
Matte ---- do	702	573	6,869	9,339
Blister ---- do	34,545	60,236	24,084	41,976
Refined in ingots, etc ---- do	501,984	677,010	469,181	734,725
Scrap ---- do	27,216	31,646	33,123	45,122
Ferroalloys not elsewhere listed, including spiegeleisen short tons	3,896	18,588	3,940	22,722
Gallium ---- kilograms	17,202	6,954	12,490	4,874
Germanium ---- do	12,911	7,526	17,498	10,491
Gold:				
Ore and base bullion ---- troy ounces	1,948,996	677,337	1,420,200	580,025
Bullion, refined ---- do	13,800,451	5,016,558	2,423,053	1,052,941
Hafnium ---- short tons	(1)	76	1	180
Indium ---- thousand troy ounces	1,380	4,633	1,522	9,796
Iron ore (usable) ---- thousand long tons	16,743	460,643	16,583	408,783
Iron and steel:				
Pig iron ---- short tons	294,967	42,482	354,712	52,500
Iron and steel products (major):				
Steel mill products ---- do	r20,676,642	r8,019,473	20,350,816	8,567,164
Other products ---- do	r1,257,473	r1,308,091	1,020,073	1,143,999
Scrap including tinplate ---- thousand short tons	724	49,073	843	82,016
Lead:				
Ore, flue dust, matte (lead content) ---- metric tons	4,604	1,344	873	308
Base bullion (lead content) ---- do	142	114	10,827	7,239
Pigs and bars (lead content) ---- do	140,221	59,172	185,673	123,157
Reclaimed scrap, etc. (lead content) ---- do	3,290	1,471	6,587	3,128
Sheets, pipes, shot ---- do	1,344	1,825	2,793	5,301
Magnesium:				
Metal and scrap ---- short tons	r5,192	r12,010	6,832	16,223
Alloys (magnesium content) ---- do	1,808	7,008	2,921	8,624
Sheets, tubing, ribbons, wire, other forms (magnesium content) ---- do	2,210	5,556	2,208	6,117
Manganese:				
Ore (35% or more contained manganese) ---- do	463,242	23,122	340,539	15,079
Ferromanganese ---- do	395,650	120,482	367,675	113,630
Ferrosilicon-manganese (manganese content) ---- do	131,425	58,839	124,315	58,461
Metal ---- do	9,668	9,800	8,925	9,600
Mercury:				
Compounds ---- pounds	316,224	1,395	475,015	2,136
Metal ---- 76-pound flasks	20,187	4,176	18,451	3,860

See footnotes at end of table.

Table 9.—U.S. imports for consumption of principal minerals and products, excluding mineral fuels —Continued

Mineral	1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)
METALS —Continued				
Molybdenum:				
Ore and concentrate (molybdenum content) thousand pounds	1,120	$3,057	1,264	$3,109
Waste and scrap (gross weight) do	NA	2,870	NA	2,545
Metal:				
Unwrought (molybdenum content) do	191	2,510	174	2,308
Wrought (gross weight) do	102	2,701	158	2,801
Ferromolybdenum (gross weight) do	1,599	3,626	3,815	8,042
Material in chief value molybdenum (molybdenum content) do	1,102	3,284	5,248	15,497
Compounds (gross weight) do	4,650	9,091	6,711	13,407
Nickel:				
Pigs, ingots, shot, cathodes short tons	99,017	407,210	113,249	455,126
Plates, bars, etc do	6,590	53,894	5,444	54,861
Slurry do	9,170	19,281	5,241	24,754
Scrap do	6,795	19,581	7,567	25,133
Powder and flakes do	10,342	51,051	11,977	60,406
Ferronickel do	37,901	53,672	45,389	57,481
Oxide do	2,868	4,372	2,278	4,277
Platinum-group metals:				
Unwrought:				
Grains and nuggets (platinum) troy ounces	10,465	4,758	821	368
Sponge (platinum) do	1,713,971	780,382	1,124,018	621,321
Sweepings, waste, scrap do	737,813	95,466	624,916	106,920
Iridium do	30,368	13,517	11,814	4,319
Palladium do	1,387,131	174,856	1,529,161	210,670
Rhodium do	179,068	195,666	211,466	249,811
Ruthenium do	176,580	13,649	84,399	6,269
Other platinum-group metals do	32,010	9,217	17,620	6,204
Semimanufactured:				
Platinum do	94,655	44,766	45,804	24,840
Palladium do	114,596	14,376	151,499	22,312
Rhodium do	1	3	829	649
Other platinum-group metals do	519	59	4,200	925
Rare-earth metals:				
Ferrocerium and other cerium alloys kilograms	[r]94,370	[r]1,151	94,829	1,294
Monazite metric tons	2,960	1,106	1,121	627
Metals including scandium and yttrium kilograms	19,558	1,837	13,490	1,350
Rhenium:				
Metal including scrap pounds	5,495	2,617	7,436	2,072
Ammonium perrhenate (rhenium content) do	[r]12,189	[r]2,199	7,225	2,122
Selenium and selenium compounds (selenium content) kilograms	462,646	9,550	495,862	10,108
Silicon:				
Metal (over 96% silicon content) short tons	[r]40,851	65,180	36,930	74,298
Ferrosilicon do	223,031	100,578	230,658	108,749
Silver:				
Ore and base bullion thousand troy ounces	5,516	30,926	2,681	18,019
Bullion, refined do	125,365	688,296	67,959	460,235
Sweepings, waste, doré do	14,008	78,962	11,186	76,372
Tantalum ore thousand pounds	905	7,713	697	5,186
Tellurium (gross weight) kilograms	30,721	911	26,700	808
Thallium pounds	[r]2,902	[r]91	3,138	89
Tin:				
Concentrate (tin content) metric tons	3,936	13,693	2,953	9,509
Dross, skimmings, scrap, residue, tin alloys, n.s.p.f. do	1,121	1,899	2,270	9,241
Tinfoil, powder, flitters, etc	XX	1,280	XX	1,854
Tin compounds metric tons	860	5,165	838	5,162
Titanium:				
Ilmenite[2] short tons	827,489	81,563	789,585	94,987
Rutile do	174,820	52,214	218,188	72,113
Metal do	[r]5,194	[r]34,203	4,521	29,759
Ferrotitanium and ferrosilicon-titanium do	681	1,421	1,425	2,521
Pigments do	202,674	240,058	192,043	236,945
Tungsten ore and concentrate (tungsten content) metric tons	2,522	13,840	4,414	23,964
Vanadium (vanadium content):				
Ferrovanadium thousand pounds	1,189	6,423	685	3,777
Pentoxide do	824	3,564	457	2,210
Vanadium-bearing materials do	4,027	5,720	4,528	5,903

See footnotes at end of table.

Table 9.—U.S. imports for consumption of principal minerals and products, excluding mineral fuels —Continued

Mineral	1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)
METALS —Continued				
Zinc:				
Ore and concentrates (zinc content) metric tons	75,786	$19,096	46,464	$12,322
Blocks, pigs, slabs do	665,126	487,030	705,985	581,221
Sheets, etc do	3,811	3,048	960	1,384
Fume (zinc content) do	11	2	16	18
Waste and scrap do	4,521	1,937	4,025	1,928
Dross and skimmings do	6,087	3,098	6,711	3,443
Dust, powder, flakes do	7,446	8,260	7,001	7,940
Manufactured do	XX	1,206	XX	1,570
Zirconium:				
Ore including zirconium sand do	68,764	7,836	67,917	10,243
Metal, scrap, compounds do	3,280	18,974	4,233	25,592
INDUSTRIAL MINERALS				
Abrasives:				
Diamond (industrial) thousand carats	45,991	110,648	48,877	95,555
Other	XX	294,125	XX	329,105
Asbestos metric tons	108,352	26,537	93,763	22,022
Barite:				
Crude and ground thousand short tons	767	28,858	837	29,519
Witherite short tons	147	78	436	144
Chemicals do	31,603	21,733	42,537	22,072
Boron:				
Boric acid (contained boron oxide) do	3,000	3,824	2,240	2,899
Colemanite (contained boron oxide) thousand short tons	16,000	8,770	8	2,763
Ulexite do	42	17,766	52	20,597
Bromine (contained in compounds) thousand pounds	18,815	9,734	25,326	19,237
Calcium chloride:				
Crude short tons	143,328	14,403	229,964	20,917
Other do	2,098	1,264	1,282	706
Cement: Hydraulic and clinker thousand short tons	16,319	468,993	17,726	488,532
Clays short tons	38,398	7,501	37,679	9,392
Cryolite do	11,344	6,959	13,605	7,693
Feldspar:				
Crude do	568	474	344	4
Ground and crushed do	683	68	4,489	472
Fluorspar do	552,785	45,675	585,901	48,429
Gem stones:				
Diamond thousand carats	9,192	3,459,931	9,121	3,423,094
Emeralds do	2,757	152,396	2,075	141,575
Other	XX	566,325	XX	524,851
Graphite, natural short tons	42,790	15,758	47,768	17,654
Gypsum:				
Crude, ground, calcined thousand short tons	9,562	65,432	9,719	59,555
Manufactured do	XX	115,735	XX	104,026
Iodine, crude thousand pounds	3,028	17,199	2,542	17,595
Lime:				
Hydrated short tons	57,842	4,108	39,734	3,021
Other do	142,865	8,129	138,171	7,558
Lithium:				
Ore do	13,327	3,616	18,174	3,987
Compounds do	2,095	9,166	2,309	6,485
Magnesium compounds:				
Crude magnesite do	37	15	3,318	733
Lump or ground caustic-calcined magnesia do	78,742	11,493	42,011	4,575
Refractory magnesia, dead-burned, fused magnesite, dead-burned dolomite do	213,135	38,906	223,555	43,539
Compounds do	39,807	11,038	70,746	20,593
Mica:				
Waste, scrap, ground thousand pounds	21,962	3,549	21,142	3,928
Block, film, splittings do	r1,866	r653	2,460	1,230
Manufactured, cut or stamped, built-up do	r2,105	4,859	1,645	5,125
Mineral-earth pigments, iron oxide:				
Ocher, crude and refined short tons	604	78	59	99
Siennas, crude and refined do	144	73	289	177
Umber, crude and refined do	5,855	1,071	6,123	1,058
Vandyke brown do	572	293	1,576	342
Other natural and refined do	845	619	1,598	769
Synthetic do	28,754	19,382	32,679	18,235
Nepheline syenite:				
Crude do	2,970	205	3,720	142
Ground, crushed, etc do	295,836	11,075	304,965	11,259
Nitrogen compounds (major) including urea thousand short tons	7,903	777,906	7,065	582,553

See footnotes at end of table.

Table 9.—U.S. imports for consumption of principal minerals and products, excluding mineral fuels —Continued

Mineral	1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)
INDUSTRIAL MINERALS —Continued				
Peat:				
Fertilizer-grade short tons	540,729	$68,054	500,142	$69,076
Poultry- and stable-grade do	12,367	1,452	14,373	1,890
Phosphates, crude and apatite thousand metric tons	528	22,265	464	18,816
Phosphatic fertilizers:				
Fertilizer and fertilizer materials do	69	8,351	55	7,820
Elemental phosphorus do	2	3,548	4	6,609
Other do	2	473	53	8,514
Pigments and salts:				
Lead pigments and compounds metric tons	r17,133	12,932	21,213	21,145
Zinc pigments and compounds do	57,317	47,006	68,672	60,078
Potash do	6,933,800	385,100	6,706,200	432,700
Pumice:				
Crude or unmanufactured short tons	3,488	297	17,353	2,414
Wholly or partly manufactured do	509	204	1,201	380
Manufactured, n.s.p.f	XX	512	XX	899
Quartz crystal (Brazilian lascas) thousand pounds	52	51	146	157
Salt thousand short tons	6,665	79,709	5,716	66,936
Sand and gravel:				
Industrial sand do	88	1,014	104	1,071
Other sand and gravel do	205	1,412	283	2,367
Sodium compounds:				
Sodium carbonate do	106	15,023	150	18,334
Sodium sulfate do	188	13,829	138	10,363
Stone:				
Crushed do	2,864	10,902	3,595	12,500
Dimension	XX	379,724	XX	439,278
Calcium carbonate fines thousand short tons	351	1,548	263	1,524
Strontium:				
Minerals short tons	33,236	3,396	42,469	3,670
Compounds do	8,495	5,871	10,004	7,307
Sulfur and compounds, sulfur ore and other forms, n.e.s thousand metric tons	1,347	142,220	1,599	152,096
Talc, unmanufactured thousand short tons	52	8,715	53	10,348
Total[3]	XX	31,964,000	XX	28,416,000

[r]Revised. NA Not available. XX Not applicable.
[1]Less than 1/2 unit.
[2]Includes titanium slag averaging about 70% TiO_2. For details, see "Titanium" chapter.
[3]Data may not add to totals shown because of independent rounding.

Table 10.—Comparison of world and U.S. production of selected nonfuel mineral commodities

(Thousand short tons unless otherwise specified)

Mineral	1986 World production[1]	1986 U.S. production	1986 U.S. percent of world production	1987[p] World production[1]	1987[p] U.S. production	1987[p] U.S. percent of world production
METALS, MINE BASIS						
Antimony (content of ore and concentrate) short tons	64,146	W	NA	61,875	--	--
Arsenic trioxide[2] metric tons	56,513	--	--	54,840	--	--
Bauxite[3] thousand metric tons	86,093	510	1	90,302	576	1
Beryl short tons	9,897	6,533	66	9,480	6,062	64
Bismuth thousand pounds	8,711	W	NA	8,956	W	NA
Chromite	12,327	--	--	12,222	--	--
Cobalt (content of ore and concentrate) thousand pounds	107,812	--	--	103,246	--	--
Columbium-tantalum concentrate (gross weight) do	76,666	--	--	70,442	--	--
Copper (content of ore and concentrate) thousand metric tons	8,125	1,147	14	8,475	1,256	15

See footnotes at end of table.

Table 10.—Comparison of world and U.S. production of selected nonfuel mineral commodities —Continued

(Thousand short tons unless otherwise specified)

Mineral	1986 World production[1]	1986 U.S. production	1986 U.S. percent of world production	1987[p] World production[1]	1987[p] U.S. production	1987[p] U.S. percent of world production
METALS, MINE BASIS —Continued						
Gold (content of ore and concentrate) thousand troy ounces	51,620	3,739	7	52,481	4,966	9
Iron ore (gross weight) thousand long tons	NA	38,862	NA	NA	46,817	NA
Lead (content of ore and concentrate) thousand metric tons	3,376	353	10	3,454	319	9
Manganese ore (gross weight)	26,158	--	--	25,101	--	--
Mercury thousand 76-pound flasks	179	W	NA	179	W	NA
Molybdenum (content of ore and concentrate) thousand pounds	203,466	93,976	46	186,405	75,117	40
Nickel (content of ore and concentrate)	836	1	(4)	867	--	--
Platinum-group metals[3] thousand troy ounces	8,314	W	NA	8,671	W	NA
Silver (content of ore and concentrate) do	415,929	34,524	8	429,091	39,790	9
Tin (content of ore and concentrate) metric tons	179,377	W	NA	179,713	W	NA
Titanium concentrates (gross weight):						
Ilmenite	3,735	W	NA	4,061	W	NA
Rutile	433	W	NA	496	W	NA
Tungsten (content of ore and concentrate) metric tons	42,656	780	2	40,232	34	(4)
Vanadium (content of ore and concentrate) short tons	32,530	W	NA	34,300	W	NA
Zinc (content of ore and concentrate) thousand metric tons	6,829	216	3	7,144	233	3
METALS, SMELTER BASIS						
Aluminum (primary only) do	15,341	3,037	20	16,016	3,343	21
Cadmium metric tons	18,525	1,486	8	18,566	1,515	8
Cobalt short tons	67,622	--	--	59,391	--	--
Copper smelter (primary and secondary)[5] thousand metric tons	8,715	1,196	14	8,865	1,249	14
Iron, pig (shipments)	553,369	44,287	8	564,918	48,308	9
Lead (primary and secondary)[6] thousand metric tons	5,541	995	18	5,647	1,084	19
Magnesium (primary)	362	138	38	355	137	39
Nickel[7]	862	2	(4)	892	--	--
Selenium[8] kilograms	1,193,744	W	NA	1,245,059	W	NA
Steel, raw	783,347	[9]81,606	10	804,164	88,472	11
Tellurium[8] kilograms	85,436	W	NA	90,305	W	NA
Tin metric tons	191,403	[10]3,213	2	189,556	[10]3,927	2
Zinc (primary and secondary) thousand metric tons	6,761	316	5	7,030	343	5
INDUSTRIAL MINERALS						
Asbestos do	4,050	51	1	4,054	51	1
Barite	5,204	[11]297	6	5,137	[11]448	9
Boron minerals	2,687	1,251	47	2,898	1,385	48
Bromine thousand pounds	824,380	[11]310,000	38	846,530	[11]335,000	40
Cement, hydraulic	1,100,814	[12]79,916	7	1,138,673	[12]79,501	7
Clays:						
Bentonite[2]	9,703	[11]2,813	29	9,579	2,806	29
Fuller's earth[8]	2,438	[11]1,910	78	2,642	[11]2,057	78
Kaolin[2]	26,152	[11]8,549	33	26,491	[11]8,827	33
Diamond thousand carats	91,756	--	--	93,029	--	--
Diatomite	2,042	628	31	2,008	658	33
Feldspar	4,610	735	16	4,531	720	16
Fluorspar	5,232	78	1	5,244	80	2
Graphite short tons	736,513	--	--	694,167	--	--
Gypsum	95,360	15,403	16	98,897	15,612	16
Iodine, crude thousand pounds	28,484	W	NA	27,913	W	NA
Lime	120,964	[11,12]14,498	12	122,715	[11,12]15,758	13
Magnesite	16,313	W	NA	16,454	W	NA
Mica (including scrap and ground) thousand pounds	636,207	296,300	47	654,531	321,100	49
Nitrogen: N content of ammonia	99,275	11,499	12	102,653	13,284	13
Peat	236,505	912	(4)	252,465	955	(4)

See footnotes at end of table.

Table 10.—Comparison of world and U.S. production of selected nonfuel mineral commodities —Continued

(Thousand short tons unless otherwise specified)

Mineral	1986 World production[1]	1986 U.S. production	1986 U.S. percent of world production	1987[p] World production[1]	1987[p] U.S. production	1987[p] U.S. percent of world production
INDUSTRIAL MINERALS —Continued						
Perlite	1,804	[11]507	28	1,829	[11]533	29
Phosphate rock (gross weight) thousand metric tons	138,740	38,710	28	145,148	40,954	28
Potash (K_2O equivalent) do	28,758	1,202	4	29,812	1,202	4
Pumice[8]	11,458	[11]554	5	11,753	[11]392	3
Salt	194,720	[11 12]36,703	19	195,594	[11 12]36,532	19
Sodium compounds, natural and manufactured:						
Carbonate	31,179	8,438	27	32,395	8,891	27
Sulfate	4,974	812	16	5,007	805	16
Strontium[8] short tons	164,809	--	--	202,342	--	--
Sulfur, all forms thousand metric tons	54,074	11,087	21	54,221	10,538	19
Talc and pyrophyllite	8,256	1,302	16	8,310	1,349	16
Vermiculite[8]	579	[11]317	55	601	[11]303	50

[p]Preliminary. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1]The reporting of world production of natural corundum was dropped from the 1987 edition of the Minerals Yearbook, therefore, corundum no longer appears in this table. For those commodities for which U.S. data are withheld to avoid disclosing company proprietary data, the world total excludes U.S. output and the U.S. percentage of world production cannot be reported.

[2]World total does not include an estimate for output in China.

[3]U.S. figures represent dried bauxite equivalent of crude ore; to the extent possible, individual country figures that are included in the world total are also on the dried bauxite equivalent basis, but for some countries, available data are insufficient to permit this adjustment.

[4]Less than 0.5%.

[5]Primary and secondary blister and anode copper, including electrowon refined copper that is not included as blister or anode.

[6]Includes bullion.

[7]Refined nickel plus nickel content of ferronickel and nickel oxide.

[8]World total does not include estimates for output in the U.S.S.R. or China.

[9]Data from American Iron and Steel Institute. Excludes production of castings by companies that do not report steel ingot.

[10]Includes tin content of alloys made directly from ore.

[11]Quantity sold or used by producers.

[12]Includes Puerto Rico.

Abrasive Materials

By Gordon T. Austin[1]

CONTENTS

The combined production value of natural abrasives, which consist of tripoli, special silica stone, garnet, staurolite, and emery, increased in 1987. The increase was, in certain cases, because the materials were used in nonabrasive applications, such as the increased use of tripoli as a filler and special silica stone material as a special-purpose crushed stone. The increased use of garnet as a blasting media accounts for most of its growth. Production and sales of garnet were at a record-high level in 1987.

Table 1.—Salient U.S. abrasives statistics

	1983	1984	1985	1986	1987
Natural abrasives production by producers:					
Tripoli (crude) short tons	111,020	124,482	W	117,174	114,926
Value thousands	$649	$699	W	$918	$975
Special silica stone[1] short tons	1,101	1,290	1,157	1,073	12,773
Value thousands	$482	$602	$515	$501	$957
Garnet[2] short tons	29,767	29,647	36,727	32,296	42,277
Value thousands	$2,533	$2,487	$2,973	$2,603	$4,350
Emery short tons	W	W	W	2,878	1,945
Value thousands	W	W	W	W	W
Staurolite	W	W	W	W	W
Value thousands	W	W	W	W	W
Manufactured abrasives[3] [4] short tons	418,153	531,264	478,897	482,860	486,442
Value[4] thousands	$167,430	$203,231	$171,974	$173,858	$182,039
Foreign trade (natural and artificial abrasives):					
Exports (value)[5] do	$192,794	$191,003	$191,272	$207,624	$238,522
Reexports (value)[5] do	$24,111	$27,248	$23,845	r$27,011	$21,192
Imports for consumption (value)[5] do	$289,865	$381,694	$382,877	r$406,572	$424,640

rRevised. W Withheld to avoid disclosing company proprietary data.
[1]Includes grindstones, oilstones, whetstones, and deburring media. Excludes grinding pebbles and tube-mill liners.
[2]Primary garnet; denotes first marketable product.
[3]Includes Canadian production of crude silicon carbide and fused aluminum oxide and shipments of metallic abrasives by producers.
[4]Excludes United States and Canadian production and value of aluminum-zirconium oxide.
[5]: Bureau of the Census.

Sales of special silica stone finished products, grinding stones, oilstones, whetstones, and deburring media, suffered from declining domestic and foreign markets. Manufactured abrasive products are displacing the natural abrasive in many of the traditional sharpening and grinding areas. The significant increase in production of crude silica stone indicated in table 1 is the result of a change in the method of reporting production of crude, not a change in actual production.

The nonmetallic manufactured abrasives industry, which includes only silicon carbide and fused aluminum oxide in the reported statistics, continued to decline in quantity of material produced for the second year. However, the value of production increased because of an increase in the average unit value of the materials produced. Production trends for the last 3 years showed an increase in the amount of silicon carbide produced and a decrease in the amount of fused aluminum oxide produced.

The metallic abrasives industry, which includes the primary producers of steel shot and grit, chilled and annealed iron shot and grit, cut wire shot, and shot and grit, reclaimed by primary manufacturers, experienced the third year of sales recovery in both quantity and value. Sales are still approximately 18% below the 10-year high of 264,135 short tons in 1979.

The United States continued as the world's largest single manufacturer, exporter, and consumer of synthetic industrial diamond. The estimated apparent U.S. consumption of industrial diamond was 72.8 million carats of all types and classes.

Domestic Data Coverage.—Domestic production data for abrasive materials are developed by the Bureau of Mines from six separate, voluntary surveys. Of the 61 operations canvassed, producing natural and manufactured abrasives, all responded, representing 100% of the total production shown in tables 1, 5, 6, 8, 15, 16, and 17.

FOREIGN TRADE

Exports plus reexports of industrial diamonds continued at record-high levels. Exports plus reexports have increased every year for the past 10 years, with the exception of the essentially constant levels of 1985 and 1986. The total exports of industrial diamonds have grown approximately 175% in the past 10 years or at a compounded average rate of approximately 11% per year.

The total value of abrasive materials, exports plus reexports, was $251.9 million in 1987. The average total value for the last 10 years was $222.2 million per year with the high in 1979 of $278.4 million and the low in 1977 of $156.9 million. The last 2 years have shown significant increases in total value compared with the essentially level years 1983-85. The United States was a net exporter of industrial diamonds in 1987.

Industrial diamond imports were at a record high 48.9 million carats of loose material. This was an increase of 6% after 2 years of essentially level imports. However, the growth is significant in view of the approximately 76% increase in imports from 1983 to 1984.

Imports of industrial diamond stones were at the lowest level since 1939. The Republic of South Africa supplied 42% of the industrial stones imported into the United States in 1986, but furnished only about 4% of the 1987 imports. The Republic of South Africa's share of total U.S. imports of industrial diamonds dropped to about 0.3% in 1987 from 9% in 1986. The major sources of imports, in order of rank, were Ireland, Japan, Zaire, Belgium-Luxembourg, and the U.S.S.R. Total imports continued to increase for the fifth consecutive year and established a record value of $418.4 million. This resulted in an abrasive materials trade deficit of $166.5 million.

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

(Thousands)

Kind	1986 Quantity	1986 Value	1987 Quantity	1987 Value
NATURAL				
Industrial diamond, natural or synthetic, powder or dust carats	46,839	$83,853	55,003	$88,710
Industrial diamond, natural or synthetic, other do	1,669	10,444	1,004	12,164
Emery, natural corundum, pumice in blocks pounds	2,374	1,061	3,092	1,069
MANUFACTURED				
Artificial corundum (fused aluminum oxide) do	21,836	18,963	28,017	22,298
Silicon carbide, crude or in grains do	8,386	7,110	10,505	7,819
Carbide abrasives, n.e.c do	327	509	426	491
Other refined abrasives do	23,896	14,287	31,435	19,417
Grinding and polishing wheels and stones:				
Diamond carats	451	5,358	489	5,793
Polishing stones, whetstones, oilstones, hones, similar stone number	1,086	2,416	1,020	2,009
Wheels and stones, n.e.c pounds	4,459	21,295	5,640	25,876
Abrasive paper and cloth, coated with natural or artificial abrasive materials do	11,455	36,365	16,508	46,007
Grit and shot including wire pellets do	13,964	5,963	15,967	6,869
Total	XX	207,624	XX	238,522

XX Not applicable.

Source: Bureau of the Census.

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

(Thousands)

Kind	1986 Quantity	1986 Value	1987 Quantity	1987 Value
NATURAL				
Industrial diamond, natural or synthetic, powder or dust carats	4,324	$5,959	1,789	$4,148
Industrial diamond, natural or synthetic, other do	1,895	19,869	1,538	15,428
Emery, natural corundum, pumice in blocks pounds	145	264	258	156
MANUFACTURED				
Artificial corundum (fused aluminum oxide) do	23	17	181	135
Silicon carbide, crude or in grains do	122	87	2	6
Grinding and polishing wheels and stones:				
Diamond carats	13	239	4	171
Polishing stones, whetstones, oilstones, hones, similar stone number	4	2	3	10
Wheels and stones, n.e.c pounds	111	453	214	847
Abrasive paper and cloth, coated with natural or artificial abrasive materials do	90	121	133	291
Total	XX	[r]27,011	XX	21,192

[r]Revised. XX Not applicable.

Source: Bureau of the Census.

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

(Thousands)

Kind	1986 Quantity	1986 Value	1987 Quantity	1987 Value
Emery, flint, rottenstone, tripoli, crude or crushed ___short tons__	3	$2,187	8	$451
Silicon carbide, crude ___do___	76	30,046	84	35,603
Aluminum oxide, crude ___do___	142	55,884	142	58,541
Other crude artificial abrasives ___do___	7	719	3	704
Abrasives, ground grains, pulverized or refined:				
Silicon carbide ___do___	7	10,558	9	11,566
Aluminum oxide ___do___	17	13,805	17	16,103
Emery, corundum, flint, garnet, other, including artificial abrasives ___do___	2	7,330	4	9,471
Papers, cloths, other materials wholly or partly coated with natural or artificial abrasives	(1)	106,704	(1)	117,208
Hones, whetstones, oilstones, polishing stones ___number__	3,147	1,745	1,483	1,362
Abrasive wheels and millstones:				
Burrstones manufactured or bound up into millstones short tons__	(2)	20	1	129
Solid natural stone wheels ___number__	816	550	773	489
Diamond ___do___	807	10,553	414	12,685
Abrasive wheels bonded with resins ___pounds__	10,733	19,642	11,147	21,711
Other	(1)	18,829	(1)	20,777
Articles not specifically provided for:				
Emery or garnet	(1)	327	(1)	708
Natural corundum or artificial abrasive materials	(1)	10,251	(1)	12,319
Other n.s.p.f	(1)	4,275	(1)	5,275
Grit and shot, including wire pellets ___pounds__	6,767	1,799	5,950	2,236
Diamond, natural and synthetic:				
Diamond dies ___number__	13	700	53	1,767
Crushing bort ___carats__	252	338	327	408
Natural industrial diamond stones ___do___	8,436	61,808	3,322	34,771
Miners' diamond ___do___	472	2,645	3551	3,166
Powder and dust, synthetic ___do___	29,570	38,018	432,000	43,901
Powder and dust, natural ___do___	7,261	7,839	12,677	13,289
Total	XX	r406,572	XX	424,640

rRevised. XX Not applicable.
1Quantity not reported.
2Less than 1/2 unit.
3Includes 74,077 carats of synthetic miners' diamond.
4Includes 403,977 carats of other synthetic diamonds.

Source: Bureau of the Census.

TRIPOLI

Fine-grained, porous silica materials are grouped together under the category tripoli because they have similar properties and end uses. Processed tripoli, sold or used, decreased slightly in quantity but increased 6% in value. The value increased 15% for filler material, but for the third consecutive year, decreased slightly for abrasive material.

Because tripoli grains lack distinct edges and corners, they were used as mild abrasives in toothpaste and toothpolishing compounds, industrial soaps, metal and jewelry polishing compounds, and as buffing and polishing compounds in lacquer finishing in the automobile industry. The mineral also was used as a filler and extender in paint, plastic, rubber, and enamels.

The six firms producing tripoli were Malvern Minerals Co., Garland County, AR, which produced crude and finished material; American Tripoli Co., which produced crude material in Ottawa County, OK, and finished material in Newton County, MO; Illinois Minerals Co. and Tammsco Inc., both in Alexander County, IL, which produced crude and finished amorphous (microcrystalline) silica; and Keystone Filler and Manufacturing Co. in Northumberland County, PA, which processed rottenstone, a decomposed fine-grained siliceous shale produced by B. J. Ulrich & Sons, also in Northumberland County, PA.

Tripoli, paper bags, carload in cents per pound:	
White, Elco, IL:	
Air floated through 200 mesh	3.55
Rose and cream, f.o.b. Seneca, MO, and Rogers, AR:	
Once ground	2.90
Double ground	2.90
Air float	3.15
Amorphous silica, 50-pound, bags, f.o.b. Elco, IL, in dollars per short ton:	
Through 200 mesh:	
90% to 95%	$71.00
96% to 99%	72.00
98% to 99.4%	78.00
99.5%	95.00
99.9% passing 400 mesh	128.00
99% below 15 micrometers	137.00
99% below 10 micrometers	164.00
99% below 8 micrometers	196.00

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

Use		1983	1984	1985	1986	1987
Abrasives	short tons	38,073	40,812	40,022	36,584	29,362
Value	thousands	$3,203	$3,738	$3,670	$3,590	$3,089
Filler	short tons	65,138	65,941	68,800	73,908	78,440
Value	thousands	$6,077	$6,989	$6,452	$8,588	$9,855
Other	short tons	--	--	--	W	W
Value	thousands	--	--	--	W	W
Total	short tons	103,211	106,753	108,822	110,492	107,802
Total value	thousands	$9,280	$10,727	$10,122	$12,178	$12,944

W Withheld to avoid disclosing company proprietary data.
[1]Includes amorphous silica and Pennsylvania rottenstone.
[2]Partly estimated.

SPECIAL SILICA STONE PRODUCTS

Production of special silica stone products included oilstones, hones, and whetstones from Arkansas and Indiana, grindstones from Ohio, and deburring media from Arkansas and Wisconsin. Production of special silica stone products dropped, due in large part to displacement in the traditional whetstone, hone, and grindstone markets by manufactured abrasives, industrial diamond, and ceramics.

Four main grades of whetstone were produced, ranging from the high-quality Black Hard Arkansas Stone, with porosity of 0.07% and characterized by a waxy luster, down to the Washita Stone, with a porosity of 16% and resembling unglazed porcelain. The four main types were as follows:

Trade name	Use
Black Hard Arkansas Stone	Polishing the most perfect edge possible.
Hard Arkansas Stone	Polishing blades to a very fine edge.
Soft Arkansas Stone	General purpose.
Washita Stone	Rapid sharpening.

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

Year	Quantity (short tons)	Value (thousands)
1983	602	$3,814
1984	683	3,975
1985	443	1,452
1986	437	4,771
1987	220	2,159

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

Table 7.—Producers of special silica stone products in 1987

Company and location	Type of operation	Product
Arkansas Oilstone Co.: Hot Springs, AR. (inactive)	Stone cutting and finishing	Whetstones and oilstones.
Arkansas Whetstone Co. Inc.:		
Hot Springs, AR	do	Do.
Do	Quarry	Crude novaculite.
Baraboo Quartzite Co. Inc.:		
Baraboo, WI	Crushing and sizing	Deburring media.
Do	Quarry	Crude silica stone.
Buffalo Stone Corp.: Hot Springs, AR	Tumbling and sizing novaculite.	Metal finishing media and deburring media.
Cleveland Quarries Co.:		
Amherst, OH	Stone cutting and finishing	Grindstones.
Do	Quarry	Crude silica stone.
Dans Whetstone Cutting Co. Inc.:		
Royal, AR	Stone cutting and finishing	Whetstones and oilstones.
Do	Quarry	Crude novaculite.
Halls Arkansas Oilstones Inc.: Pearcy, AR	Stone cutting and finishing	Whetstones and oilstones.
Hindostan Whetstone Co.:		
Bedford, IN	do	Cuticle stones.
Do	Quarry	Crude silica stone.
Hiram A. Smith Whetstone Co. Inc.:		
Hot Springs, AR	Stone cutting and finishing	Whetstones and oilstones.
Do	Quarry	Crude novaculite.
Norton Co. Oilstones, Norton Pike Div.:		
Hot Springs, AR	do	Do.
Littleton, NH	Stone cutting and finishing	Whetstones and oilstones.
Pioneer Whetstone Co.: Hot Springs, AR	do	Do.
Poor Boy Whetstones: Hot Springs, AR (inactive)	do	Do.
Robert Lowery: Hot Springs, AR	do	Do.
Taylor Made Crafts Inc.: Lake Hamilton, AR	do	Do.
Wallis Whetstone Inc.:		
Malvern, AR	do	Do.
Do	Quarry	Crude novaculite.
Washita Mountain Whetstone Co.: Lake Hamilton, AR	Stone cutting and finishing	Whetstones and oilstones.

Arkansas accounted for 76% of the value and 88% of the total quantity of special silica stone products sold or used by U.S. producers.

GARNET

The United States continued to be the largest garnet producer and consumer, accounting for about 63% of the world's production; the remainder was produced primarily, in order of size, by India, Australia, China, and the U.S.S.R. A major garnet processing complex was under construction at yearend in Norway. Four domestic producers were active in 1987, two in New York and one each in Idaho and Maine. Barton Mines Corp., Warren County, NY, produced garnet for use in coated abrasives, glass grinding and polishing, and metal lapping. The NYCO Div. of Processed Minerals Inc., Essex County, NY, reported that crude garnet concentrate was recovered as a byproduct at its Wollastonite operation and was sold to a U.S. garnet producer for refinement and sales. Emerald Creek Garnet Milling Co. continued to operate two mines and a single mill in Benewah County, ID, and reported that its garnet was used chiefly in sandblasting and water filtration. Industrial Garnet Extractives Inc., near Rangeley in Oxford County, ME, produced a range of garnet products, which were used mostly in sandblasting and water filtration. At yearend, International Garnet Abrasives had completed construction and began startup procedures for a 10,000-ton-per-year facility to reclaim garnet near Harvey, LA. Commercial operation is planned for 1988.

Production of crude garnet concentrates increased 31% in quantity and 67% in value. The quantity of refined garnet sold or used increased 24% and the value increased about 15% compared with that of 1986. The quantities and values in both crude and refined garnets were record highs.

Table 8.—Garnet sold or used by producers in the United States

Year	Quantity (short tons)	Value (thousands)
1983	30,300	$5,970
1984	27,672	5,677
1985	30,634	6,102
1986	31,856	6,748
1987	39,476	7,744

EMERY

One company, John Leardi Emery Mine, continued to produce emery from a mine near Peekskill in Westchester County, NY. The crude material, an impure corundum containing magnesium-aluminum silicates, was processed by Washington Mills Abrasives Co., North Grafton, MA, and Emeri-Crete Inc., New Castle, NH. Domestic emery was used as an abrasive aggregate for nonskid, wear-resistant floors, pavements, and stair treads. Minor uses of domestic emery were as coated abrasives and tumbling or deburring media.

World production of emery was primarily from Turkey and Greece. In 1987, production of emery in Turkey was reported as 10,991 short tons, and production in 1986 in Greece was reported to be 8,267 short tons. General Abrasives Co. imported emery from Turkey and Greece, processed it at its Westfield, MA, facility, and distributed the product.

STAUROLITE

Staurolite is a naturally occurring, complex, hydrated aluminosilicate of iron having a variable composition. The mineral most commonly occurs as opaque reddish-brown to black crystals with specific gravity ranging from 3.74 to 3.83 and Mohs' hardness between 7 and 8.

A limited rock-shop trade in cruciform twinned staurolite crystals ("fairy crosses") exists, notably from deposits in Georgia, North Carolina, and Virginia. Staurolite was produced commercially in 1987 by E. I. du Pont de Nemours & Co. Inc.

Staurolite is a byproduct of heavy-mineral concentrates recovered from a glacial-age beach sand in Clay County, north-central Florida. The staurolite is removed by electrical and magnetic separation after the concentrates have been scrubbed and chemically washed with caustic, rinsed, and dried. The resulting material is comprised of about 77% clean, rounded, and uniformly sized grains of staurolite, with minor proportions of tourmaline, ilmenite and other titanium minerals, kyanite, zircon, and quartz. A nominal composition of this staurolite sand is 45% aluminum oxide (minimum), 18% ferric oxide (maximum), 5% silica (maximum), and 3% zirconium dioxide (maximum).

Although originally marketed only as an ingredient in some portland cement formulations, staurolite is now marketed as a specialty sand under the trade name Biasill for use as molding material in nonferrous foundries, owing to its low thermal expansion, high thermal conductivity, and high melting point. Its low softening point tends to restrict it to nonferrous casting. Its major use is as an abrasive for impact finishing of metals and sandblasting of buildings under the trade names Starblast (80 mesh) and Biasill (90 mesh). A coarse grade (55 mesh) is also used as an abrasive.

Quantitative production data are withheld from publication to avoid disclosing company proprietary data, but the 1987 production of staurolite decreased 25% from that of 1986; shipments increased 14% in tonnage and 24% in value. Domestic production capacity was slightly under 100,000 tons per year because only one of two producers operated in 1987, and because that producer made a higher purity product, which increased processing losses. The purified product was created in response to the need to lower the free silica content of staurolite used for sandblasting to reduce the risk of silicosis caused by free silica dust.

Staurolite continued to be produced in India in small quantities and sometimes by other nations as well. A significant deposit of staurolite was discovered 125 miles north of Toronto, Canada. The deposit is in a pelite schist and is about 1.5 miles long and 130 feet wide. The material graded 10% magnetite, 25% staurolite, and 5% garnet.

INDUSTRIAL DIAMOND

The four domestic firms that produced synthetic industrial diamond in 1987 were DuPont Industrial Diamond Div., Gibbstown, NJ; General Electric Co. (GE), Specialty Materials Department, Worthington, OH; Megadiamond Industries Inc., a subsidiary of Smith International Inc., Provo, UT; and Valdiamant International, a division of Valeron Corp., Ann Arbor, MI. During 1987, GE purchased Valdiamant's manufacturing facilities and closed and disassembled them. Secondary production of industrial diamond, as reclaimed from used drill bits, diamond tools, and wet and dry diamond-containing waste, was estimated to be 3.3 million carats.

The National Defense Stockpile of industrial diamonds, as of December 31, 1987, was 22 million carats of crushing bort; however, the 8.5 million carats of stones exceeded the proposed goal of 7.7 million carats. Available for disposal, from enabling legislation effective October 1, 1984, was 0.8 million carats of stone. The inventory of small diamond dies was 25,473 pieces, compared with a goal of 60,000 pieces; however, no purchase authorization was issued. Certain industrial diamond stones in excess of stockpile goals were sold during 1987 to support the program to upgrade ferroalloys.

Exports plus reexports of industrial diamond dust and powder, natural and synthetic, were a record high 56.8 million carats, and the value was a record high $92.9 million. Exports plus reexports of stone totaled 2.5 million carats valued at $27.6 million.

The United States remained the largest consumer of industrial diamond. Apparent consumption of natural and synthetic grit, dust, and powder was estimated to be 70.9 million carats, and apparent consumption of natural stones was estimated to be 1.3 million carats. This was the lowest apparent consumption of industrial stones in 48 years.

WORLD REVIEW

De Beers Consolidated Mines Ltd.'s sales of uncut diamonds through the Central Selling Organization in 1987 were reported to be a record high $3.07 billion compared with $2.56 billion in 1986, an increase of approximately 20%.

Angola.—Sociedade Portuguesa de Empreendimentas and Endeama (SPE), a Portuguese company, signed a 2-year agreement with the Angolan state mining company to mine and appraise diamonds. SPE will also assist in diamond exploration and training Angolan personnel.[2] Angolan diamond production continues to suffer because of the civil war.

Australia.—Argyle Diamond Mines Joint Venture completed the second year of production from the AK-1 lamproite pipe. Production of 30.3 million carats exceeded the planned production of 25 million carats. Additionally, Argyle formed a direct relationship with the Indian diamond cutting trade to upgrade its diamond cutting technology to reduce the amount of Argyle near gem material that is reclassified as industrial because of cutting difficulties.[3]

Freeport Bow River Properties Inc., the operating company of the Freeport-McMoRan Australia Ltd. and Gem Exploration and Minerals Ltd. joint venture, started construction of the Bow River alluvial diamond project. The project will process 4,000 metric tons per day of gravel. Diamond output is expected to exceed 600,000 carats per year. The diamond production is expected to be 18% to 25% gem quality, 65% to 72% near gem quality, and 8% to 10% bort.

Botswana.—Debswana, the Botswana diamond mining company that is a 50-50 joint venture between De Beers and the Government of Botswana, sold its significant diamond stockpile to De Beers for cash and newly issued De Beers shares. The stockpile was estimated to contain a high proportion of large, high-quality gem material. The Government of Botswana now owns 2.6% of De Beers and has the right to appoint two members to the board of directors of De Beers and the De Beers Diamond Trading Co.[4]

Brazil.—Mining and production started on a diamond-rich kimberlite pipe in the State of Mato Grosso, approximately 20 kilometers from Julina. This is the first production from a kimberlite pipe in Brazil. All production to date was from secondary alluvial sources.

Canada.—Dia Met Minerals of Vancouver continued to negotiate financing for drilling the Jack Kimberlite Pipe in British Columbia. The pipe, 55 kilometers north of Golden, British Columbia, contains minute gem-quality diamonds. The company sampled additional pipes in the area during the summer months. Information from the summer program is not available at this time.

Central African Republic.—African Star Mining Co., a subsidiary of the U.S. firm O'Hara Mining and Drilling Co., established the first large-scale mechanized diamond mining operation in the Central African

Republic. Two mines and associated washing plants, with an initial production rate of 2,500 cubic meters per day, were under construction with production to begin in early 1988. Annual production is expected to be approximately 670,000 carats per year, 200% of the current total production of the Central African Republic.

China.—Boarara Mining Ltd. of Australia entered into an agreement with Southolme Ltd. of Hong Kong to explore and develop diamond projects in Hunan Province in China. Diamonds are found along the 1,000-kilometer length of the Yuan Jiang River terraces and channels, which are often 20 to 30 meters deep and up to 300 to 400 meters wide. The terraces have been mined for years by local farmers. A source pipe for the diamonds has not been found.

The Yuan Jiang River Alluvial Project, a joint venture between City Resources (Asia) Ltd. (a subsidiary of the Australian company, City Resource Ltd.), China Hunan International Development Corp. and China Geology Import and Export Group, was formed to explore for and produce diamonds and gold on the lower reaches of the Yuan Jiang River. City Resources will supervise and control the work, and the Chinese partners will furnish the labor force. The project area is approximately 120 square kilometers.

Indonesia.—Acorn Securities Ltd. continued negotiations with the Government of Indonesia for a long-term production agreement for the Southeast Kalimantan diamond project. The first parcel of diamonds from the project, 1,032 carats, was evaluated at an average value of $170 per carat. The parcel of 6,342 stones was 97% gem quality. Acorn has a reserve base of 16 million cubic meters with an average grade of 0.2 carats of diamond, 80 milligrams of gold, and 20 milligrams of platinum per cubic meter.

Sierra Leone.—Diamond Corp. a subsidiary of De Beers, negotiated with the Government of Sierra Leone regarding a $3 million loan to rehabilitate the mining equipment for the National Diamond Mining Co.'s operations at Yengema.[5] Oliver Resources PLC, through its Sierra Leone subsidiary, was granted exclusive gold and diamond licenses on about 78 square kilometers of alluvial deposits along tributaries of the Pampana River.

South Africa, Republic of.—Thirteen additional marine diamond concessions were allocated off the South African west coast. Fourteen companies or individuals are working the concessions that were issued in 1983-84. The 1987 marine diamond production was estimated at 55,000 carats. De Beers began procedures to reactivate the Koffiefontein Mine in the Orange Free State. The mine, idle since 1982, is expected to be back in production in early 1988.

TECHNOLOGY

A British firm developed a polycrystalline diamond (PCD) tipped sawblade for cutting melamine PVC and Formica-faced chipboard used in the manufacture of furniture. The PCD tipped blades replaced carbide tipped blades, which had to be sharpened every 3 to 4 hours. The PCD was used continuously for 6 months before a regrind was necessary.[6]

A British manufacturer of ironing boards made from chipboard was using a tungsten-carbide tooled profiling router. The tungsten-carbide cutter had a life between regrinds of 150 boards. The tungsten-carbide tools were replaced by Syndite PCD tooling resulting in a 98% savings in manufacturing cost per board by increasing the regrind intervals from 150 boards to 30,000 boards.[7]

Pennsylvania State University developed a method for depositing diamond-type coatings on silicon and other materials. The diamond coatings' electric- and heat-conducting properties are suitable for coating computer chips. The diamond coatings, created by passing methane and hydrogen through a microwave plasma, were chemically and structurally identical to natural diamond.[8]

A U.S. firm developed a thermally stable, continuously self-sharpening PCD compact for implanting into drill bits. Comparison tests between drill bits using the PCD compacts and natural diamonds demonstrated that the PCD compacts averaged 57% higher penetration rates, 277% longer bit life, and reduced bit costs to $6.35 per foot as opposed to $11.00 per foot.[9]

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

(Thousand carats and thousand dollars)

Year	Quantity	Value
1983	24,877	88,617
1984	43,710	113,632
1985	46,222	127,191
1986	45,991	110,648
1987	48,877	95,559

Table 10.—U.S. imports for consumption of industrial diamond, by country[1]

(Thousand carats and thousand dollars)[2]

Country	Natural industrial diamond stones (including glazers' and engravers' diamond, unset) (520.2900)[3]				Miners' diamond Natural and synthetic[4] (520.1900 and 520.2340)[3]				Diamond powder and dust, synthetic (520.2000, 520.2020, 520.2040, 520.2060, 520.2100)[3]				Diamond powder and dust, natural (520.2800)[3]			
	1986		1987		1986		1987		1986		1987		1986		1987	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Australia	72	154	9	114	--	--	--	--	11	10	--	--	--	--	4	47
Belgium-Luxembourg	970	8,132	553	4,653	20	281	33	423	330	853	459	763	1,084	801	703	833
Canada	71	121	2	166	--	--	(5)	4	38	36	70	59	1,118	1,904	208	89
China	4	6	(5)	13	--	--	--	--	--	--	23	42	--	--	6	326
Congo	8	22	2	58	--	--	--	--	--	--	--	--	--	--	--	--
Finland	--	--	--	--	--	--	--	--	--	--	--	--	--	--	43	78
France	2	85	(5)	16	12	18	18	57	40	12	30	9	--	--	1	2
Germany, Federal Republic of	1	40	42	490	23	102	13	180	181	251	1,044	379	174	344	108	260
Ghana	71	232	156	1,826	--	--	--	--	--	--	--	--	--	--	794	889
Greece	--	--	--	--	--	--	--	--	857	446	525	240	--	--	--	--
Hong Kong	6	142	2	66	--	--	1	51	--	--	(5)	11	--	--	(5)	1
Iran	247	165	20	69	5	12	86	313	82	173	--	--	--	--	--	--
Ireland	330	1,199	201	924	113	727	154	1,011	21,205	32,351	22,751	37,925	982	1,369	4,038	3,253
Israel	138	190	6	303	3	11	--	--	148	56	45	84	55	54	(5)	24
Italy	90	28	--	--	(5)	15	--	--	337	108	361	226	3	48	25	51
Japan	46	1,462	14	614	--	--	--	--	4,281	2,119	4,694	3,000	1,316	419	1,405	620
Mexico	10	84	--	--	--	--	--	--	1	5	--	--	1	1	--	--
Netherlands	151	1,191	60	642	--	--	1	9	--	--	--	12	19	139	--	--
South Africa, Republic of	3,556	37,622	131	1,539	5	5	1	18	64	194	--	--	611	382	7	112
Switzerland	20	793	4	326	--	--	--	--	426	379	299	148	461	581	210	175
U.S.S.R.	--	--	1	68	--	--	--	--	62	17	391	102	--	--	1,206	372
United Kingdom	1,975	6,418	806	14,594	89	378	40	135	1,136	609	367	308	923	1,016	844	1,884
Venezuela	8	978	--	--	--	--	(5)	6	(5)	3	--	--	--	--	--	--
Zaire	571	1,672	1,203	7,581	198	1,070	134	702	13	26	(5)	7	381	728	2,664	3,828
Other Africa, n.e.c[6]	38	319	6	177	--	--	--	--	43	20	3	1	--	--	6	63
Other	51	753	104	532	4	26	106	257	314	353	938	585	133	53	405	382
Total[6]	8,436	61,808	3,322	34,771	472	2,645	587	3,166	29,570	38,018	32,000	43,901	7,261	7,839	12,677	13,289

[1]Excludes 390,400 carats of crushing bort from Belgium-Luxembourg, Canada, Japan, the Republic of South Africa, and the United Kingdom in 1986, and 251,600 carats from Belgium-Luxembourg, Japan, and the Netherlands in 1987.
[2]Customs value.
[3]TSUS No.
[4]Includes 111,000 carats of synthetic miners' diamonds in 1986.
[5]Less than 1/2 unit.
[6]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

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

(Thousand carats)

Country	1983			1984			1985			1986[p]			1987[e]		
	Gem[2]	Industrial	Total	Gem	Industrial	Total	Gem	Industrial	Total	Gem[2]	Industrial	Total	Gem[2]	Industrial	Total
Angola	775	259	1,034	652	250	902	464	250	714	240	10	[e]250	180	10	190
Australia	3,720	2,480	6,200	3,415	2,277	5,692	4,242	2,828	7,070	13,145	16,066	29,211	[3]13,650	[3]16,683	[3]30,333
Botswana	4,829	5,902	10,731	5,810	7,104	12,914	6,318	6,317	12,635	9,610	3,500	13,110	[3]9,367	[3]3,840	[3]13,207
Brazil	80	450	530	200	550	750	233	217	450	[r]310	[r]315	625	320	325	645
Central African Republic	230	65	295	236	101	337	190	87	277	259	99	358	245	105	350
China[e]	200	800	1,000	200	800	1,000	200	800	1,000	200	800	1,000	200	800	1,000
Ghana	34	306	340	35	311	346	[r]60	[r]572	632	[r]50	[r]510	560	60	540	600
Guinea	23	17	[e]40	44	3	47	123	9	132	90	14	204	[3]163	[3]12	[3]175
Guyana[e]	5	5	10	6	8	14	4	7	11	3	6	[3]9	4	7	11
India	12	2	14	13	2	15	14	2	16	[r]13	2	15	13	2	15
Indonesia[e]	5	22	27	5	22	27	5	22	27	5	22	27	5	25	30
Ivory Coast[4]	NA	NA	NA	[r]20	[r]5	[r]25	[r]15	[r]5	[r]20	[r]10	[r]4	[r]14	15	5	20
Liberia	132	198	330	108	132	240	66	72	138	63	189	252	60	190	250
Namibia	915	48	963	884	46	930	865	45	910	[r]970	[r]40	1,010	980	40	[3]1,020
Sierra Leone	242	103	345	240	105	345	243	106	349	215	100	315	200	100	300
South Africa, Republic of:															
Finsch Mine	1,765	3,278	5,043	1,714	3,184	4,898	1,770	3,184	4,954	[r]1,821	[r]3,208	5,029	1,455	2,701	[3]4,156
Premier Mine	800	1,844	2,644	765	1,785	2,550	820	1,864	2,684	[r]882	[r]1,977	2,859	772	1,713	[3]2,485
Other De Beers properties[5]	1,400	569	1,969	1,452	593	2,045	1,500	569	2,069	[r]1,428	[r]529	1,957	1,427	546	[3]1,973
Other	589	66	655	585	65	650	460	35	495	[r]342	[r]41	383	409	30	439
Total	4,554	5,757	10,311	4,516	5,627	10,143	4,550	5,652	10,202	[r]4,473	[r]5,755	10,228	4,063	4,990	[3]9,053
Swaziland	--	--	--	7	10	17	9	12	21	17	23	[e]40	17	23	40
Tanzania	183	78	261	193	84	277	[r]165	[r]71	236	[r]133	[r]57	190	133	57	190
U.S.S.R.[e]	3,700	7,000	10,700	4,300	6,400	10,700	4,400	6,400	10,800	4,400	6,400	10,800	4,900	7,100	12,000
Venezuela	45	234	279	40	232	272	35	180	215	[r]45	[r]189	234	50	200	250
Zaire	3,355	8,627	11,982	5,169	13,290	18,459	[r]4,032	[r]16,127	20,159	4,661	18,643	23,304	4,670	18,680	23,350
Total	23,039	32,353	55,392	[r]26,093	[r]37,359	[r]63,452	26,233	39,781	66,014	39,012	52,744	91,756	39,295	53,734	93,029

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.

[1]Table includes data available through June 3, 1988. Total diamond output (gem plus industrial) for each country is actually reported except where indicated by a footnote to be estimated. In contrast, the detailed separate production data for gem diamond and industrial diamond are Bureau of Mines estimates in the case of every country except Australia (1983-87), Botswana (1987), the Central African Republic (1983-86), Guinea (1984-87), and Liberia (1984-86), for which source publications give details on grade as well as totals. The estimated distribution of total output between gem and industrial diamond is conjectural and, for most countries, is based on the best available data at time of publication.

[2]Includes near-gem and cheap-gem qualities.

[3]Reported figure.

[4]Figures are estimated based on reported exports and do not include smuggled diamonds.

[5]Other De Beers Group output from the Republic of South Africa includes Kimberley Pool, Koffiefontein Mine, and the Namaqualand Mines.

MANUFACTURED ABRASIVES

Manufactured abrasives production experienced a mixed year. For silicon carbide, the quantity and value increased; for fused aluminum oxide, the quantity decreased and value increased; and for metallic abrasives, the quantity and the value increased. In the aggregate, production was essentially unchanged in quantity, but the value increased 5%.

At yearend, four firms were producing fused aluminum oxide at eight plants in the United States and Canada. Production was at 61% of furnace capacity. Reported production of high-purity material increased 31% in quantity and 25% in value compared with that of 1986. Production of regular material decreased 8% in quantity but increased 9% in value to 124,174 tons and $47.4 million. Almost all of the combined output of high purity and regular material was for abrasive applications. One firm reported shipping a quantity of regular material for refractory manufacture. Reported yearend stocks totaled 5,822 tons, a decrease of 72% compared with that of 1986.

One firm produced fused alumina-zirconia in two plants, one each in the United States and Canada. All production was used for abrasive applications. Output increased in both tonnage and value compared with that of 1986.

At yearend, four firms were producing silicon carbide in six plants in the United States and Canada. The companies produced crude material for abrasives, refractories, metallurgical uses, and other applications. Total production was 87% of furnace capacity. Output and value during the year increased slightly to 125,000 tons and $48.8 million. Abrasive use accounted for about 44% of the output, metallurgical use accounted for 55% of output, and refractory and other uses were 1%. Yearend stocks totaled 13,644 tons, a decrease of 25% compared with that of 1986. Cold Spring Granite Co., Cold Spring, MN, and Northern Recovery Systems Inc., Barre, VT, both recovered silicon carbide from the stone cutting industry. The recovered silicon carbide was sold for metallurgical and refractory uses.

The National Defense Stockpile, as of December 31, 1987, contained 249,867 tons of crude fused aluminum oxide and 50,786 tons of abrasive grain-fused aluminum oxide. The crude and grain-fused aluminum oxide was being held as an offset against 379,253 tons of bauxite abrasive grain objective. Silicon carbide stocks were 72,950 tons, and the goal was 29,000 tons.

Metallic abrasives were produced by 11 firms in 12 plants in the United States. Steel shot and grit comprised 92% of the total quantity and 90% of the total value of metallic abrasives sold or used; the balance included chilled iron shot and grit, annealed iron shot and grit, cut wire shot, and steel shot and grit reclaimed by a primary producer. The following six States, in decreasing order of quantity, supplied 100% of the total sold or used steel shot and grit: Michigan, Ohio, Pennsylvania, Virginia, Maryland, and Indiana.

Chilled and annealed iron shot and grit was produced by two companies, one each in Indiana and Ohio. Cut wire shot production was reported by two firms, one in Michigan and one in New York.

WORLD REVIEW

India.—Norton closed one of its two silicon carbide manufacturing facilities and reduced production to 3,000 tons per year at the other plant. Apparently, a power cost escalation of 40% was the reason for the decrease in production. It was more cost effective to import silicon carbide than to manufacture it.[10]

Japan.—Silicon carbide production has been reduced from 115,000 tons per year to an effective capacity of about 50,000 tons per year. Domestic production in 1986 and 1987 was approximately 30,000 tons. It was more economical in 1987 to import silicon carbide, 80% of which was from China, than to manufacture the material domestically.[11]

Norway.—Norton Co. purchased Arendal Smeltewerk A/S of Wydehavn, a major producer of high-quality silicon carbide. The acquisition was made through the purchase of 95% of the foreign-owned shares of Arendal. The Government of Norway, which must approve the sale of Norway-based companies to overseas interests, did not object.[12]

TECHNOLOGY

Silicon carbide ceramic armor, similar to compositions used in kiln furniture, is being used in place of the more expensive boron carbide for armor plating in certain military applications. This includes helicopter armor plating, nose cones of rockets, and other classified applications.[13]

A British firm began manufacturing large complex silicon carbide shapes for lining equipment subject to highly corrosive and erosive conditions, such as cyclones, micronizer mills, classification equipment, slurry pumps components, and venturis and nozzles.[14]

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[1]Physical scientist, Branch of Industrial Minerals.
[2]Industrial Minerals (London). Co. News. No. 240, Sept. 1987, p. 101.
[3]Jewelers' Circular-Keystone. V. 157, No. 5, May 1987, p. G.
[4]Industrial Minerals (London). World of Minerals. No. 239, Aug. 1987, p. 9.
[5]Mining Journal (London). Development. V. 309, No. 7931, Aug. 21, 1987, p. 141.
[6]Industrial Diamond Review. News. V. 47, No. 523, June 1987.
[7]Indiaqua. Woodworking With PCD tools. No. 48, 3d quarter-1987, p. 106.
[8]Research & Development. Coatings. V. 29, No. 7, July 1987, p. 44.
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[10]Dickson, T. Silicon Carbide-Potential in Maturity. Ind. Miner. (London), No. 234, pp. 63-77.
[11]Page 64 of work cited in footnote 10.
[12]Industrial Minerals (London). Filler/Extender. No. 236, p. 42.
[13]Mining Magazine (London). MINPREP 87. Apr. 1987, p. 323.
[14]Work cited in footnote 13.

Table 12.—Crude artificial abrasives manufacturers in 1987

Company	Location	Product
Electro Minerals (Canada) Ltd	Niagara Falls, Ontario, Canada	Fused aluminum oxide (regular).
Electro Minerals (U.S.) Inc	Niagara Falls, NY	Fused aluminum oxide (high-purity).
The Exolon-ESK Co	Hennepin, IL	Silicon carbide.
Do	Thorold, Ontario, Canada	Fused aluminum oxide (regular) and silicon carbide.
General Abrasives, a division of Dresser Industries Inc.	Niagara Falls, NY	Fused aluminum oxide (regular and high-purity).
Do	Niagara Falls, Ontario, Canada	Fused aluminum oxide (regular) and silicon carbide.
Norton Co	Huntsville, AL	Fused aluminum oxide (high-purity) and aluminum-zirconium oxide.
Do	Worcester, MA	General abrasive processing.
Do	Cap-de-la-Madeleine, Quebec, Canada	Silicon carbide.
Do	Chippewa, Ontario, Canada	Fused aluminum oxide (regular and high-purity) and aluminum-zirconium oxide.
Do	Shawinigan, Quebec, Canada	Silicon carbide.
Superior Graphite Co	Hopkinsville, KY	Do.
Washington Mills Abrasives Co	Niagara Falls, Ontario, Canada	Fused aluminum oxide (regular).

Table 13.—Producers[1] of metallic abrasives in 1987

Company	Location	Product (shot and/or grit)
Abrasive Materials Inc	Hillsdale, MI	Cut wire, steel.
Chesapeake Specialty Products	Baltimore, MD	Steel.
Durasteel Co	Pittsburgh, PA	Do.
Ervin Industries Inc	Adrian, MI	Do.
Do	Butler, PA	Do.
Globe Steel Abrasives Co	Mansfield, OH	Do.
Metaltec Steel Abrasives Co	Canton, MI	Do.
National Metal Abrasive Co	Wadsworth, OH	Do.
The Pangborn Co	Butler, PA	Do.
Pellets Inc	Tonawanda, NY	Cut wire.
Steel Abrasives Inc	Fairfield, OH	Chilled iron.
U.S. Abrasives Inc.	Tippecanoe, IN	Chilled and annealed iron and steel.
Wheelabrator-Frye Inc	Bedford, VA	Steel.

[1]Excludes secondary (salvage) producers.

Table 14.—Crude manufactured abrasives produced in the United States and Canada, by kind

(Thousand short tons and thousand dollars)

Kind	1983	1984	1985	1986	1987
Silicon carbide[1]	109	137	113	124	125
Value	$52,016	$57,125	$42,563	$48,064	$48,790
Aluminum oxide (abrasive grade)[1]	137	177	169	151	144
Value	$50,565	$63,818	$54,061	$50,584	$56,393
Aluminum-zirconium oxide	W	W	W	W	W
Value	W	W	W	W	W
Metallic abrasives[2]	172	217	197	208	217
Value	$64,849	$82,288	$75,349	$75,210	$76,856
Total[3]	418	531	479	483	486
Total value[3]	167,430	203,231	[4]171,974	173,858	182,039

W Withheld to avoid disclosing company proprietary data.
[1]Figures include material used for refractories and other nonabrasive purposes.
[2]Shipments for U.S. plants only.
[3]Excludes U.S. and Canadian production and value of aluminum-zirconium oxide.
[4]Data do not add to total shown because of independent rounding.

Table 15.—End uses of crude silicon carbide and aluminum oxide (abrasive grade) in the United States and Canada, as reported by producers

Use	1986			1987		
	Quantity (short tons)	Value (thousands)	Yearend stocks (short tons)	Quantity (short tons)	Value (thousands)	Yearend stocks (short tons)
SILICON CARBIDE						
Abrasives	47,248	$19,973	9,858	54,599	$23,128	9,127
Metallurgical	63,293	22,719	5,545	69,109	25,049	4,298
Refractories and other	13,407	5,372	2,743	1,302	613	219
Total	123,948	48,064	18,146	125,010	48,790	13,644
ALUMINUM OXIDE						
Regular: Abrasives plus refractories[1]	135,301	43,347	18,961	124,174	47,354	5,560
High purity	15,251	7,237	2,058	19,946	9,039	262
Total	150,552	50,584	21,019	144,120	56,393	5,822

[1]Abrasives combined with refractories to avoid disclosing company proprietary data.

Table 16.—Production, shipments, and annual capacities of metallic abrasives in the United States, by product[1]

Product	Production		Shipments		Annual capacity[2] (short tons)
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	
1986:					
Chilled iron shot and grit	W	W	W	W	W
Annealed iron shot and grit	W	W	W	W	W
Steel shot and grit	184,416	$59,654	192,457	$67,505	277,600
Other[3]	14,718	6,023	15,903	7,705	18,100
Total	199,134	65,677	208,360	75,210	XX
1987:					
Chilled iron shot and grit	W	W	W	W	W
Annealed iron shot and grit	W	W	W	W	W
Steel shot and grit	200,255	56,371	198,743	68,885	253,800
Other[3]	18,470	62,410	18,569	7,971	XX
Total	218,725	118,781	217,312	76,856	XX

W Withheld to avoid disclosing company proprietary data; included with "Other." XX Not applicable.
[1]Excludes secondary (recycle) producers.
[2]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.
[3]Includes cut wire, aluminum, stainless steel shot, and data indicated by symbol W.

Aluminum

By Patricia A. Plunkert[1]

The domestic aluminum industry improved markedly in 1987. A strong increase in demand and declining inventories prompted the restart of idled primary aluminum metal capacity and by yearend smelters were operating at close to their full capability. The tight supply contributed to a rapid rise in aluminum ingot prices both domestically and overseas. The increase in world demand and lower value of the dollar overseas prompted a significant increase in U.S. exports. The buying price for used beverage can (UBC) scrap increased significantly and just over one-half of all aluminum cans shipped during the year were recycled.

Domestic Data Coverage.—Domestic production data for aluminum are developed by the Bureau of Mines from two separate, voluntary surveys of U.S. operations. Typical of these surveys is the "Aluminum" survey. Of the 12 companies to which monthly survey requests were sent, all responded, representing 100% of the total domestic primary aluminum production shown in tables 1, 6, and 14.

Table 1.—Salient aluminum statistics

(Thousand metric tons and thousand dollars unless otherwise specified)

	1983	1984	1985	1986	1987
United States:					
Primary production	3,353	4,099	3,500	3,037	3,343
Value	$5,754,298	$7,319,844	$6,249,614	$5,422,993	$5,328,300
Price: Average cents per pound:					
Producer list	77.8	81.0	81.0	[1]81.0	NA
Market (spot)	68.3	61.1	48.8	55.9	72.3
Secondary recovery[2]	1,564	1,760	1,762	1,773	1,986
Exports (crude and semicrude)	776	734	908	753	916
Imports for consumption (crude and semicrude)	1,091	1,477	1,420	1,967	1,849
Aluminum industry shipments[3]	5,857	6,552	6,382	6,545	[p]6,813
Consumption, apparent	5,035	5,279	5,174	5,143	5,469
World: Production	[r]13,904	[r]15,714	15,367	[p]15,341	[e]16,016

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.
[1]Based on 7 months in 1986.
[2]Beginning with 1984, metallic recovery from purchased, tolled, or imported new and old aluminum scrap expanded for full industry coverage. Prior to 1984, aluminum recovered from all types of purchased scrap not expanded for full industry coverage.
[3]To domestic industry.

Legislation and Government Programs.—In July, the Southwire Co. filed a petition with the U.S. Department of Commerce on behalf of the U.S. redraw rod industry alleging that manufacturers, producers, or exporters of redraw rod in Venezuela received subsidies and that such imports caused or threatened injury to the U.S. industry. In October, Commerce issued a preliminary determination that electrical conductor aluminum redraw rod from Venezuela was subsidized and imposed an immediate 12.99% ad valorem duty deposit on these imports.[2] Commerce expected to make a preliminary determination on the dumping charges and a final determination on the subsidy allegations in 1988.

DOMESTIC PRODUCTION

Primary.—Increased demand and declining inventories encouraged the restart of smelting capacity that had been temporarily shut down and in the case of the Aluminum Co. of America (Alcoa) permanently closed the year before. By yearend 1987, the operating capacity of U.S. primary smelters was about 94% with 233,000 tons[3] of the 3.9 million tons of annual capacity shut down, compared with 71.8% of the 4 million tons operational at yearend 1986. The status of the primary industry at yearend 1987 was 1 smelter temporarily closed, 7 operating at reduced capacity, 14 operating at full capacity, and 2 operating above full-capacity levels.

Alcoa announced the temporary restart of 145,000 tons of annual capacity that had been permanently closed in 1986. The company attributed the temporary restart of 40,000 tons per year of primary metal capacity at the Alcoa, TN, smelter to strong demand and the loss of metal output from its Suriname smelter, which had been idle since January 1987. The revival of 105,000 tons of annual capacity at its Rockdale, TX, plant was attributed to high metal prices and the inability to sell unused power dedicated to the Rockdale smelter.

In the second quarter of 1987, Kaiser Aluminum & Chemical Corp. wrote off the remaining 105,000 tons per year of capacity at its idle Chalmette, LA, smelter. A 38,000-ton-per-year potline at the Ravenswood, WV, smelter, which had been idled following a power outage in 1981, was also written off.

Commonwealth Aluminum Corp. announced the sale of its Goldendale, WA, primary aluminum smelter to Columbia Aluminum Corp. of Hermiston, OR. The smelter was expected to be operated on a tolling basis, using alumina input from Norsk Hydro A/S of Norway. By yearend, two of the smelter's three potlines were operational.

Alcoa reported the sale of its Vancouver, WA, smelter to Vanalco Inc., a private group of investors. The Vancouver smelter was the fourth smelter in the Pacific Northwest to shift to independent operation since 1985. However, unlike the other three smelters—Columbia Falls, MT, Goldendale, WA, and The Dalles, OR—which were designed as tolling operations, Vanalco expected to produce metal for its own account. By yearend, three of the smelter's five potlines were operating.

In December, Clarendon Ltd. reported the purchase of a 27% equity interest in Alumax Inc.'s Mount Holly, SC, primary smelter. One-half on Mount Holly's capacity was previously covered by a 10-year tolling agreement between the two companies.

Workers at Alumax's Ferndale, WA, smelter ratified a new 3-year agreement reached between representatives of the company and the Bellingham Metal Trades Council. According to company officials, the new contract, which maintained the basic wage rate of $13 per hour but cut extended vacations and vacation bonuses, was expected to improve the cost effectiveness of the plant. The contract was scheduled to run through September 26, 1990.

Power rates to two primary aluminum smelters—Alcan Aluminum Corp.'s Sebree, KY, plant and National Southwire Aluminum Co.'s Hawesville, KY, smelter, serviced by the Big Rivers Electric Corp.—were raised in September after months of court battles. The Kentucky Public Service Commission (PSC) approved a demand charge increase and a variable power-rate plan that linked energy charges to aluminum ingot prices. The demand charge to the two aluminum smelters rose from $6.25 per kilowatt to $7.50 per kilowatt. The flexible power rate provided for a 32 mills per kilowatt hour (mills/kW•h) power charge when the monthly average of the Metals Week U.S. transaction price for aluminum ingot was at 62 cents per pound for the month billed. The energy charge would rise 0.7 mill/kW•h for each 1-cent-per-pound increase in ingot prices above the pivot price of 62 cents per pound, until the power ceiling rate of 44 mills/kW•h was reached. Power rates would fall 0.8 mill/kW•h for each penny decrease in ingot prices below the pivot price to a floor rate of 18.1 mills/kW•h. Both the smelters and Big Rivers have filed suits in an attempt to overturn the PSC-approved rate increases. At yearend, the suits were still pending in the State circuit court.

The Kentucky smelters, which comprised about 9% of the total U.S. primary metal capacity and consumed about 70% of the power generated by Big Rivers, claimed that these increased power costs threatened their viability. A comparison of Kentucky power costs and the power costs at the Pacific Northwest aluminum smelters serviced by the Bonneville Power Administration (BPA), another variable power-rate source, shows that with aluminum ingot prices in and above the 80-cent-per-pound range, power charges at both the Kentucky and Pacific Northwest smelters were at the ceiling rate. However, the Kentucky power ceiling rate of 44 mills/kW•h was more than 50% above the BPA ceiling rate for 1987 of 28.6 mills/kW•h.

Alcan Aluminum and Toyo Aluminium K.K. (Toyal) reportedly agreed to form a joint venture, Alcan-Toyo America Inc., to produce and market aluminum powder and paste in the United States. Toyal would own 80% and Alcan Aluminum 20% of the joint venture. Alcan Aluminium Ltd., the parent company of Alcan Aluminum, owned 50% of Toyal. Under the agreement, Alcan Aluminum's existing Joliet, IL, powder plant would be sold to Alcan-Toyo. Pending arrangement of appropriate financing, Alcan-Toyo reportedly planned to expand the Joliet plant by adding a production line for automotive finish aluminum paste.

Alcan Rolled Products Co. announced plans to eliminate specialty and general sheet production at its Terre Haute, IN, plant and to concentrate on producing aluminum foil for the containers and packaging markets. The company cited the age and limitations of equipment at the plant as the reason for the decision.

Alcoa dedicated its $150 million continuous cold mill in Alcoa, TN, which company officials predicted would eventually produce all of the company's drawn and ironed beverage can body stock. The sister plant in Warrick, IN, reportedly would focus its production on can end stock. When fully operational, the Tennessee cold mill was expected to produce more than 700 million pounds of can stock annually.

Alcoa also announced the addition of a new wide cold-rolling mill as part of its announced modernization program for the Davenport, IA, works. Davenport, unlike Alcoa's can stock-dedicated mills in Warrick, IN, and Alcoa, TN, was a multipurpose unit, reportedly manufacturing products in 2,400 different shapes and sizes fabricated from 83 different alloys. The cold mill was expected to come on-stream in 1989.

Alumax announced plans to close its extrusion plant in Rockwall, TX, at yearend. The extrusions produced were reportedly for the housing industry. The company cited the area's depressed business conditions and unsatisfactory losses as reasons for its decision.

As part of its restructuring and reorganization plan, Kaiser announced the sale and closure of several fabricating plants during 1987. Kaiser confirmed the closure of two of the company's three electrical conductor plants, San Leandro, CA, and Portsmouth, RI. The third plant, in Bay Minette, AL, reportedly was being run at a reduced rate. Kaiser also announced the sale of most of its food-service aluminum foil and foil container business to Packaging Corp. of America. The operations reportedly included a plant in Wanatah, IN; a small manufacturing facility in Bensenville, IL; food service production equipment at Permanente, CA; and product inventories.

In a move designed to increase its share of the aluminum beverage can stock market, Kaiser announced plans to install a high-speed, wide-coil coating line at its Trentwood, WA, rolling mill. The new line reportedly would be able to make coated aluminum coils up to 60 inches wide for beverage can ends.

National Aluminum Corp. officially opened a new extrusion plant in Anniston, AL, which reportedly could produce in excess of 60 million pounds of extrusions per year for use in the construction industry. The company stated that 70% of its extrusion market was in the Southeastern United States and that the company would concentrate its extrusion business in this area. As a result, the company reported the sale of its extrusion plant in Indianapolis, IN, along with a foil-rolling facility in Danbury, CT, to Worldmark Materials Corp., and the closure of its Murrysville, PA, extrusion plant.

Large overseas-based casting companies announced plans to produce aluminum castings for the U.S. automotive industry. Teksid Aluminum Foundry, a partnership of the Fiat Group and Wabash Alloys Inc., reportedly opened a plant in Dickson, TN, to produce aluminum cylinder head castings under contract for General Motors Corp. (GM) and Chrysler Corp. When fully operational, the Dickson plant would have the capacity to produce 800,000 cylinder heads per year. Founderies Montupet of France announced plans to construct a plant in the United States to produce medium to large automotive castings. The plant reportedly would produce aluminum intake manifolds initially and then gradually would move to large components, such as cylinder heads. Montupet exported aluminum intake manifolds to several Ford Motor Co. plants in the United States and Mexico. Ryobi Ltd., the largest aluminum castings producer in Japan, joined with Sheller Globe Corp. and reportedly produced aluminum transmission cases for Ford and GM at a plant in Shelbyville, IN. These and several smaller foundries reportedly have edged into the North American market to take advantage of a pronounced trend toward lightweight aluminum castings in the automotive industry.

Table 2.—Primary aluminum production capacity in the United States, by company

Company	Yearend capacity (thousand metric tons) 1986	1987	1987 ownership (percent)
Alcan Aluminum Corp.:			
Sebree, KY	163	163	Alcan Aluminium Ltd., 100%.
Alumax Inc.:[1]			
Ferndale, WA (Intalco)	254	254	AMAX Inc., 100%.
Frederick, MD (Eastalco)	160	160	Do.
Mount Holly, SC	181	181	Amax, 73%; Clarendon Ltd., 27%.
Total	595	595	
Aluminum Co. of America:			
Alcoa, TN	160	160	Aluminum Co. of America, 100%.
Badin, NC	115	115	Do.
Evansville, IN (Warrick)	270	270	Do.
Massena, NY	127	127	Do.
Rockdale, TX	205	205	Do.
Wenatchee, WA	205	205	Do.
Total	1,082	1,082	
Columbia Aluminum Corp.:[2]			
Goldendale, WA	168	168	Columbia Aluminum Corp., 70%; employees, 30%.
Columbia Falls Aluminum Co.:			
Columbia Falls, MT	163	163	Montana Aluminum Investors Corp., 100%.
Kaiser Aluminum & Chemical Corp.:			
Chalmette, LA[3]	105	--	Kaiser Aluminum & Chemical Corp., 100%.
Mead, WA (Spokane)	200	200	Do.
Ravenswood, WV	148	110	Do.
Tacoma, WA	73	73	Do.
Total	526	383	
National-Southwire Aluminum Co.:			
Hawesville, KY	172	172	National Steel Corp., 50%; Southwire Co., 50%.
Noranda Aluminum Inc.:			
New Madrid, MO	204	204	Noranda Mines Ltd., 100%.
Northwest Aluminum Corp.:[4]			
The Dalles, OR	82	82	Martin Marietta Corp., 87.2%; private interests, 12.8%.
Ormet Corp.:			
Hannibal, OH	245	245	Ohio River Associates Inc., 100%.
Revere Copper and Brass Inc.:[5]			
Scottsboro, AL	105	105	Revere Copper and Brass Inc., 100%.
Reynolds Metals Co.:			
Longview, WA	191	191	Reynolds Metals Co., 100%.
Massena, NY	114	114	Do.
Troutdale, OR	118	118	Do.
Total	423	423	
Vanalco Inc.:[6]			
Vancouver, WA	110	110	Vanalco Inc., 100%.
Grand total	4,038	3,895	

[1]AMAX Inc. purchased 45% from Mitsui & Co. and 5% from Nippon Steel Corp. in Nov. 1986.
[2]Purchased from Comalco Pty. Ltd. in Aug. 1987.
[3]Kaiser Aluminum & Chemical Corp. wrote off 131,000 tons of annual capacity in Nov. 1986 and the remaining 105,000 tons in July 1987.
[4]Northwest Aluminum Corp. signed a lease-purchase agreement for The Dalles smelter with Martin Marietta Corp. in 1986.
[5]Revere Copper and Brass Inc. filed for bankruptcy in 1982.
[6]Purchased from Aluminum Co. of America in June 1987.

Secondary.—Metal recovered from purchased new and old aluminum scrap increased to about 2 million tons in 1987. Recycled UBC continued to be a major source of old scrap. According to the Institute of Scrap Recycling Industries, 36.5 billion aluminum cans were recycled in 1987, representing 50.5% of aluminum cans shipped.[4]

Alcan Aluminum announced plans to construct a $50 million aluminum can recycling plant in Berea, KY, capable of processing 120,000 tons of UBC per year. Construction was expected to begin in the first quarter of 1988 and to be completed within 2 years.

Wabash Alloys reportedly began pouring metal at its newly constructed secondary aluminum smelter in Dickson, TN, having a rated capacity of 6 million pounds of ingot and liquid metal per month.

Timco Corp. announced plans to add a third furnace at its secondary aluminum smelter in Fontana, CA. The furnace reportedly would increase production capacity by 36 million pounds per year.

Advanced Aluminum Products Inc. announced plans to triple the capacity of its Hammond, IN, plant to 120 million pounds per year of sheet products. The minimill was designed to process aluminum alloy scrap into alloy sheet.

Vulcan Materials Co. announced that the company was divesting its metal operations to devote full attention to its construction materials and chemical divisions. Wabash Alloys purchased two of Vulcan's secondary aluminum smelters situated in Benton, AR, and Milwaukee, WI, with a combined capacity of 12 million pounds of production per month. By yearend, Vulcan reportedly sold its two remaining secondary aluminum smelters, a UBC recovery plant in Corona, CA, and an extrusion scrap recovery plant in Sandusky, OH, to Thakar Aluminum Corp.

An investment group, Rochester Aluminum Smelting Corp., reportedly purchased the physical assets of Rochester Smelting & Refining Co. Inc.'s secondary aluminum plant in Rochester, NY, which had been idle since November 1986. The 3-million-pound-per-month plant was expected to process scrap on a tolling basis.

CONSUMPTION

Apparent consumption of aluminum metal increased 6% in 1987, reversing the downward trend in consumption that began in 1985. Shipments of aluminum to all end-use markets increased in 1987, led by a 6.5% increase in the container and packaging industry, which remained the largest consumer of aluminum products.

During the year, several companies announced plans to construct aluminum can-manufacturing facilities, which were scheduled to come on-stream in 1988. Ball Corp. reported the selection of Conroe, TX, as the site for a new plant having the capacity to produce 1 billion aluminum cans for the soft drink market. Metal Container Corp., a subsidiary of Anheuser-Busch Inc., reportedly began work on two can-manufacturing facilities, one in Windsor, CO, and the other in Orange County, NY, to service the parent company's breweries. In addition, Metal Container announced plans to construct a plant in Fort Atkinson, WI, to supply, on an exclusive basis, 1 billion aluminum cans annually to a group of PepsiCo Inc. bottlers. American National Can Co. reportedly planned to construct an aluminum beverage can plant in Olive Branch, MS.

The battle for the food can market continued in 1987. Aluminum, which dominated the beverage can market, accounted for only about 5% of the food can market. In an attempt to increase aluminum's share of the market, Alcoa reported that it had provided its high-speed electrophoretic can coating technology to Central States Can Co. for use in Central States planned aluminum food can facility. Reynolds Metals Co. announced that it would provide 10- and 12-ounce aluminum containers to two unnamed food processors. However, the steel industry, which dominated the food can market, continued its own product development work. Weirton Steel Corp. reported the development of a easy-opening top for steel cans that the company hoped would help steel to maintain its preeminence in the food packaging industry.

Alcan Aluminum and Sumitomo Electric Industries Ltd. announced plans to open a plant in Durham, NC, to make aluminum-clad steel cable that surrounds optical fibers for use in overhead power transmission lines.

Western Wheel Corp., a subsidiary of Kelsey-Hayes Co., reportedly agreed to establish a joint venture with Nippon Light

Metals Co. to market aluminum wheels manufactured by Western in Japan. The initial sales target for the imported aluminum wheels was 20,000 units per month. Hitachi Metals Ltd. reported the establishment of a wholly owned subsidiary in Saint Marys, OH, to manufacture aluminum wheels. Construction reportedly began on the plant, which was to have an initial production capacity of 500,000 units per year.

The Bureau of Mines released a study that examined the displacement of conventional nonfuel mineral materials by certain new materials, specifically advanced plastics and ceramics. Analyses of substitution by plastics were conducted for five major U.S. industrial sectors: motor vehicle manufacturing, aerospace applications, building and construction, packaging, and heavy machinery production. Forecasts of substitution by plastics during the 1990's were made for aluminum, steel, and glass. In addition, study findings identified key factors that would influence the emergence of advanced materials in the next decade.[5]

Table 3.—U.S. consumption of and recovery from purchased new and old aluminum scrap,[1] by class

(Metric tons)

Class	Consumption	Calculated recovery	
		Aluminum	Metallic
1986			
Secondary smelters	808,869	659,828	711,696
Primary producers	780,582	656,934	703,767
Fabricators	191,509	166,496	178,138
Foundries	84,846	70,399	75,852
Chemical producers	16,749	11,394	11,542
Total	1,882,555	1,565,051	1,680,995
Estimated full industry coverage	1,986,000	1,651,000	1,773,000
1987			
Secondary smelters	803,188	663,180	714,451
Primary producers	964,072	815,805	873,637
Fabricators	221,878	193,510	207,017
Foundries	79,067	65,927	70,930
Chemical producers	27,866	22,572	22,720
Total	2,096,071	1,760,994	1,888,755
Estimated full industry coverage	2,204,000	1,851,000	1,986,000

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

Table 4.—U.S. stocks, receipts, and consumption of purchased new and old aluminum scrap[1] and sweated pig in 1987

(Metric tons)

Class of consumer and type of scrap	Stocks, Jan. 1[r]	Net receipts[2]	Consumption	Stocks, Dec. 31
Secondary smelters:				
New scrap:				
Solids	14,359	230,165	236,029	8,495
Borings and turnings	5,917	140,209	141,842	4,284
Dross and skimmings	6,422	34,865	37,926	3,361
Other[3]	3,558	62,775	60,968	5,365
Total	30,256	468,014	476,765	21,505
Old scrap:				
Castings, sheet, clippings	7,345	187,250	180,671	13,924
Aluminum-copper radiators	1,083	12,925	13,090	918
Aluminum cans	2,109	[4]57,497	[4]58,787	819
Other[5]	435	15,659	15,009	1,085
Total	10,972	273,331	267,557	16,746
Sweated pig	7,065	54,369	58,866	2,568
Total secondary smelters	48,293	795,714	803,188	40,819

See footnotes at end of table.

Table 4.—U.S. stocks, receipts, and consumption of purchased new and old aluminum scrap[1] and sweated pig in 1987 —Continued

(Metric tons)

Class of consumer and type of scrap	Stocks, Jan. 1[r]	Net receipts[2]	Consumption	Stocks, Dec. 31
Primary producers, foundries, fabricators, chemical plants:				
New scrap:				
Solids	14,379	555,178	555,123	14,434
Borings and turnings	143	23,885	23,908	120
Dross and skimmings	451	10,662	10,689	424
Other[3]	2,610	99,821	99,243	3,188
Total	17,583	689,546	688,963	18,166
Old scrap:				
Castings, sheet, clippings	2,317	91,712	92,549	1,480
Aluminum-copper radiators	49	1,173	1,189	33
Aluminum cans	16,131	465,930	471,887	10,174
Other[5]	1,474	15,480	15,480	1,474
Total	19,971	574,295	581,105	13,161
Sweated pig	1,588	22,707	22,815	1,480
Total primary producers, etc	39,142	1,286,548	1,292,883	32,807
All scrap consumed:				
New scrap:				
Solids	28,738	785,343	791,152	22,929
Borings and turnings	6,060	164,094	165,750	4,404
Dross and skimmings	6,873	45,527	48,615	3,785
Other	6,168	162,596	160,211	8,553
Total new scrap	47,839	1,157,560	1,165,728	39,671
Old scrap:				
Castings, sheet, clippings	9,662	278,962	273,220	15,404
Aluminum-copper radiators	1,132	14,098	14,279	951
Aluminum cans	18,240	523,427	530,674	10,993
Other	1,909	31,139	30,489	2,559
Total old scrap	30,943	847,626	848,662	29,907
Sweated pig	8,653	77,076	81,681	4,048
Total of all scrap consumed	87,435	2,082,262	2,096,071	73,626

[r]Revised.
[1]Includes imported scrap. According to reporting companies, 6.11% of total receipts of aluminum-base scrap, or 127,187 metric tons, was received on toll arrangements.
[2]Includes inventory adjustment.
[3]Includes data on foil, can stock clippings, and other miscellaneous.
[4]Used beverage cans toll treated for primary producers are included in secondary smelter tabulation.
[5]Includes municipal wastes (includes litter) and fragmentized scrap (auto shredder).

Table 5.—Production and shipments of secondary aluminum alloys by independent smelters in the United States

(Metric tons)

	1986		1987	
	Production	Net shipments[1]	Production	Net shipments[1]
Die-cast alloys:				
13% Si, 360, etc. (0.6% Cu, maximum)	104,153	104,419	108,807	108,864
380 and variations	278,692	279,004	255,405	257,546
Sand and permanent mold:				
95/5 Al-Si, 356, etc. (0.6% Cu, maximum)	26,706	26,548	27,768	27,839
No. 12 and variations	W	W	W	W
No. 319 and variations	48,391	48,263	54,350	54,994
F-132 alloy and variations	8,237	8,326	9,661	9,471
Al-Mg alloys	84	86	216	235
Al-Zn alloys	5,087	4,913	3,835	4,599
Al-Si alloys (0.6% to 2.0% Cu)	5,213	5,390	5,986	6,012
Al-Cu alloys (1.5% Si, maximum)	1,450	1,465	1,198	1,216
Al-Si-Cu-Ni alloys	1,064	1,048	1,016	1,011
Other	833	838	3,272	3,288
Wrought alloys: Extrusion billets	106,297	103,949	147,253	146,644

See footnotes at end of table.

Table 5.—Production and shipments of secondary aluminum alloys by independent smelters in the United States —Continued

(Metric tons)

	1986		1987	
	Production	Net shipments[1]	Production	Net shipments[1]
Miscellaneous:				
Steel deoxidation	27,146	27,716	22,311	23,101
Pure (97.0% Al)	823	667	140	156
Aluminum-base hardeners	745	730	1,727	1,638
Other[2]	20,694	20,179	20,853	19,434
Total	635,615	633,541	663,798	666,048
Less consumption of materials other than scrap:				
Primary aluminum	47,808	--	42,740	--
Primary silicon	26,223	--	31,122	--
Other	3,091	--	3,263	--
Net metallic recovery from aluminum scrap and sweated pig consumed in production of secondary aluminum ingot[3]	558,493	XX	586,673	XX

W Withheld to avoid disclosing company proprietary data; included with "Sand and permanent mold: Other." XX Not applicable.
[1]Includes inventory adjustment.
[2]Includes other die-cast alloys and other miscellaneous.
[3]No allowance made for melt-loss of primary aluminum and alloying ingredients.

Table 6.—U.S. apparent aluminum supply and consumption

(Thousand metric tons)

	1983	1984	1985	1986	1987
Primary production	3,353	4,099	3,500	3,037	3,343
Change in stocks:[1] Aluminum industry	+547	-388	+312	+108	+341
Imports	1,091	1,477	1,420	1,967	1,849
Secondary recovery:[2]					
New scrap	953	935	912	989	1,134
Old scrap	820	825	850	784	852
Total supply	6,764	6,948	6,994	6,885	7,519
Less total exports	776	734	908	753	916
Apparent aluminum supply available for domestic manufacturing	5,988	6,214	6,086	6,132	6,603
Consumption, apparent[3]	5,035	5,279	5,174	5,143	5,469

[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 in the United States, by industry

Industry	1985		1986		1987[p]	
	Quantity (thousand metric tons)	Percent of grand total	Quantity (thousand metric tons)	Percent of grand total	Quantity (thousand metric tons)	Percent of grand total
Containers and packaging	1,862	26.9	1,926	27.7	2,052	27.8
Building and construction	1,375	19.8	1,432	20.6	1,434	19.4
Transportation	1,383	20.0	1,372	19.7	1,410	19.1
Electrical	642	9.3	626	9.0	629	8.5
Consumer durables	484	7.0	540	7.8	573	7.8
Machinery and equipment	377	5.4	383	5.5	400	5.4
Other markets	264	3.8	252	3.6	262	3.6
Statistical adjustment	-5	-.1	+14	+.2	+53	+.7
Total to domestic users	6,382	92.1	6,545	94.1	6,813	92.3
Exports	546	7.9	413	5.9	569	7.7
Grand total	6,928	100.0	6,958	100.0	7,382	100.0

[p]Preliminary.

Source: The Aluminum Association Inc.

Table 8.—U.S. net shipments[1] of aluminum wrought and cast products, by producers

(Metric tons)

	1986	1987[p]
Wrought products:		
Sheet, plate, foil	3,397,401	3,739,865
Rod, bar, pipe, tube, shapes	1,334,450	1,350,615
Rod, wire, cable	337,327	346,040
Forgings (including impacts)	65,566	70,886
Powder, flake, paste	43,646	41,792
Total	5,178,390	5,549,198
Castings:		
Sand	77,218	NA
Permanent mold	154,725	NA
Die	748,842	NA
Other	51,419	NA
Total	1,032,204	949,107
Grand total	6,210,594	6,498,305

[p]Preliminary. NA Not available.
[1]Net shipments derived by subtracting the sum of producers' domestic receipts of each mill shape from the domestic industry's gross shipments of that shape.

Source: U.S. Department of Commerce.

Table 9.—Distribution of wrought products in the United States

(Percent)

	1986	1987
Sheet, plate, foil:		
Nonheat-treatable	54.4	56.7
Heat-treatable	3.7	3.6
Foil	7.5	7.0
Rod, bar, pipe, tube, shapes:		
Rod and bar (rolled and extruded)	1.7	1.8
Pipe and tube (extruded and drawn)	2.4	2.2
Extruded shapes	21.5	20.2
Rod, wire, cable:		
Rod and bare wire	1.0	1.1
Cable and insulated wire	5.5	5.1
Forgings (including impacts)	1.3	1.3
Powder, flake, paste	1.0	1.0
Total	100.0	100.0

Source: U.S. Department of Commerce.

STOCKS

Inventories of aluminum ingot, mill products, and scrap at reduction and other processing plants, as reported by the U.S. Department of Commerce, decreased from about 2.24 million tons at yearend 1986 to about 1.89 million tons at yearend 1987.

PRICES

The monthly average U.S. market price for primary aluminum ingot had an upward trend during the year. The monthly average price reached a high for the year of 84.4 cents per pound in October. The price softened in November but made a strong recovery at yearend. Increased demand, tight supply, and decreasing inventories, in the domestic and world markets, contributed to the rise in aluminum ingot prices.

The London Metal Exchange (LME) and New York Commodity Exchange (COMEX) prices for aluminum futures followed the same general trend as the U.S. market price. Early in the year, aluminum supply and demand were in relative balance, and the COMEX prices for future deliveries were slightly higher than short-term delivery prices, a normal market situation referred to as contango. In March, the futures market became inverted and was said to be in backwardation, a term used to describe situations where near-term delivery prices were at a premium over distant contracts. This backwardation of COMEX prices reflected the tightness of aluminum supply prevalent during most of 1987.

The following table summarizes the average monthly and annual aluminum prices during the year, in cents per pound:

	COMEX 1[1]	COMEX 2[1]	COMEX 3[1]	LME (cash)	U.S. market	U.S. transaction
1986: Annual average	52.93	53.28	54.71	52.18	55.87	56.52
1987:						
January	52.37	52.64	53.33	53.13	54.60	55.15
February	56.57	56.77	56.49	58.22	59.45	60.63
March	60.46	59.68	57.12	62.02	62.55	63.66
April	64.30	62.32	58.65	63.55	64.97	65.59
May	70.09	67.20	65.08	64.03	68.90	70.17
June	72.44	70.23	68.92	66.78	72.55	73.10
July	74.03	73.17	68.32	74.98	74.24	75.48
August	78.61	77.70	70.36	82.12	81.67	82.30
September	81.01	78.97	68.72	79.21	80.69	82.31
October	82.47	82.03	70.00	89.03	84.39	85.10
November	79.41	76.79	70.64	76.25	80.16	81.10
December	83.13	81.24	76.01	82.73	83.39	84.59
Annual average	71.24	69.89	65.30	70.84	72.30	73.26

[1]COMEX delivery positions: 1—within 1 month; 2—within 3 months; and 3—within 12 months.

Source: Metals Week.

Purchase prices for aluminum scrap and secondary aluminum ingot, as quoted by American Metal Market, followed the upward trend of primary aluminum ingot prices. Purchase prices of old sheet and cast aluminum scrap rose from 34 cents per pound in January to a high of 54 cents per pound at yearend. UBC scrap, processed and delivered to producers, was bought at a range of 34 to 37 cents per pound at the beginning of 1987. By yearend, the UBC purchase price range was 60 to 63 cents per pound. Secondary aluminum alloy 360 prices increased from a range of about 59 to 61 cents per pound in January to close the year at 88 to 90 cents per pound. Alloy 413 and alloy 380 prices were within a penny or two of the alloy 360 prices throughout the year.

FOREIGN TRADE

Exports of all forms of aluminum from the United States increased substantially from the 1986 level. The increase in world demand for aluminum and the declining value of the dollar resulted in a better competitive position for U.S. exports. Exports of semifabricated products showed the most dramatic increase. Japan, which remained the major recipient of U.S. aluminum materials, nearly doubled its imports of crude metal and alloys from the United States in 1987 compared with those of 1986.

Imports for consumption of aluminum decreased slightly compared with those of 1986. Canada remained the major shipping country to the United States, supplying just over 60% of the total U.S. imports in 1987.

U.S. tariff rates in effect in 1987 for aluminum products from countries with most-favored-nation status were as follows:

Item	TSUS No.	Import duty
Unwrought metal (in coils)	618.01	2.6% ad valorem.
Unwrought (other than Si-Al alloys)	618.02	Free.
Wrought (bars, plates, sheets, strip)	618.25	3% ad valorem.
Waste and scrap	618.10	2% ad valorem.

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

Class	1986 Quantity (metric tons)	1986 Value (thousands)	1987 Quantity (metric tons)	1987 Value (thousands)
Crude and semicrude:				
Metals and alloys, crude	209,794	$282,958	281,163	$415,003
Scrap	350,858	333,187	368,492	409,686
Plates, sheets, bars, etc	180,057	442,681	251,572	647,890
Castings and forgings	6,902	59,979	6,902	65,504
Semifabricated forms, n.e.c	5,584	32,632	7,874	41,405
Total	753,195	1,151,437	916,003	1,579,488
Manufactures:				
Foil and leaf	27,548	29,717	55,834	59,917
Powders and flakes	2,125	7,553	2,420	9,694
Wire and cable	2,912	11,088	4,449	15,856
Total	32,585	48,358	62,703	85,467
Grand total	785,780	1,199,795	978,706	1,664,955

Source: Bureau of the Census.

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

Country	Metals and alloys, crude		Plates, sheets, bars, etc.[1]		Scrap		Total	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1986:								
Belgium-Luxembourg	100	$144	1,031	$6,529	3,894	$3,675	5,025	$10,348
Brazil	541	676	492	2,634	3,596	3,350	4,629	6,660
Canada	30,300	51,992	127,950	305,079	14,706	15,110	172,956	372,181
France	166	261	803	4,913	465	377	1,434	5,551
Germany, Federal Republic of	1,570	2,967	1,965	11,709	5,403	5,899	8,938	20,575
Hong Kong	883	1,113	761	2,294	454	471	2,098	3,878
Italy	49	179	2,990	15,024	7,270	6,567	10,309	21,770
Japan	131,608	162,156	7,531	25,548	243,329	228,979	382,468	416,683
Korea, Republic of	10,939	13,830	3,936	11,066	1,930	1,608	16,805	26,504
Mexico	7,772	11,259	21,130	55,634	25,643	28,578	54,545	95,471
Netherlands	473	845	1,609	8,718	5,099	4,688	7,181	14,251
Panama	958	1,670	81	255	64	101	1,103	2,026
Peru	389	496	64	231	6	78	459	805
Singapore	738	885	257	1,552	219	156	1,214	2,593
Spain	110	81	780	3,933	1,060	892	1,950	4,906
Taiwan	13,821	16,314	619	2,922	35,827	30,512	50,267	49,748
United Kingdom	2,247	4,173	5,015	22,648	680	818	7,942	27,639
Other[r]	7,130	13,917	15,529	54,603	1,213	1,328	23,872	69,848
Total	209,794	282,958	192,543	535,292	350,858	333,187	753,195	1,151,437
1987:								
Belgium-Luxembourg	11	18	883	4,366	1,253	2,861	2,147	7,245
Brazil	102	359	1,093	5,699	1,974	1,794	3,169	7,852
Canada	25,815	52,319	163,379	417,008	20,995	22,272	210,189	491,599
France	24	192	1,028	9,986	2,227	2,391	3,279	12,569
Germany, Federal Republic of	89	1,601	2,240	11,372	3,097	3,395	5,426	16,368
Hong Kong	3,437	4,796	6,843	14,609	759	707	11,039	20,112
Italy	256	518	3,493	20,395	3,362	2,807	7,111	23,720
Japan	226,884	310,618	13,936	45,451	263,296	300,858	504,116	656,927
Korea, Republic of	3,145	4,704	9,318	24,364	6,312	7,886	18,775	36,954
Mexico	6,799	11,500	26,806	68,233	21,672	23,314	55,277	103,047
Netherlands	561	892	1,955	10,965	4,869	5,381	7,385	17,238
Panama	667	1,163	171	474	210	229	1,048	1,866
Peru	129	167	218	843	12	24	359	1,034
Singapore	3,283	5,896	387	3,396	155	165	3,825	9,457
Spain	5	21	918	3,219	642	434	1,565	3,674
Taiwan	4,869	7,048	3,538	9,589	34,258	30,698	42,665	47,335
United Kingdom	548	2,001	5,489	25,380	946	1,053	6,983	28,434
Other	4,539	11,190	24,653	79,450	2,453	3,417	31,645	94,057
Total	281,163	415,003	266,348	754,799	368,492	409,686	916,003	1,579,488

[r]Revised.
[1]Includes castings, forgings, and unclassified semifabricated forms.

Source: Bureau of the Census.

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

Class	1986 Quantity (metric tons)	1986 Value (thousands)	1987 Quantity (metric tons)	1987 Value (thousands)
Crude and semicrude:				
Metals and alloys, crude	1,348,816	$1,682,907	1,245,510	$1,852,152
Circles and disks	14,541	31,230	16,068	34,293
Plates, sheets, etc., n.e.c	373,056	755,070	339,547	695,451
Rods and bars	61,833	90,474	54,937	92,372
Pipes, tubes, etc	6,101	37,531	4,659	18,293
Scrap	162,317	141,702	188,612	202,292
Total	1,966,664	2,738,914	1,849,333	2,894,853
Manufactures:				
Foil	27,345	96,241	29,145	63,098
Leaf	(1)	163	(1)	220
Flakes and powders	3,507	6,211	3,678	5,885
Wire	3,215	9,893	3,512	10,493
Total	34,067	112,508	36,335	79,696
Grand total	2,000,731	2,851,422	1,885,668	2,974,549

[1]1986—aluminum leaf not over 30.25 square inches in area, 3,653,187 leaves, and aluminum leaf over 30.25 square inches in area, 403,820,038 square inches; and 1987—aluminum leaf not over 30.25 square inches in area, 3,618,270 leaves, and aluminum leaf over 30.25 square inches in area, 834,506,782 square inches.

Source: Bureau of the Census.

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

Country	Metals and alloys, crude: Quantity (metric tons)	Metals and alloys, crude: Value (thousands)	Plates, sheets, bars, etc.[1]: Quantity (metric tons)	Plates, sheets, bars, etc.[1]: Value (thousands)	Scrap: Quantity (metric tons)	Scrap: Value (thousands)	Total: Quantity (metric tons)	Total: Value (thousands)
1986:								
Argentina	32,055	$29,832	6,278	$9,753	--	--	38,333	$39,585
Australia	31,906	38,695	8,415	16,087	2,391	$3,804	42,712	58,586
Belgium-Luxembourg	103	228	30,873	51,101	402	399	31,378	51,728
Brazil	116,498	148,524	7,418	29,964	--	--	123,916	178,488
Canada	868,722	1,092,129	57,999	109,704	115,714	100,971	1,042,435	1,302,804
France	3,240	4,060	29,063	63,700	375	335	32,678	68,095
Germany, Federal Republic of	695	4,637	19,751	50,054	714	728	21,160	55,419
Israel	320	260	2,710	10,009	--	--	3,030	10,269
Italy	11	37	7,026	13,801	68	58	7,105	13,896
Japan	637	2,413	144,129	311,506	42	23	144,808	313,942
Mexico	2,887	2,874	1,566	1,547	12,260	7,619	16,713	12,040
Netherlands	1,765	2,097	7,013	23,286	--	--	8,778	25,383
Norway	184	274	4,404	81,165	--	--	4,588	81,439
Romania	15,926	23,551	6,342	9,002	--	--	22,268	32,553
South Africa, Republic of	32,372	37,021	4,404	6,499	184	158	36,960	43,678
United Kingdom	1,745	3,105	11,476	35,607	927	930	14,148	39,642
U.S.S.R.	5,530	5,017	--	--	19,906	18,571	25,436	23,588
Venezuela	69,182	75,215	54,145	71,031	6,532	6,079	129,859	152,325
Other[r]	165,038	212,938	52,519	20,489	2,802	2,027	220,359	235,454
Total	1,348,816	1,682,907	455,531	914,305	162,317	141,702	1,966,664	2,738,914
1987:								
Argentina	16,201	23,331	4,545	8,624	204	328	20,950	32,283
Australia	12,429	17,480	7,296	13,861	1,404	1,282	21,129	32,623
Belgium-Luxembourg	271	475	28,472	53,452	15	95	28,758	54,022
Brazil	67,596	101,029	6,314	11,033	215	295	74,125	112,357
Canada	918,884	1,351,269	91,537	167,888	125,369	140,657	1,135,790	1,659,814
France	859	1,418	23,382	55,024	589	376	24,830	56,818
Germany, Federal Republic of	7,379	14,199	10,624	30,727	346	703	18,349	45,629
Israel	71	89	1,943	6,712	339	434	2,353	7,235
Italy	197	234	3,288	6,934	51	52	3,536	7,220
Japan	541	2,061	99,852	221,200	8	32	100,401	223,293

See footnotes at end of table.

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

Country	Metals and alloys, crude		Plates, sheets, bars, etc.[1]		Scrap		Total	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1987: —Continued								
Mexico	1,473	$2,111	3,658	$6,660	15,295	$12,415	20,426	$21,186
Netherlands	1,872	2,283	7,717	30,967	1,116	1,444	10,705	34,694
Norway	2,492	4,585	3,222	5,894	--	--	5,714	10,479
Romania	17,325	24,834	9,217	14,380	--	--	26,542	39,214
South Africa, Republic of	5,526	6,957	4,119	7,000	--	--	9,645	13,957
United Kingdom	544	1,091	6,921	24,867	1,393	1,755	8,858	27,713
U.S.S.R.	2,016	2,322	--	--	24,399	24,364	26,415	26,686
Venezuela	42,909	61,645	43,012	64,374	11,543	11,596	97,464	137,615
Other	146,925	234,739	60,092	110,812	6,326	6,464	213,343	352,015
Total	1,245,510	1,852,152	415,211	840,409	188,612	202,292	1,849,333	2,894,853

[r]Revised.
[1]Includes circles, disks, rods, pipes, tubes, etc.

Source: Bureau of the Census.

WORLD REVIEW

World primary aluminum production capacity was essentially unchanged from that of 1986. However, the shifting of capacity from countries with high energy and labor costs to areas of the world with lower cost labor and energy, principally hydroelectric power, continued. Reductions in capacity were made in Japan and the United States, whereas Canada, China, and India expanded smelter capacity.

Despite an increase in world production of primary aluminum, supply was apparently inadequate to meet the rise in demand reported in 1987. Depressed aluminum prices in 1985 and 1986 led to a temporary idling of smelter capacity, especially in the United States. When the increase in demand appeared in 1987, these temporarily reduced production levels were not able to meet demand and resulted in sharp price increases and reductions in inventories. Japan, with its recent closures of primary aluminum capacity, was forced to compete for supplies in what was already a tight international market. Additionally, several countries, namely Brazil, Cameroon, Indonesia, and Suriname, were forced to reduce production during 1987 because of drought conditions that curtailed the supply of available hydroelectric power. By yearend, smelter operating capacity had increased significantly, but inventory levels remained depressed.

Primary aluminum inventories held by members of the International Primary Aluminium Institute (IPAI), which represent the bulk of stocks held outside the centrally planned economy countries, decreased from 1.853 million tons at yearend 1986 to 1.390 million tons at yearend 1987. IPAI reported that total metal inventories, including secondary aluminum, decreased by over one-half million tons to 3.050 million tons at yearend 1987.

Brazil.—Two primary aluminum smelters, Alumínio do Brazil Nordeste S.A. and Alcoa Alumínio S.A. (Alumar), were forced to cut back on aluminum metal production during most of the year, owing to the shortage of available hydroelectric power caused by severe drought conditions in the northeastern section of the country. Power rationing, which went into effect on March 1, reportedly forced the two plants to operate at 15% below capacity.

The shortage of power also forced an indefinite postponement of expansion plans at the Alumar smelter. Brazil's Interministerial Council for the Greater Carajas project reportedly denied the company permission to proceed with a scheduled 135,000-ton-per-year capacity expansion at the 245,000-ton-per-year smelter in São Luís.

In October, Consorcio de Alumínio Albrás e Alunorte S.A. reportedly began construction work on phase 2 of the Albras aluminum project. The $625 million expansion was expected to increase the smelter's annual capacity from 160,000 tons to 320,000 tons by 1991.

Reynolds announced plans to construct Brazil's first aluminum beverage can plant, which would be capable of producing about 700 million cans per year. Bardella, a large machinery manufacturer in Brazil, was expected to contribute one-half of the funds needed to construct the $55 million plant. The plant, to be built in the town of Pouso Alegre in Minas Gerais, reportedly would take 2 years to complete.

Canada.—The second 115,000-ton-per-year potline of the 230,000-ton-per-year Aluminiere de Bécancour Inc. aluminum smelter began operations in February. In July, Reynolds announced the purchase of one-half of Pechiney's interest in the Bécancour smelter. After the purchase, Reynolds and Pechiney each held a 25.05% interest, and Alumax and Société Générale de Financement du Quebec owned 24.95% each. The four owners commissioned a feasibility study on the addition of a third 115,000-ton-per-year potline at the smelter.

Alcan Aluminium announced that it had decided to proceed with the construction of the first phase of the Laterriere aluminum smelter in Chicoutimi, Quebec, which had been put on hold since September 1985. Construction of the first phase, which would consist of about 50,000 tons per year of capacity, was scheduled to begin in mid-1988. Alcan Aluminium confirmed that the smelter would use Alcoa's P155 reduction cell technology, a technology already in use at Alcan Aluminium's Grand Baie, Quebec, and Sebree, KY, smelters. The Laterriere smelter, which reportedly would have a total annual smelting capacity of 200,000 tons, was expected to be completed over a period of 5 to 7 years at an estimated cost of $450 million.

Labor contracts at Alcan Aluminium's four Quebec primary aluminum smelters expired on August 31. Workers at the Arvida, Beauharnois, and Isle Maligne smelters continued to work under the old labor contract through yearend while negotiations continued between the company and the Federation des Syndicats du Secteur Aluminium. However, operations at Alcan's fourth Quebec smelter, the 84,000-ton-per-year Shawinigan smelter, were halted on October 31. Talks between the Confederation of National Trade Unions, which represented the workers at Shawinigan, and Alcan Aluminium continued at yearend.

China.—The first phase of the Qinghai primary aluminum smelter, with a projected annual capacity of 100,000 tons, reportedly began operations on October 1. Construction began in early 1984 with an investment of $135 million. The second phase, which was reportedly scheduled for completion by 1989, would add an additional 100,000 tons of annual capacity.

In June, the China International Trust and Investment Corp. (CITIC) and Aluvic, a Victoria, Australia, government-owned company, reportedly signed an agreement to build an aluminum rolling mill and extrusion plant in Qinhuangdao in northern China. A joint-venture company, Bohai Aluminium Industries, would be set up to run the plant and would be owned by CITIC, 75%; and by Aluvic, 25%. The 100,000-ton-per-year plant reportedly would take 3 years to build.

Germany, Federal Republic of.—In March, Alcan Aluminium announced the closure of its 44,000-ton-per-year primary aluminum smelter in Ludwigshafen, reportedly owing to uneconomic energy costs.

Iceland.—The Government of Iceland conducted a prefeasibility study for a 200,000-ton-per-year primary aluminum smelter. The new smelter reportedly would be owned by a new independent company and be run separately from the existing Isal smelter, although making use of Isal's infrastructure.

India.—In May, the National Aluminium Co. Ltd. (Nalco) energized the first 109,000-ton-per-year potline at its 218,000-ton-per-year primary aluminum smelter at Orissa. Nalco expected the initial potline to be at full production by 1989 and construction of the smelter's second phase to be completed by 1991.

Indonesia.—The Governments of Indonesia and Japan reportedly reached an agreement to restructure Indonesia's Asahan aluminum smelter. As a result of the agreement, the Japanese consortium, Nippon Asahan Aluminium Co. Ltd., reportedly would decrease its share of ownership from 75% to 59%, and the Indonesian Government would increase its stake to 41%. The restructuring plan reportedly included the infusion of capital and the renegotiation of current loan interest rates and repayment schedules.

Japan.—During the year, aluminum companies continued to shut down primary aluminum smelters, a trend that began in 1985. In March, Mitsui Aluminum Co. Ltd. announced the closure of its 144,000-ton-per-year Omuta smelter, and Ryoka Light

Metal Industries Ltd. reported the closure of its 76,000-ton-per-year Sakaide smelter. With these announced closures, Nippon Light Metal Co. Ltd.'s 64,000-ton-per-year Kambara plant was the only primary aluminum smelter still operating in Japan.

The Ministry of International Trade and Industry (MITI) and the Japanese Aluminum Federation (JAF) studied the possibility of establishing an aluminum futures exchange in Japan. Two proposals were explored: locating an LME warehouse in Japan and/or establishing a Japan Metal Exchange (JME) for aluminum, copper, lead, and zinc. The JAF requested MITI to repeal the import duty on primary aluminum ingot, which was reduced to 1% on January 1, 1988. The JAF stated that an import duty would be a barrier to the smooth management of a futures warehouse in Japan. A decision on these proposals was expected in 1988.

Mexico.—Primary metal production capacity at Mexico's only aluminum smelter Aluminio S.A., in Vera Cruz, increased from 44,000 tons per year to 66,000 tons per year. In addition, a recycling facility reportedly was opened, with a secondary ingot production capacity of 28,000 tons per year.

Netherlands.—Kaiser reported the sale of its subsidiary, Kaiser Aluminium Europe (KAE) to the Dutch steel and aluminum company, Hoogovens Group BV. The sale included KAE's 72,000-ton-per-year primary aluminum smelter in Voerde, Federal Republic of Germany, and fabrication facilities in Belgium, the Federal Republic of Germany, and Switzerland.

Norway.—Hydro Aluminium A/S reported the completion of a feasibility study on the conversion of the Norsk Jernverk steel plant at Mo i Rana into a 200,000-ton-per-year aluminum smelter. The project's viability reportedly hinged on the availability and price of power.

Spain.—Inespal reported that a 3-day strike in mid-December damaged the potlines of the San Ciprian smelter, forcing it to close for 6 months for repairs.

Suriname.—In January, Suriname Aluminium Co. (Suralco), a subsidiary of Alcoa, reported the closure of its 60,000-ton-per-year smelter at Paranam for an indefinite period because of a power outage that resulted from activities of anti-Government insurgents. In midyear, Alcoa announced the permanent shutdown of one 30,000-ton-per-year potline at the Suralco smelter.

Thailand.—Japan's largest manufacturer of aluminum building materials, Toyo Sash, announced the investment of about $10 million to build a factory in Thailand to produce aluminum doors and other extrusion products. The plant, Tostem Thai Co. Ltd., was expected to be finished next year with an initial production level of 1,000 tons per month.

U.S.S.R.—The Soviet Union and Comalco Pty. Ltd. of Australia reportedly were studying the possibility of a joint-venture aluminum complex to be built on the Pacific Coast of the U.S.S.R. in the early 1990's. The complex, consisting of a 1-million-ton-per-year alumina refinery and a 500,000-ton-per-year primary metal smelter, would make use of the Soviet Union's hydroelectric power supplies and Australia's large bauxite reserves.

United Arab Emirates.—The Dubai Aluminium Co. Ltd. reported plans to expand its extrusion billet production capacity from 90,000 tons per year to 125,000 tons per year by January 1989 in response to strong billet demand.

United Kingdom.—American National Can Co., a subsidiary of Chicago-based Triangle Industries Inc., announced plans to build an eighth aluminum beverage can plant in the United Kingdom to meet growing demand in the European market. The new unit was expected to come on-stream in 1988.

Star Aluminium Co. Ltd., a subsidiary of Swiss Aluminium Ltd. (Alusuisse) reportedly invested $54 million to modernize and expand its aluminum foil plant in Bridgnorth, England. The expansion, including a new thin strip mill and fully automated thin foil facilities to be completed by 1991, was expected to increase the company's consumption of aluminum from 25,000 tons per year to 40,000 tons per year.

Venezuela.—Austria Metall AG reported the company's withdrawal from the Aluminio del Sur (Alusur) smelter project. Alcoa announced the signing of a letter of intent to become a partner in the 120,000-ton-per-year Alusur smelter scheduled to come on-stream by yearend 1990. The joint-venture company reportedly was composed of Suramericana de Aleaciones Laminados, 40%; Alcoa, 40%; and Corporación Venezolana de Guayana, 20%.

Aluminio del Caroní S.A. (ALCASA) and Industria Venezolana de Aluminio C.A. (VENALUM) have both announced expansions to their existing smelters planned for the early 1990's.

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

(Thousand metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
Argentina	133	[r]138	140	[e]150	155
Australia	478	758	851	882	[2]1,004
Austria	94	96	94	93	93
Bahrain	172	177	175	[e]178	194
Brazil	401	455	549	758	840
Cameroon	77	73	90	84	80
Canada	1,091	1,227	1,282	1,364	1,530
China[e]	400	400	410	410	410
Czechoslovakia	36	32	[e]32	33	33
Egypt	140	170	209	175	175
France	361	342	293	322	300
German Democratic Republic[e]	57	58	60	60	60
Germany, Federal Republic of	743	777	745	765	730
Ghana	42	--	49	125	150
Greece[3]	136	136	125	126	130
Hungary	74	74	74	74	74
Iceland	76	80	73	76	[2]85
India[3]	204	269	260	257	250
Indonesia[3]	115	199	217	219	210
Iran	39	42	43	40	40
Italy	196	230	221	243	240
Japan[4]	256	287	227	140	[2]41
Korea, North[e]	10	10	10	10	10
Korea, Republic of[3]	13	18	18	19	19
Mexico[3]	40	44	43	37	43
Netherlands	235	249	251	266	280
New Zealand	219	243	241	173	230
Norway	713	765	712	712	[2]725
Poland[5]	44	46	47	48	48
Romania[6]	223	244	247	269	240
South Africa, Republic of	161	167	165	172	170
Spain	358	381	370	350	350
Suriname[7]	[r]29	29	[r e]29	30	5
Sweden	82	83	84	77	76
Switzerland	76	79	73	80	80
Turkey	30	38	54	[e]50	50
U.S.S.R.[e]	2,000	2,100	2,200	2,300	2,400
United Arab Emirates: Dubai	151	155	153	155	[2]155
United Kingdom	[r]253	288	275	276	[2]297
United States	3,353	4,099	3,500	3,037	[2]3,343
Venezuela	335	386	396	[e]424	427
Yugoslavia[e 3]	[2]258	[r]270	[r]280	[r]282	244
Total	[r]13,904	[r]15,714	15,367	15,341	16,016

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

[1]The Bureau of Mines defines primary aluminum as "The weight of liquid aluminum as tapped from pots, excluding the weight of any alloying materials as well as that of any metal produced from either returned scrap or remelted materials." International reporting practices vary from country to country, some nations conforming to the foregoing definition and others using different definitions. For those countries for which a different definition is given specifically in the source publication, that definition is provided in this table by footnote. Table includes data available through June 3, 1988.

[2]Reported figure.

[3]Primary ingot.

[4]Excludes high-purity aluminum containing 99.995% or more as follows, in metric tons: 1983—2,679; 1984—4,348; 1985—4,783; 1986—8,140; and 1987—12,099.

[5]Primary unalloyed ingot plus secondary unalloyed ingot.

[6]Primary unalloyed metal plus primary alloyed metal, thus including weight of alloying material.

[7]Data represent exports of ingot aluminum, presumably all primary.

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

(Thousand metric tons)

Continent and country	1985	1986	1987[p]
North America:			
Canada	1,347	1,462	1,577
Mexico	45	45	66
United States	4,706	4,038	3,895
South America:			
Argentina	146	150	150
Brazil	629	869	884
Suriname	60	60	30
Venezuela	400	430	430
Europe:			
Austria	92	92	92
Czechoslovakia	60	60	60
France	[r]304	394	346
German Democratic Republic	85	85	85
Germany, Federal Republic of	777	777	733
Greece	145	145	145
Hungary	76	76	76
Iceland	86	86	86
Italy	276	276	276
Netherlands	266	266	266
Norway	770	770	834
Poland	110	110	110
Romania	250	250	250
Spain	379	344	344
Sweden	82	82	91
Switzerland	86	72	72
U.S.S.R	[r]2,500	2,540	2,590
United Kingdom	287	287	287
Yugoslavia	357	357	357
Africa:			
Cameroon	80	80	80
Egypt	170	170	170
Ghana	200	200	200
South Africa, Republic of	172	172	172
Asia:			
Bahrain	170	180	180
China	[r]431	471	615
India	363	363	472
Indonesia	225	225	225
Iran	50	50	50
Japan	425	284	64
Korea, North	20	20	20
Korea, Republic of	18	18	18
Taiwan	50	50	50
Turkey	60	60	60
United Arab Emirates: Dubai	149	149	149
Oceania:			
Australia	862	1,012	1,012
New Zealand	244	244	244
Total	[r]18,010	17,871	17,913

[p]Preliminary. [r]Revised.

[1]Detailed information on the individual aluminum reduction plants is available in a 2-part report that can be purchased from Chief, Division of Finance, Bureau of Mines, Bldg. 20, Federal Center, Denver, CO 80225. Part 1 of "Primary Aluminum Plants, Worldwide" details location, ownership, and production capacity for 1985-92 and sources of energy and aluminum raw materials for foreign and domestic primary aluminum plants, including those in centrally planned economy countries. Part 2 summarizes production capacities for 1985-92 by smelter and country.

TECHNOLOGY

Several aluminum companies announced the commercialization of aluminum-lithium alloy products. Commercial applications for these alloys centered around aerospace industry products such as passenger aircraft fuselage skin, floor beams in the MD-11 transport, and wing surfaces. The advantages cited for the aluminum-lithium alloys were lower density and increased strength-to-weight performance with no sacrifice in ease of fabrication on existing aircraft-manufacturing equipment.

The Boeing Co. reported the development of a patented scrap-processing method for aluminum-lithium alloys. A maximum 50% mix of 2090 aluminum-lithium alloy with aluminum was processed together, and the bulk of the lithium was removed as a powder with salts in the dross. Reynolds also reported that recycling capability for aluminum-lithium alloys would be included in its aluminum-lithium casting facility under construction in McCook, IL. A Reynolds spokesperson stated that the recycling capability would help to make the facility commercially viable.[6]

Titanium tetrachloride, aluminum chloride, and vanadium tetrachloride were coreduced simultaneously via a Kroll-type magnesium reduction process to form an alloy sponge, as part of a research effort by the Bureau of Mines to produce titanium alloy powder. The important possible advantage in the coreduction approach, as related to powder production, was the elimination of the master alloy addition step and subsequent vacuum arc melts. Analysis of the individual sponge particles indicated that grinding the alloy sponge prepared by the coreduction process did not produce a powder product of acceptable chemical homogeneity. However, melting the alloy sponge in a consumable-electrode, annular-anode furnace did produce a material with acceptable homogeneity.[7]

Alcoa announced that its new metal matrix composite made from aluminum sheet and aramid epoxy fibers (Arall) had entered the commercial marketing stage. High-strength aramid fibers were embedded in resins between thin sheets of high-strength aluminum alloys. The laminates reportedly could be machined in a manner similar to that used to produce monolithic aluminum sheet. The primary benefits of the laminated material were a decrease in fatigue crack growth rate compared with that of monolithic aluminum structures and a greater resistance to impact damage compared with that of carbon fiber composites. The material reportedly would be a candidate for use in fatigue-critical structures requiring relatively light-gauge sheet such as lower wing skins and fuselage and tail skin sections of commercial aircraft. Several domestic military and commercial aircraft manufacturers were considering the new composite.[8]

Showa Denko K.K. and Taiyo Fishery Co. of Japan reportedly developed a plastic-aluminum composite can. The can, developed for use as a food container, was a four-layer composite. The surface layer was polypropylene plastic, reinforced by a polypropylene film second layer. The third layer consisted of aluminum foil, with polypropylene film used again for the fourth or innermost layer. Initially, the companies planned to produce about 960,000 composite cans for testing and evaluation.[9]

Reynolds reported the development of a resealable aluminum can to compete with glass and plastic containers, which held about 60% of the soft drink market and about 38% of the beer market. Reynolds stressed the light weight and recyclability of the new container. According to the company, a one-liter version of the resealable can weighed 20% less than a comparable plastic container. PepsiCo reportedly was considering test-marketing the can.[10]

A process reportedly was developed that converted spent aluminum potliners, which contained fluorides and cyanides, into a product suitable for disposal in landfills. Ground potlining particles were hydrolyzed to remove the contained cyanides and subsequently encapsulated with gypsum to prevent leaching of water-soluble fluorides. The proposed process reportedly was economically attractive compared to the cost of preparing and maintaining an environmentally sealed disposal site for spent potliners.[11]

[1]Physical scientist, Branch of Nonferrous Metals.

[2]Federal Register. Preliminary Affirmative Countervailing Duty Determination; Certain Electrical Conductor Aluminum Redraw Rod From Venezuela. V. 52, No. 198, Oct. 14, 1987, pp. 38113-38117.

[3]All quantities in this chapter are given in metric tons unless otherwise specified.

[4]American Metal Market. UBC Recycling Rate Moves Back Above 50% Level During '87. V. 96, No. 90, May 9, 1988, p. 9.

[5]Balazik, R. F. and B. W. Klein. The Impact of Advanced Materials on Conventional Nonfuel Mineral Markets: Selected Forecasts For 1990-2000. BuMines IC 9150, 1987, 18 pp.

[6]Jones, S. L. Aluminum-Lithium Use Hurdle Bridged By Boeing Process. Am. Met. Mark., v. 95, No. 178, Sept. 14, 1987, pp. 12, 14.

[7]Traut, D. E., G. J. Slavens, and D. A. Hansen. Coreduction of $TiCl_4$, $AlCl_3$, and VCl_4 To Produce Titanium Alloy Sponge. BuMines RI 9133, 1987, 17 pp.

[8]Froes, F. H. Metals and Metals Processing. J. Met., v. 39, No. 11, Nov. 1987, pp. 28-29.

[9]Furukawa, T. Showa Denko and Taiyo Develop Plastic-Aluminum Composite Can. Am. Met. Mark., v. 95, No. 202, Oct. 16, 1987, p. 5.

[10]Wartzman, R. Aluminum Maker's Big Coup: The Resealable Beverage Can. Wall St. J., v. 210, No. 87, Oct. 30, 1987, p. 25.

[11]Deutschman, J. E., J. S. Lobos, D. O. Johnson, and A. S. Reid. A Process To Produce From Potlining An Inert Residue Suitable For Landfill Sites. Paper in Light Metals 1987, ed. by R. D. Zabreznik. Metall. Soc. AIME, Warrendale, PA, pp. 669-675.

Antimony

By Thomas O. Llewellyn[1]

The production of primary antimony products increased compared with that of 1986 as a result of increasing demand. Exports and imports of antimony materials were also up from those of the previous year. In November, the General Services Administration (GSA) completed the sale of antimony metal from the National Defense Stockpile (NDS) that was in excess of the goal. As the result of continued research, a new technique was developed to produce antimony trichloride and antimony trioxide using sulfide ores containing a high percentage of impurities.

Domestic Data Coverage.—Domestic production data for antimony are developed by the Bureau of Mines from two voluntary surveys of U.S. operations. Typical of these surveys is the "Primary Antimony" survey. Of the nine operations to which a survey request was sent, all responded, representing 100% of the primary smelter production shown in table 1 and 100% of the total antimony content of primary antimony production by class shown in table 3.

Table 1.—Salient antimony statistics

(Short tons of antimony content unless otherwise specified)

	1983	1984	1985	1986	1987
United States:					
Production:					
Primary:					
Mine (recoverable antimony)	838	557	W	W	--
Smelter	14,557	17,639	16,449	17,978	20,704
Secondary	14,204	14,823	15,030	r15,522	16,647
Exports of metal, alloys, waste and scrap	304	511	362	595	876
Exports of antimony oxide	365	480	885	580	777
Imports for consumption	12,885	23,089	20,694	25,401	26,729
Reported industrial consumption, primary antimony	10,418	12,465	11,697	r10,952	11,086
Stocks: Primary antimony, all classes, Dec. 31	3,935	6,895	6,040	r6,131	6,835
Price: Average, cents per pound[1]	91.3	151.2	131.1	121.9	110.6
World: Mine production	55,881	60,309	62,367	p64,146	e61,875

eEstimated. pPreliminary. rRevised. W Withheld to avoid disclosing company proprietary data.
[1]New York dealer price for 99.5% to 99.6% metal, c.i.f. U.S. ports.

Legislation and Government Programs.—On January 7, 1987, pursuant to section 303(a)(2) of the Comprehensive Anti-Apartheid Act of 1986, as amended (Public Law 99-440), antimony was certified by the U.S. Department of State as a strategic mineral essential for the economy or defense of the United States that was unavailable in adequate quantities from reliable and secure suppliers.[2]

The Department of Defense Authorization Act, 1987 (Public Law 99-661), signed by the President on November 14, 1986, authorized the disposal of 1,500 short tons of antimony metal from the NDS. As a result of this authorization, the GSA continued the offering of excess antimony metal from the NDS as tender for its program to upgrade stockpile ferroalloys. The total sale of excess antimony metal under this program during calendar year 1987 was 1,381 tons. In November, GSA completed its latest sale of excess antimony metal from the NDS. Further sales of antimony from the stockpile will require new legislative authority.

GSA reported that Government stock of antimony metal in the NDS totaled 35,998 tons of stockpile-grade material at yearend. The national stockpile goal of 36,000 tons remained unchanged through 1987.

DOMESTIC PRODUCTION

Primary.—In 1987, antimony oxide production reached its highest level in over 30 years, owing to an increased demand for flame-retardant applications.

In December, Anzon America Inc., a U.S. subsidiary of the London-based Cookson Group, signed an agreement to purchase McGean-Rohco Inc.'s antimony oxide plant in Cleveland, OH, and McGean's interest in an antimony smelter in the Republic of South Africa.

The producers of primary antimony metal and oxide products were ASARCO Incorporated, Omaha, NE; Amspec Chemical Corp., Gloucester City, NJ; Anzon America, Laredo, TX; Chemet Co., Moscow, TN; Laurel Industries Inc., La Porte, TX; McGean Chemical Co. Inc., Cleveland, OH; M&T Chemicals Inc., Baltimore, MD; Sunshine Mining Co., Kellogg, ID; and U.S. Antimony Corp., Thompson Falls, MT.

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

(Short tons of recoverable antimony)

Year	Produced	Shipped
1983	838	878
1984	557	711
1985	W	W
1986	W	W
1987	--	--

W Withheld to avoid disclosing company proprietary data.

Table 3.—Primary antimony produced in the United States

(Short tons of antimony content)

Year	Class of material produced or generated: Metal	Oxide	Residues	Byproduct antimonial lead	Total
1983	1,121	13,153	283	W	14,557
1984	1,113	16,379	147	W	17,639
1985	943	15,398	108	W	16,449
1986	378	17,525	75	W	17,978
1987	W	20,677	27	W	20,704

W Withheld to avoid disclosing company proprietary data; not included in "Total."

Secondary.—Production of antimony from purchased scrap increased compared with that of 1986. Old scrap, predominantly lead battery plates containing antimony, was the source of most of the secondary material. New scrap, mostly drosses and residues from various sources, supplied the remainder. The antimony content of scrap was chiefly recovered and consumed as antimonial lead with removal or addition of antimony metal as required in the refining procedure to meet specifications for antimonial lead alloys.

Table 4.—Secondary antimony produced in the United States, by kind of scrap and form of recovery

(Short tons of antimony content unless otherwise specified)

	1986[r]	1987
KIND OF SCRAP		
New scrap: Lead- and tin-base	1,366	1,435
Old scrap: Lead- and tin-base	14,156	15,212
Total	15,522	16,647
FORM OF RECOVERY		
In antimonial lead	14,776	15,943
In other lead- and tin-base alloys	746	704
Total	15,522	16,647
Value (millions)	$41	$44

[r]Revised.

CONSUMPTION AND USES

Antimony compounds were used in plastics both as stabilizers and as flame retardants. Antimony trioxide in an organic solvent was used to make textiles, plastics, and other combustible flame retardants. Antimony was used as a decolorizing and refining agent in some forms of glass, such as special optical glass. The largest end use for antimony compounds was in flame retardants.

Lead-antimony alloys were used in starting-lighting-ignition (SLI) batteries, ammunition, corrosion resistant pumps and pipes, tank linings, roofing sheets, solder, cable sheaths, and antifriction bearings. In 1987, the Battery Council International reported that the total domestic shipments of replacement and original equipment of SLI batteries for automotives remained at the same level as that of 1986.

Table 5.—Reported industrial consumption of primary antimony in the United States

(Short tons of antimony content)

Year	Class of material consumed: Metal	Oxide	Sulfide	Residues	Byproduct antimonial lead	Total
1983	1,245	8,867	23	283	W	10,418
1984	1,543	10,747	28	147	W	12,465
1985	1,503	10,053	33	108	W	11,697
1986	r2,437	8,410	30	75	W	r10,952
1987	2,194	8,799	66	27	W	11,086

rRevised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

Table 6.—Reported industrial consumption of primary antimony in the United States, by product

(Short tons of antimony content)

Product	1983	1984	1985	1986r	1987
Metal products:					
Ammunition	175	W	410	W	W
Antimonial lead	926	845	568	607	732
Bearing metal and bearings	143	182	177	153	206
Cable covering	31	W	W	68	W
Castings	9	11	11	12	9
Collapsible tubes and foil	W	W	W	W	W
Sheet and pipe	43	80	W	40	84
Solder	154	232	336	278	383
Type metal	10	31	31	9	9
Other	71	337	105	418	827
Total	1,562	1,718	1,638	1,585	2,250
Nonmetal products:					
Ammunition primers	16	21	27	23	58
Ceramics and glass	1,252	1,292	1,187	1,027	1,237
Fireworks	4	7	4	4	3
Pigments	198	178	147	250	307
Plastics	993	1,108	998	975	827
Rubber products	70	21	25	41	W
Other	119	161	141	162	220
Total	2,652	2,788	2,529	2,482	2,652
Flame-retardant:					
Adhesives	184	343	310	170	347
Paper	133	159	111	1	W
Pigments	14	8	8	14	33
Plastics	4,441	5,858	5,529	4,979	4,490
Rubber	220	342	315	439	426
Textiles	1,212	1,249	1,257	1,282	882
Other	--	--	--	--	6
Total	6,204	7,959	7,530	6,885	6,184
Grand total	10,418	12,465	11,697	10,952	11,086

rRevised. W Withheld to avoid disclosing company proprietary data; included with "Other."

Table 7.—Industry stocks of primary antimony in the United States, December 31

(Short tons of antimony content)

Stocks	1983	1984	1985	1986	1987
Antimonial lead[1]	W	W	W	W	W
Metal	805	582	807	r957	954
Ore and concentrate	446	1,304	1,164	1,030	1,265
Oxide	2,614	4,926	3,954	4,019	4,499
Residues and slags	51	69	99	106	92
Sulfide	19	14	16	19	25
Total	3,935	6,895	6,040	r6,131	6,835

rRevised. W Withheld to avoid disclosing company proprietary data; not included in "Total."
[1]Inventories from primary sources at primary lead refineries only.

PRICES

The New York dealer price range for antimony metal, published by Metals Week, began 1987 at $1.05 to $1.10 per pound. The price range showed minor fluctuations throughout the year, and by yearend was $1.12 to $1.16 per pound.

Asarco's published price for high-tint antimony trioxide in lots of 40,000 pounds was $1.25 per pound at the beginning of the year. This price was increased to $1.30 at the end of April, held steady until November 5, when it was raised to $1.35 per pound, and remained constant for the rest of 1987.

European price quotations for antimony ore and concentrates, published by the Metal Bulletin (London), held steady during the first 4 months of the year, and followed an upward trend for the rest of 1987. At yearend, the published price range quotations were as follows: clean sulfide concentrates, 60% antimony content, $21.50 to $23.00 per metric ton unit (equivalent to $19.50 to $20.85 per short ton unit); and lump sulfide ore, 60% antimony content, $23.00 to $25.00 per metric ton unit (equivalent to $21.30 to $22.70 per short ton unit).

Table 8.—Antimony price ranges in 1987, by type

Type	Price per pound
Domestic metal[1]	$2.00
Foreign metal[2]	$1.05- 1.16
Antimony trioxide[3]	1.25- 1.35

[1]Based on antimony in alloy.
[2]Duty-paid delivery, New York.
[3]Producer price, published by ASARCO Incorporated, for high-tint antimony trioxide.

FOREIGN TRADE

The United States also exported 1,479 tons (gross weight) of other antimony compounds with a value of 4.6 million. The Federal Republic of Germany, the Republic of Korea, Mexico, and the United Kingdom were the recipients of approximately 70% of these exports, and the remainder was distributed among 24 other countries.

China, Hong Kong, Mexico, and the Republic of South Africa, supplied over 72% of the materials imported into the United States during 1987. China was the principal supplying country of antimony to the United States for the last 4 years and was expected to continue in that position because it has displaced the other two principal antimony suppliers, Bolivia and the Republic of South Africa.

Table 9.—U.S. exports of antimony metal, alloys, waste and scrap, by country

Country	1986		1987	
	Gross weight (short tons)	Value (thousands)	Gross weight (short tons)	Value (thousands)
Belgium-Luxembourg	--	--	45	$390
Canada	28	$83	199	863
Dominican Republic	--	--	16	39
Germany, Federal Republic of	26	41	46	117
Italy	1	30	1	6
Japan	130	278	43	68

Table 9.—U.S. exports of antimony metal, alloys, waste and scrap, by country —Continued

Country	1986 Gross weight (short tons)	1986 Value (thousands)	1987 Gross weight (short tons)	1987 Value (thousands)
Korea, Republic of	10	$15	4	$6
Mexico	29	49	61	109
Netherlands	14	24	52	390
Saudi Arabia	191	147	--	--
Spain	44	103	110	90
Taiwan	1	3	(1)	9
Trinidad	13	49	--	--
United Kingdom	31	84	81	154
Venezuela	30	68	124	224
Other	46	237	94	352
Total[2]	595	1,210	876	2,817

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

Source: Bureau of the Census.

Table 10.—U.S. exports of antimony oxide, by country

Country	1986 Gross weight (short tons)	1986 Antimony content[1] (short tons)	1986 Value (thousands)	1987 Gross weight (short tons)	1987 Antimony content[1] (short tons)	1987 Value (thousands)
Australia	2	2	$9	--	--	--
Belgium-Luxembourg	14	12	53	22	18	$76
Brazil	--	--	--	16	13	62
Canada	319	265	916	395	328	1,141
Costa Rica	--	--	--	23	19	34
Germany, Federal Republic of	48	40	146	52	43	165
India	13	11	56	15	12	50
Israel	--	--	--	11	9	21
Italy	111	92	423	99	82	360
Japan	10	8	25	53	44	167
Korea, Republic of	43	36	95	31	26	90
Mexico	42	35	117	48	40	82
Singapore	12	10	41	28	23	79
Taiwan	18	15	65	23	19	63
Turkey	23	19	74	55	46	169
United Kingdom	10	8	29	35	29	83
Uruguay	12	10	38	--	--	--
Venezuela	3	2	15	8	7	39
Other	17	15	79	22	19	71
Total[2]	699	580	2,182	936	777	2,752

[1]Estimated by the Bureau of Mines.
[2]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

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

Class and country	1986 Gross weight (short tons)	1986 Antimony content[1] (short tons)	1986 Value (thousands)	1987 Gross weight (short tons)	1987 Antimony content[1] (short tons)	1987 Value (thousands)
Antimony ore and concentrate:						
Bangladesh	--	--	--	66	43	$61
Bolivia	741	470	$661	1,329	825	1,182
Canada	1	(2)	1	--	--	--
Chile	65	39	40	66	43	60
China	1,450	886	1,088	2,167	1,269	1,558
Guatemala	1,094	616	726	2,436	1,379	718
Guyana	54	33	32	--	--	--
Honduras	66	26	19	100	45	34
Hong Kong	850	387	484	513	302	362
Korea, Republic of	19	11	40	--	--	--

See footnotes at end of table.

Table 11.—U.S. imports for consumption of antimony, by class and country —Continued

Class and country	1986 Gross weight (short tons)	1986 Antimony content[1] (short tons)	1986 Value (thousands)	1987 Gross weight (short tons)	1987 Antimony content[1] (short tons)	1987 Value (thousands)
Antimony ore and concentrate —Continued						
Mexico	5,541	2,913	$2,255	3,772	1,308	$1,312
Peru	70	40	56	120	69	75
South Africa, Republic of	19	16	7	--	--	--
Thailand	779	366	386	745	307	343
Trindad	--	--	--	22	12	12
United Kingdom	83	53	96	53	32	15
Total[3]	10,833	5,855	5,892	11,389	5,634	5,732
Antimony oxide:						
Belgium-Luxembourg	472	392	1,243	807	670	1,853
Bolivia	833	691	1,315	546	453	918
Chile	221	183	333	--	--	--
China	3,410	2,830	7,818	3,404	2,825	6,653
France	881	731	2,463	883	733	2,206
Germany, Federal Republic of	101	84	703	96	80	731
Guatemala	--	--	--	75	62	70
Hong Kong	1,155	959	2,566	1,103	915	2,321
Japan	1	1	14	3	2	37
Mexico	27	22	28	460	382	408
Netherlands	38	32	92	--	--	--
South Africa, Republic of	5,889	4,888	3,884	4,332	3,596	2,986
Spain	56	46	138	--	--	--
Taiwan	195	162	365	187	155	372
United Kingdom	241	200	567	159	132	411
Yugoslavia	--	--	--	1,590	1,320	1,058
Total[3]	13,521	11,221	21,529	13,645	11,325	20,024
Antimony sulfide:[4]						
Austria	4	3	15	7	5	24
Belgium-Luxembourg	--	--	--	9	6	18
China	538	360	565	86	58	70
Hong Kong	20	13	8	--	--	--
Mexico	13	9	9	--	--	--
Total[3]	576	385	596	102	69	112

[1]Antimony ore and concentrate content reported by Bureau of the Census. Antimony oxide and antimony sulfide content estimated by the Bureau of Mines.
[2]Less than 1/2 unit.
[3]Data may not add to totals shown because of independent rounding.
[4]Includes needle or liquated.

Source: Bureau of the Census.

Table 12.—U.S. imports for consumption of antimony metal, by country

Country	1986 Gross weight (short tons)	1986 Value (thousands)	1987 Gross weight (short tons)	1987 Value (thousands)
Belgium-Luxembourg	--	--	5	$4
Bolivia	127	$229	43	83
Canada	(1)	109	1	171
Chile	65	117	106	202
China	4,634	9,828	6,883	13,416
Germany, Federal Republic of	20	107	3	88
Hong Kong	1,232	2,810	1,184	2,268
Indonesia	--	--	66	409
Japan	(1)	1	--	--
Korea, Republic of	154	403	168	356
Mexico	1,359	896	990	669
Netherlands	20	51	(1)	9
Peru	11	24	--	--
Taiwan	--	--	19	30
Thailand	58	117	--	--
U.S.S.R	236	502	189	383
United Kingdom	22	47	44	83
Total[2]	7,940	15,242	9,701	18,171

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

Source: Bureau of the Census.

WORLD REVIEW

Argentina.—An antimony deposit with possible reserves of about 0.5 million tons of ore was discovered in the Province of La Rioja. The provincial authorities were in the process of financing the exploration and development of the deposit, which could meet future domestic demand of antimony metal.

Mexico.—Anzon America and Cía. Minera y Refinadora Mexicana S.A. completed the installation and construction of a new concentration plant for low-grade ore at their mine in Wadley. The company expected to have the plant operating by early 1988, which would increase capacity by 1,100 tons per year.

South Africa, Republic of.—Consolidated Murchison Ltd., the Republic of South Africa's only antimony producer, raised funds to finance projects to explore areas where both gold and antimony mineralization had been known to exist and to deepen the Monarch East shaft to gain access to additional antimony reserves. Shaft sinking at the Monarch East area was completed, and the antimony ore mined contained a higher gold content.

United Kingdom.—Sassoon Metals and Chemicals AG formed a joint venture with China's Guangdong Metals and Minerals to market mineral commodities. The new trading company, China Industrial Resources (CIR), would buy and sell antimony, bismuth, copper, zinc, and other minerals worldwide. It was reported that CIR would be staffed by Chinese and Europeans with headquarters in London.[3]

U.S.S.R.—The Anzob antimony-mercury mining and beneficiation operation, in the Soviet Central Asian Republic of Tadzhikistan, was planning to increase production. The 5-year plan (1986-90) called for a plant-capacity expansion, which when completed would result in an antimony production increase of about 11% and a mercury production increase of 15%.

Table 13.—Antimony: World mine production (content of ore unless otherwise specified), by country[1]

(Short tons)

Country	1983	1984	1985	1986[p]	1987[e]
Australia[2]	593	1,267	2,317	991	1,100
Austria	726	577	526	566	580
Bolivia	10,969	10,231	9,838	11,291	9,000
Canada[3]	--	610	1,185	4,194	3,900
China[e]	16,500	16,500	16,500	16,500	16,500
Czechoslovakia	990	1,100	[e]1,100	[e]1,000	1,100
France	122	--	--	--	--
Guatemala	--	[e]100	1,165	2,092	2,100
Honduras[e]	--	120	100	110	110
Italy	--	269	546	336	330
Malaysia (Sarawak)	148	19	13	([4])	--
Mexico[5]	2,777	3,377	4,702	3,678	3,300
Morocco (content of concentrates)	500	1,071	[e]830	680	720
Pakistan	--	1	4	--	11
Peru (recoverable)	786	741	655	[e]740	720
South Africa, Republic of (content of concentrates)	6,947	8,201	8,150	7,513	7,500
Spain	539	643	273	[e]220	220
Thailand	1,315	2,172	1,367	1,123	1,400
Turkey	926	1,121	1,082	1,039	[6]1,104
U.S.S.R.[e]	10,000	10,300	10,400	10,500	10,600
United States[7]	838	557	W	W	--
Yugoslavia[e]	1,047	1,050	1,400	[r]1,380	1,390
Zimbabwe (content of concentrates)	158	282	214	193	190
Total	55,881	60,309	62,367	64,146	61,875

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Table includes data available through May 27, 1988.
[2]Antimony content of antimony ore and concentrates, lead concentrates, and lead-zinc concentrates.
[3]Partly estimated on the basis of reported value of total production.
[4]Revised to zero.
[5]Antimony content of ores for export plus antimony content of antimonial lead and other smelter products produced.
[6]Reported figure.
[7]Production from antimony mines; excludes amount produced as a byproduct of domestic lead ores.

TECHNOLOGY

Preussag AG, Erdol und Chemie, Federal Republic of Germany, announced the development of a new process for producing antimony trichloride and antimony trioxide from sulfide ores that previously were not treated because of their high percentage of impurities. In the new technique, the finely ground ore was reacted with gaseous hydrogen chloride in a salt melt to remove the sulfur in the form of hydrogen sulfide. Antimony trichloride was recovered from the reaction mixture by distillation. The antimony trichloride was hydrolyzed to produce antimony trioxide. Preussag claimed to have successfully tested the new technique on a pilot plant scale, and that its main advantages were cost effectiveness, limited environmental impact, and a high-purity final product.[4]

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[1]Physical scientist, Branch of Nonferrous Metals.

[2]Federal Register. Strategic Minerals Listing. V. 52, No. 28, Feb. 11, 1987, p. 4454.

[3]Metals Week. Chinese, Sassoon Set Up Trading Unit. V. 58, No. 52, Dec. 28, 1987, p. 6.

[4]Engineering and Mining Journal. Preussag Process Produces Antimony Trioxide From Multi-Metal Sulphides. V. 188, No. 2, Feb. 1987, p. 55.

Asbestos

By Robert L. Virta[1]

U.S. apparent consumption of asbestos declined in 1987. Shipments from domestic mines decreased slightly, and imports for consumption decreased 13% from those of 1986. Adverse publicity on asbestos-related health risks and a proposed Environmental Protection Agency (EPA) ban of certain asbestos products contributed to the poor market conditions in the United States.

Domestic Data Coverage.—Domestic production data for asbestos are developed by the Bureau of Mines by means of a voluntary industry survey. Of the three canvassed operations to which a survey request was sent, all responded, representing 100% of the total production data shown in table 1.

Table 1.—Salient asbestos statistics

	1983	1984	1985	1986	1987
United States:					
Production (sales):					
Quantity metric tons	69,906	57,422	57,457	51,437	50,600
Value[1] thousands	$27,866	$24,238	$20,485	$17,367	$17,198
Exports and reexports (unmanufactured):					
Quantity metric tons	54,634	39,919	45,656	47,281	60,084
Value thousands	$19,683	$18,346	$16,489	$14,520	$16,149
Exports and reexports of asbestos products:					
Value do	$129,582	$163,347	$193,765	$163,896	$180,602
Imports for consumption (unmanufactured):					
Quantity metric tons	196,387	209,963	142,431	108,352	93,763
Value thousands	$57,956	$64,749	$44,093	$26,537	$22,022
Consumption, apparent[2] metric tons	217,000	226,000	162,000	119,627	84,279
World: Production do	[r]4,428,867	[r]4,309,179	4,272,327	[p]4,050,261	[e]4,054,088

[e]Estimated. [p]Preliminary. [r]Revised.
[1]F.o.b. mine.
[2]Production, plus imports, minus exports, plus adjustments in Government and industry stocks.

Legislation and Government Programs.—The EPA continued a regulatory impact analysis of its proposed ban and/or phaseout of asbestos and asbestos-containing products. The proposed ruling would immediately ban the manufacture, importation, and processing of certain asbestos construction materials. In addition, the mining of asbestos and the importation of asbestos and asbestos products not immediately banned would be placed under a permit system and would be phased out within 10 years.

On February 25, 1987, the EPA modified its 1986 regulation covering State and local government employees on asbestos abatement projects. The permissible exposure limit was reduced from 2 fibers per cubic centimeter to 0.2 fiber per cubic centimeter, and new requirements for engineering and work practice controls and worker training were instituted.[2]

On October 30, 1987, the EPA issued a final ruling that requires local educational districts to identify asbestos-containing materials in public and private school buildings, and to submit a management plan that describes the appropriate action to take regarding the materials to the State Governor by October 12, 1988. The ruling requires the local education districts to begin implementing the management plan by July 9, 1989.[3]

The National Bureau of Standards established an accreditation program, effective October 1, 1988, for laboratories that determine the asbestos content of insulation and building materials using polarized light microscopy and that determine airborne asbestos concentrations following asbestos abatement programs using transmission electron microscopy.[4] An interim EPA quality assurance program, established September 3, 1987, for the analysis of asbestos-containing materials using polarized light microscopy remains in effect until October 1, 1988.[5]

The Occupational Safety and Health Administration (OSHA) extended through July 21, 1988, an administrative stay on its 1986 regulation governing worker exposure to the nonasbestiform varieties of tremolite, actinolite, and anthophyllite. During the stay, OSHA continued to analyze the impact of using the asbestos standard to regulate the nonasbestiform varieties of the minerals.[6]

Stockpile goals for asbestos were unchanged from those of 1986.

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

(Metric tons)

	Stockpile goals	Total inventories 1985	1986	1987
Amosite	15,422	30,855	30,853	30,849
Chrysotile	2,722	9,772	9,711	9,709
Crocidolite	--	33	33	33
Total	18,144	40,660	40,597	40,591

Source: General Services Administration, Federal Property Service.

DOMESTIC PRODUCTION

The producers of asbestos were Calaveras Asbestos Ltd., Calaveras County, CA; KCAC Inc., San Benito County, CA; and Vermont Asbestos Group Inc., Orleans County, VT. Calaveras Asbestos permanently closed its mine in Copperopolis, CA, on December 31, 1987. The company, which was the largest of the three domestic asbestos producers, cited depleted ore reserves and decreased market demand as the reason for closing. Plans were made to open the mine in 1988 as a disposal site for asbestos-containing materials under a new company name, Cal-Safe.[7]

CONSUMPTION AND USES

Total U.S. asbestos consumption decreased 30%. Approximately 94% of the asbestos consumed was chrysotile, 1% was crocidolite, and 5% was an unspecified fiber type. Chrysotile grade 7 was most commonly used, followed by grades 4, 6, and 5. Spinning grades 1, 2, and 3 represented approximately 1% of the total consumption.

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

(Thousand metric tons)

End use	Chrysotile[1] Grades 1 and 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Total	Amosite	Crocidolite	Other[2]	Total asbestos[3]
1986 total	--	1.1	14.2	9.3	10.3	78.6	113.7	--	2.0	3.9	115.7
1987:											
Asbestos-cement pipe	--	--	6.8	1.1	2.3	--	10.2	--	1.1	--	11.3
Asbestos-cement sheet	--	--	--	--	2.2	1.7	3.9	--	--	--	3.9
Coatings and compounds	--	--	(4)	--	(4)	2.6	2.7	--	--	--	2.7
Friction products	--	(4)	.2	2.7	2.8	15.6	21.3	--	--	--	21.3
Insulation: Electrical	--	--	(4)	.1	(4)	--	.1	--	--	--	.1
Packing and gaskets	--	.1	.5	2.5	.1	6.9	10.2	--	--	--	10.2
Paper	--	--	--	--	--	4.8	4.8	--	--	--	4.8

See footnotes at end of table.

Table 3.—U.S. asbestos consumption, by end use, grade, and type —Continued

(Thousand metric tons)

End use	Chrysotile[1]							Amosite	Crocidolite	Other[2]	Total asbestos[3]
	Grades 1 and 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Total				
1987 —Continued											
Plastics	--	--	--	--	--	1.3	1.3	--	--	--	1.3
Roofing products	--	--	(4)	(4)	(4)	22.6	22.6	--	--	--	22.6
Textiles	--	0.5	--	--	--	--	.5	--	--	--	.5
Other	--	.3	0.2	0.1	--	1.2	1.8	--	--	--	1.8
Total[5]	--	1.0	7.8	6.5	7.3	56.8	79.3	--	1.1	3.8	80.4

[1]Estimated distribution based upon data provided by the Asbestos Institute, Montreal, Canada, and the Bureau of Mines asbestos producer survey.
[2]Bureau of the Census.
[3]Does not include "Other" category in total. "Other" contains unspecified fiber type and end use.
[4]Less than 1/10 unit.
[5]Data may not add to totals shown because of independent rounding.

PRICES

The average unit value of domestically produced asbestos in 1987 was $340 per metric ton. The average unit value of exported asbestos was $269 per ton.

Table 4.—Customs unit values of imported asbestos

(Dollars per metric ton)

	1983	1984	1985	1986	1987
Canada:					
Chrysotile:					
Cement	257	284	--	--	--
Crude	199	1,084	576	547	610
Spinning	932	699	731	507	598
Other	384	431	283	229	218
South Africa, Republic of:					
Amosite	840	869	830	--	--
Crocidolite	629	705	569	582	572

Source: Bureau of the Census.

FOREIGN TRADE

There was a 10% increase in the total value of asbestos fibers and asbestos products exported from the United States. The asbestos fiber portion was 8% of total value. Exports and reexports of brake linings and disc pads accounted for 74% of the value of all asbestos products exported. Canada remained the largest importer of U.S. asbestos fibers and products, followed by Mexico, Japan, Brazil, and Thailand.

Canada provided 96% of the asbestos imported into the United States, and the Republic of South Africa provided 3%. Several other countries provided minor amounts. Approximately 95% of asbestos fiber imports were chrysotile.

Table 5.—Countries importing U.S. asbestos fibers and products

(Thousand dollars)

Country	1986			1987		
	Unmanufactured fibers	Manufactured products	Total[1]	Unmanufactured fibers	Manufactured products	Total[1]
Australia	17	1,341	1,358	24	1,513	1,537
Brazil	467	2,555	3,022	401	4,642	5,043
Canada	605	123,819	124,424	673	136,828	137,501
Germany, Federal Republic of	300	2,746	3,047	673	1,975	2,648
Japan	2,981	7,867	10,848	3,604	5,931	9,535
Korea, Republic of	624	825	1,449	1,579	991	2,569
Kuwait	--	221	221	--	132	132
Mexico	2,667	5,593	8,260	2,893	6,720	9,613
Saudi Arabia	--	1,062	1,062	--	1,329	1,329
Thailand	2,490	354	2,844	3,028	397	3,425
Turkey	--	361	361	--	279	279
United Kingdom	166	1,313	1,479	359	1,949	2,307
Venezuela	218	2,688	2,906	257	2,314	2,571
Other	3,864	12,108	15,972	2,659	15,602	18,261
Total[1]	14,401	162,851	177,252	16,149	180,602	196,751

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

Source: Bureau of the Census.

Table 6.—U.S. exports and reexports of asbestos and asbestos products

Products	1985		1986		1987	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
EXPORTS						
Unmanufactured:						
Crudes, fibers, stucco ---- metric tons	29,382	$12,705	30,252	$9,728	39,720	$11,151
Sand and refuse ---- do	15,693	3,661	16,645	4,673	19,416	4,666
Total[1] ---- do	45,075	16,366	46,897	14,401	59,136	15,818
Manufactured:						
Asbestos fibers ---- do	607	3,793	723	3,902	1,078	4,761
Brake linings and disk brake pads ---- do	NA	144,262	NA	123,515	NA	133,733
Clutch facings and linings ---- number	NA	20,718	NA	16,187	NA	19,982
Gaskets ---- metric tons	78	900	266	1,285	471	1,857
Insulation ---- do	NA	4,566	NA	1,889	NA	3,700
Packing and seals ---- do	1,192	6,716	820	6,373	659	5,710
Shingles and clapboard ---- do	984	893	880	805	1,225	605
Other articles of asbestos ---- do	1,521	2,437	1,614	1,553	1,632	2,132
Other articles, n.s.p.f ---- do	NA	9,191	NA	7,342	NA	6,473
Total	XX	193,476	XX	162,851	XX	178,953
REEXPORTS						
Unmanufactured:						
Crudes and fibers ---- metric tons	369	71	329	98	904	316
Sand and refuse ---- do	212	52	54	20	44	15
Total[1] ---- do	581	123	384	119	948	331
Manufactured:						
Asbestos fibers ---- do	(2)	3	--	--	27	65
Brake linings and disk brake pads ---- do	NA	103	NA	222	NA	333
Clutch facings and linings ---- number	NA	73	NA	604	NA	845
Gaskets ---- metric tons	1	18	6	65	--	--
Insulation ---- do	NA	2	NA	23	--	--
Packing and seals ---- do	4	63	(2)	50	(2)	3
Other articles of asbestos ---- do	NA	20	NA	3	3	143
Other articles, n.s.p.f ---- do	NA	1	NA	78	NA	260
Total	XX	283	XX	1,045	XX	1,649

NA Not available. XX Not applicable.
[1]Data may not add to totals shown because of independent rounding.
[2]Less than 1/2 unit.

Source: Bureau of the Census.

Table 7.—U.S. imports for consumption of asbestos fibers, by type, origin, and value

Type	Canada		South Africa, Republic of		Other		Total[1]	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1985	131,119	$38,547	10,985	$5,224	327	$322	142,431	$44,093
1986:								
Chrysotile:								
Crude	20	12	192	104	--	--	212	116
Spinning fibers	598	304	--	--	--	--	598	304
All other	101,273	23,065	227	139	107	94	101,607	23,291
Crocidolite (blue)	--	--	1,968	1,154	20	4	1,988	1,158
Other (unspecified asbestos type)	1,626	434	2,068	1,109	253	119	3,947	1,662
Total[1]	103,517	23,814	4,455	2,506	380	217	108,352	26,537
1987:								
Chrysotile:								
Crude	19	12	10	11	15	17	44	40
Spinning fibers	589	352	--	--	15	45	604	397
All other	88,107	19,207	44	57	22	5	88,173	19,269
Crocidolite (blue)	--	--	1,113	637	--	--	1,113	637
Other (unspecified asbestos type)	1,509	526	2,079	1,083	241	70	3,829	1,679
Total[1]	90,224	20,096	3,246	1,788	293	137	93,763	22,022

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

Source: Bureau of the Census.

Imports of asbestos-containing pipes, tubes, and fittings increased from 960 tons in 1986 to 2,150 tons in 1987 according to the Bureau of the Census. Imports of spinnable asbestos fiber decreased from 750 tons in 1986 to 520 tons in 1987, and imports of other asbestos-containing products decreased from 7,530 tons in 1986 to 4,580 tons in 1987.

WORLD REVIEW

Canada.—The labor ministers for the Quebec Provincial and Federal Governments agreed to endorse the International Labor Organization convention on the controlled use of asbestos if approval is obtained from the respective Cabinets.[8]

The Canadian and Quebec Governments initiated an $8.8 million research and development program to investigate ways of improving asbestos mining techniques and reducing production costs. The Federal and Provincial Governments will provide $3.2 million each, the asbestos industry will provide $1.6 million, and the Asbestos Institute will provide $800,000 for the program.[9]

Hydrogen Energy Corp. and its subsidiary, Ulhycarb Chemicals of Canada Inc., initiated a technical and economic study of a process to produce hydrogen gas and byproducts from asbestos mine tailings. The study was supported by the Quebec government and the Hydrogen Industry Council and will focus on utilizing asbestos mine tailings from Thetford, Quebec.[10]

South Africa, Republic of.—The South African Department of Manpower issued regulations reducing worker exposure to asbestos. The new regulation limited occupational exposure to asbestos to 1 fiber per milliliter. When concentrations exceed this limit, workers are required to wear protective devices. In addition, the spray application of asbestos-containing materials was prohibited, and guidelines for labeling asbestos-containing materials, for disposal of asbestos-containing materials, and for demolition of buildings containing asbestos were established.[11]

U.S.S.R.—Production of asbestos-cement was predicted to increase 15% and 17% in 1989 and 1990, respectively. The U.S.S.R. produced over 40 asbestos-cement products including corrugated sheet, flat sheet, and pressure pipe. An extrusion process was introduced for manufacturing asbestos-cement products. The U.S.S.R. continued to upgrade equipment to reduce fuel costs and increase productivity.[12]

Table 8.—Asbestos: World production, by country[1]

(Metric tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Argentina	1,240	1,093	1,244	[e]1,100	1,000
Australia	3,909	--	--	--	--
Brazil (fiber)	158,885	134,788	165,446	204,460	210,000
Bulgaria	700	500	400	[e]500	500
Canada (shipments)	858,000	837,000	750,000	662,000	660,000
China[e]	160,000	135,000	150,000	150,000	150,000
Colombia	[e]5,400	9,982	12,435	[e]13,000	13,000
Cyprus	17,288	7,429	16,360	13,011	13,000
Egypt	245	389	229	476	450
Greece	31,811	45,376	46,811	[e]48,000	48,000
India	24,873	25,450	30,183	25,236	23,000
Indonesia[e]	25,000	25,000	25,000	25,000	25,000
Italy	139,054	147,272	136,006	115,208	120,000
Japan[e]	4,000	4,000	4,000	4,000	4,000
Korea, Republic of	12,506	8,062	4,703	2,983	3,000
Mozambique	[e]600	[e]400	55	--	--
South Africa, Republic of	221,111	167,389	164,247	138,862	[3]135,074
Swaziland	26,287	25,832	25,130	20,908	21,000
Taiwan	2,819	1,355	625	--	--
Turkey	1,510	1,499	[e]1,500	[e]1,500	1,500
U.S.S.R.[e]	[r]2,500,000	[r]2,500,000	[r]2,500,000	[r]2,400,000	2,400,000
United States (sold or used by producers)	69,906	57,422	57,457	51,437	[3]50,600
Yugoslavia	10,502	8,556	6,916	8,596	[3]10,964
Zimbabwe	153,221	165,385	173,580	163,984	164,000
Total	[r]4,428,867	[r]4,309,179	4,272,327	4,050,261	4,054,088

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

[1]Table includes data available through Apr. 29, 1988.

[2]In addition to the countries listed, Afghanistan, 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.

[3]Reported figure.

TECHNOLOGY

Contact filtration of chrysotile and amphibole asbestos suspensions was studied using magnesium oxide, sand, magnesium carbonate, acidic and basic alumina, calcite, diatomaceous earth, microcrystalline cellulose, and activated carbon as the filter media. Approximately 99% of the amphibole asbestos was removed using magnesium oxide and acidic alumina. Magnesium oxide and basic alumina were most effective for removing chrysotile from suspension by contact filtration.[13]

A study on the use of asbestos-reinforced plastics in fire and high heat environments concluded that asbestos-reinforced plastics may solve many of the problems created by burning and smoldering plastics in buildings and mass transit vehicles. Several factors considered were the dependence of flame retardancy and heat resistance on the asbestos content of the plastic, the increased use of competing reinforcement and filler materials, and the rapid change in plastic compositions as technological developments were made.[14]

In studies of asbestos, regression analysis commonly is used to correlate the number of particles in a specific size category with the incidence of cancer. An evaluation of the regression technique suggested that the strength of the correlation between particle size and carcinogenicity may not be as strong as originally theorized.[15]

Air-monitoring samples collected in occupational and mining environments were examined using the phase contrast microscope (PCM) and the scanning transmission electron microscope. The study concluded that by applying a multiplication factor to routine PCM counts, the regulatory assessment of the particle content on personal air-monitoring filters would be more accurate.[16]

The Société Nationale de l'Amiante continued investigating the use of phosphorus-rich coatings to reduce the harmful effects of asbestos. For a surface modification to be effective, the coating must penetrate the fiber bundle and coat individual fibrils, the coating must be durable enough to undergo processing and remain intact through the product life, the coating could not alter the fiber grade or processing characteristics, and the cost must be low enough to ensure that modified chrysotile would be cost competitive with asbestos substitutes.[17]

A process was developed to convert asbestos-containing waste into a harmless glass. The asbestos-containing waste was fed into a modified glassmaking furnace, where it was incorporated into the molten glass at a temperature of 1,400° C. The glass was reported to be nontoxic and safe even if broken or melted. Disposal using this technique was cost competitive with landfill disposal.[18] A second method for rendering asbestos harmless was developed at the Risoe Research Center in Copenhagen, Denmark. Ammonium sulfate at 260° C was used to decompose the asbestos.[19]

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Barite

By Sarkis G. Ampian[1]

Domestic production of barite increased more than 50%, reversing the downtrend that started in 1982, and, with the exception of 1984, has persisted ever since. Production from Nevada, the leading producer, increased about 13%. Imports for consumption of crude barite increased 11%, while ground barite imports decreased nearly 50%. Imports of barite exceeded domestic production for the sixth straight year; the import figure of 825,000 short tons for 1987 was nearly 1.6 million tons below the record-high tonnage imported during 1982. Ground barite imports, except for the drilling boom years of the late 1970's and early 1980's, were negligible. The principal use for barite, as a weighting agent in oil- and gas-well-drilling fluids (muds), accounted for 90% of U.S. consumption. Chemicals, glass, and filler and/or extender uses accounted for the remaining 10%.

Demand for barite by the oil- and gas-well-drilling industry, rebounded at midyear, owing to the firming of oil prices and improvements in the overall economy. The upturn also has been in large part due to the increase in offshore drilling, which tends to have deeper wells that consume more barite than the shallower wells, and to optimism in the oil-producing States. U.S. mine production continued, although still depressed, encouraged by regional sales and declining rail rates, which increased the competitiveness of domestic ores in the gulf coast and midcontinent areas. Barite grinding capacity, despite numerous closures, mergers, and acquisitions, continued to be in a position to meet present and future requirements.

Domestic Data Coverage.—Domestic production data for barite are developed by the Bureau of Mines from one voluntary survey of U.S. operations. Of the 64 operations to which a survey request was sent, all responded, representing 100% of the total crushed and ground production sold or used shown in table 1.

Table 1.—Salient barite and barium chemical statistics

(Thousand short tons and thousand dollars)

	1983	1984	1985	1986	1987
United States:					
Barite, primary:					
Sold or used by producers	754	775	739	297	448
Value	$29,203	$25,445	$21,501	$12,326	$15,810
Exports	23	1	6	7	9
Value	$3,514	$574	$692	$1,021	$716
Imports for consumption (crude)	1,396	1,731	2,056	745	825
Consumption, apparent[1]	2,127	2,505	2,789	1,035	1,264
Crushed and ground (sold or used by processors)[2]	2,745	2,883	2,184	1,216	1,434
Value	$194,380	$220,806	$154,463	$75,965	$108,759
Barium chemicals (sold or used by processors)	22	26	24	25	28
Value	$16,860	$17,105	$16,036	$16,871	$16,466
World: Production	5,924	[r]6,404	6,649	[p]5,204	[e]5,137

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Sold or used plus imports minus exports.
[2]Includes imports.

DOMESTIC PRODUCTION

The term "primary barite" denotes the first marketable product and includes crude run-of-mine barite, flotation concentrates, and material concentrated by other beneficiated processing such as washing, jigging, or magnetic separation. Run-of-mine barite, the lowest cost primary barite sold or used by producers, represented 54% of total production compared with 36% in 1986; the other 46% was flotation concentrate and other beneficiated material. The lower cost crude barite was used chiefly in drilling muds; the higher valued floated and other beneficiated material was used mostly in chemical and glass manufacturing and in filler applications.

Reported primary production increased more than 50%. Nevada and Georgia remained the two leading barite-producing States. Other producing States, in descending order, were Missouri, California, and Montana. All domestic barite production is a primary product. Barite was formerly produced as a coproduct of fluorspar mining and milling in Illinois.

The leading domestic barite producers were M-I Drilling Fluids Co., a Dresser Halliburton Co.; FMC Corp.; Milpark Drilling Fluids, a Baker Hughes Inc. company, with mines in Nevada; and NL Baroid, a division of NL Petroleum Services Inc., with mines in Missouri and Nevada.

The domestic barite industry recovered at midyear, primarily owing to an increase in both oil- and gas-well-drilling activity and the overall economy. The rebound in oil prices, which firmed and even tended to move upwards, was largely responsible for the increase in barite demand. This upturn reversed the trend of declining barite production rates that has been prevalent since 1981, the record-high production year (2.8 million tons). Production data also revealed that a number of factors enabled modest increases in domestic mining campaigns. Those factors included an upturn in drilling activity, competitive rail rates to the gulf coast and midcontinent areas based on unit-trains, and guaranteed-tonnage contracts, coupled with optimism in the oil-producing States.

Nevertheless, the persistent oil glut and lower energy rates, exacerbated primarily by Mideast overproduction, continued to temper or limit any major upturn in oil- and gas-well-drilling activity. Another factor, other than oil prices, depressing the domestic marketplace is the overcapacity in the drilling fluids business. In addition, rising ocean freight rates, in part due to

Table 2.—U.S. primary barite sold or used by producers, by State

State	Number of operations	Run of mine		Flotation concentrates		Beneficiated material[1]		Total[2]	
		Quantity (thousand short tons)	Value (thousands)	Quantity (thousand short tons)	Value (thousands)	Quantity (thousand short tons)	Value (thousands)	Quantity (thousand short tons)	Value (thousands)
1986:									
Georgia	2	--	--	W	W	W	W	W	W
Missouri	3	--	--	W	W	W	W	W	W
Nevada	7	[3]107	[3]$1,865	--	--	82	$1,522	[3]189	[3]$3,386
Tennessee	1	[4]W	[4]W	--	--	--	--	[4]W	[4]W
Total	13	107	1,865	W	W	[5]190	[5]10,462	[5]297	[5]12,326
1987:									
California	1	W	W	--	--	--	--	W	W
Georgia	2	--	--	W	W	W	W	W	W
Missouri	3	--	--	--	--	W	W	W	W
Montana	1	W	W	--	--	--	--	W	W
Nevada	7	214	3,249	W	W	W	W	214	3,249
Tennessee	1	W	W	--	--	--	--	W	W
Total	15	[5]244	[5]7,515	[5]61	[5]$5,238	[5]142	[5]6,300	[5]448	[5]15,810

W Withheld to avoid disclosing company proprietary data.
[1]Includes some flotation concentrates (1986).
[2]Data may not add to totals shown because of independent rounding.
[3]Includes Tennessee.
[4]Included with Nevada.
[5]Includes data indicated by symbol W.

higher bunker fuel costs and limited availability of bottoms, helped make domestic ores more competitive with foreign ores. The firming domestic market, still the world's largest, has turned relatively soft markets into a mild seller's market for both producers and grinders alike. The domestic industry, however, continued to be threatened by imports of crude and ground barite, furthering the risk of a volatile marketplace. Such a scenario could further impact the slowly recovering domestic industry.

Most mining and grinding operations continued to be either suspended or on minimal production schedules to address the industry's overcapacity. Many of the additions to mining, milling, and grinding capacity were largely to reduce operations costs to remain competitive in a firming but volatile market situation. Many ongoing and planned projects, including exploration programs, for the most part have been indefinitely deferred.

Table 3.—Producers of barium materials in 1987

Company	Plant location	Material
BARITE MATERIALS		
American Minerals Inc	Camden, NJ	Well drilling and filler.
Do	El Paso, TX	Do.
Do	Rosiclare, IL	Do.
Circle A Construction Co. Inc	Wells, NV	Primary and filler.
Clark Minerals Inc	South Plainfield, NJ	Filler.
Custom Milling & Supply Co	Salt Lake City, UT	Well drilling.
Cyprus Industrial Minerals Co	Cartersville, GA	Primary and ground.
De Soto Mining Co Inc	Richwoods, MO	Primary.
Dyna Material Inc	Pecos, TX	Well drilling.
Extender Products Ltd	Mineral Point, MO	Filler.
General Barite Co	Washington, MO	Primary.
GEO International Inc	Nevada City, CA	Do.
Industrial Chemicals Div., FMC Corp	Battle Mountain, NV	Do.
Industrial Minerals Co	Florin, CA	Filler.
International Drilling Fluids	Amelia, TX	Well drilling.
M-I Drilling Fluids Co	Battle Mountain, NV	Do.
Do	Brownsville, TX	Well drilling and filler.
Do	Galveston, TX	Well drilling.
Do	Houma, LA	Do.
Do	Houston, TX	Do.
Do	Lander, NV	Primary and ground.
Do	New Orleans, LA	Well drilling.
Do	West Lake Charles, LA	Well drilling and filler.
Milpark Drilling Fluids	Argenta, NV	Primary and ground.
Do	Clinton, OK	Well drilling.
Do	Corpus Christi, TX	Do.
Do	Galveston, TX	Do.
Do	New Orleans, LA	Do.
The Milwhite Co. Inc	Brownsville, TX	Well drilling and filler.
Do	Bryant, AK	Do.
Do	Chatworth, GA	Ground.
Do	Houston, TX	Well drilling and filler.
Do	Morgan City, LA	Well drilling.
Minerals, Pigments & Metals Div., Pfizer Inc	East St. Louis, IL	Filler.
Mountain Minerals Co. Ltd	Missoula, MT	Primary and ground.
New Riverside Ochre Co	Cartersville, GA	Primary.
NL Baroid	Battle Mountain, NV	Do.
Do	Dunphy, NV	Well drilling.
Do	Fountain Farm, MO	Do.
Do	Lake Charles, LA	Do.
Do	New Orleans, LA	Do.
Do	Potosi, MO	Primary.
Old Soldiers Minerals Ltd	Abbeville, LA	Well drilling.
Do	Elk County, OK	Do.
Ozark-Mahoning Co	Rosiclare, IL	Primary.
A. J. Smith Co. Inc	Sweetwater, TN	Primary and ground.
Standard Industrial Minerals	Laws, CA	Filler.
Standard Slag Co	Churchill, NV	Primary.
Do	Nye, NV	Do.
BARIUM COMPOUNDS		
J. T. Baker Chemical Co	Phillipsburg, NJ	Chemicals.
Chemical Products Corp	Cartersville, GA	Do.
Mallinckrodt Inc., a subsidiary of IMC Corp	St. Louis, MO	Do.

Baker Hughes Inc., formed from Baker International Corp. and Hughes Tool Co., purchased the remaining interest in Hughes Drilling Fluids, held by W. R. Grace Co. These operations have been further combined with Milchem Inc., a former unit of Baker International, to form one of the largest drilling fluids companies in the world. NL Industries Inc. adopted a tentative plan to spinoff its oilfield services business, NL Petroleum, to shareholders. NL Baroid barite and clay-producing and grinding facilities will be operated as part of a separate division. In a reorganization, Cyprus Minerals Co. Inc. announced plans to merge four groups of its industrial minerals division into a single unit. Presently, Cyprus Industrial Minerals Co. has three operating companies, one of which mines and produces filler- and extender-grade barite. In a barium chemical action, International Minerals & Chemical Corp. announced that its Mallinckrodt Inc. unit was planning to divest its chemical line for barium gastrointestinal imaging products manufactured in St. Louis, MO.

The U.S. Department of Commerce and the U.S. International Trade Commission responded to a request by a petitioner, Chemical Products Corp., Cartersville, GA, for an antidumping duty administrative review of barium chemicals from China[2] and the Federal Republic of Germany.[3]

The final results of one of the Chinese antidumping reviews covered China National Chemicals Import and Export Corp. (Sinochem), a manufacturer and exporter of barium chloride to the United States, for the period October 1, 1984 through September 30, 1985. The review determined a margin of 7.82% existed for Sinochem for the above period. The Department of Commerce instructed the Customs Service to assess antidumping duties of 7.82% on all appropriate entries. For any future entries of this chemical for a new exporter not covered in this final review, whose shipments occurred after September 30, 1985, a cash deposit of 7.82% was required. The deposit requirement was effective for all shipments of Chinese barium chloride entered or withdrawn from warehouse, and for consumption on or after the date of publication of these final results. Initiation of antidumping countervailing duty administrative reviews were also planned for Sinochem barium chloride imported between October 1, 1986, and September 30, 1987.[4] A similar preliminary study on an antidumping duty administrative review of precipitated barium carbonate from the Federal Republic of Germany indicated the existence of no dumping margins for the firm Kali-Chemie AG, for the period July 1, 1985, through June 30, 1986. For any shipments from the one remaining Chinese manufacturer and/or exporter not covered by this review, the cash deposit will continue to be the rate published in the final result of the last administrative review for that firm (April 2, 1985).

CONSUMPTION AND USES

Consumption of crushed and ground barite increased nearly 18% from 1.2 million tons in 1986 to 1.4 million tons in 1987. This upturn, except for small increase in 1984, reversed the decline in total barite consumption prevalent since 1981, when the record high of 4.7 million tons of crushed and ground barite was set. This increase not only reflects an upturn in barite requirements for oil well drilling, which still accounts for more than 90% of total sales, but also in the overall economy. The oil- and gas-well-drilling industry completed more than 26,000 wells and drilled nearly 125 million feet of hole;[5] both figures were approximately 15% lower than in 1986.

Total well footage drilled exceeded 8 million feet in four States: Texas, 47.5; Oklahoma, 15.6; Louisiana, 13.4; and Kansas, 8.3. Generally, the deeper a hole is drilled, the more barite is used per foot of drilling. Among the four leading States, Louisiana had the greatest average well depth, nearly 6,800 feet, and Kansas, the shallowest, about 3,300 feet. Wyoming, absent from the top States this year in well footage drilled, again had the greatest average well depth of nearly 7,000 feet. The U.S. average increased to nearly 4,800 feet. The main reason that barite consumption increased, despite the 15% reduction in the number of wells drilled, was the upturn in operating offshore rigs in the Gulf of Mexico and in California at the expense of the shallower drilling, onshore varieties. These offshore wells, the Overthrust Belt in Wyoming, and the Anadarko Basin in Oklahoma are all deep-drilling areas. This increase was accompanied by an increase in the amount of barite used per foot of drilling to 20.7

pounds from 15.0 pounds in 1986.

Another barometer of drilling activity, the Baker Hughes rig count, showed the average number of operating domestic rigs decreased 3% to 936 rigs.[6] This slight decrease in rigs continued a downward trend that, except for 1984, has seen the number of rigs fall from the 1981 record high of 3,974. The 1987 average rig count of 936 is the second time since 1971 (976 rigs) that the count was under 1,000. The estimated rig count during the year ranged from 744 to 1,181. The low rig count of 744, recorded the week of May 16, 1987, was the second lowest since World War II. The high, 1,181 rigs, was registered the week of December 12, 1987.

Table 4.—Crushed and ground barite[1] sold or used by processors in the United States, by State

State	1986			1987		
	Number of plants	Quantity (thousand short tons)	Value (thousands)	Number of plants	Quantity (thousand short tons)	Value (thousands)
Louisiana	9	585	$38,215	8	721	$47,133
Missouri	3	18	752	2	W	W
Nevada	4	101	2,523	3	236	14,939
Oklahoma	3	38	2,140	2	W	W
Texas	11	361	19,703	8	301	22,230
Other[2]	12	111	12,632	16	179	24,457
Total[3]	42	1,216	75,965	39	1,434	108,759

W Withheld to avoid disclosing company proprietary data.
[1]Includes imports.
[2]Includes Arkansas, California, Georgia, Illinois, Missouri (1987), New Jersey, New York, Oklahoma (1987), Tennessee, and Utah.
[3]Data may not add to totals shown because of independent rounding.

Table 5.—Crushed and ground barite[1] sold or used by processors in the United States, by use

(Thousand short tons and thousand dollars)

Use	1986		1987	
	Quantity	Value	Quantity	Value
Barium chemicals, filler and/or extender, glass	119	13,707	141	22,419
Well drilling	1,097	62,258	1,294	86,340
Total	1,216	75,965	[2]1,434	108,759

[1]Includes imports.
[2]Data do not add to total shown because of independent rounding.

Table 6.—U.S. barium chemicals[1] produced and sold or used by processors

Barium chemical	1986				1987			
	Plants[2]	Production (short tons)	Sold or used by processors		Plants[2]	Production (short tons)	Sold or used by processors	
			Quantity (short tons)	Value (thousands)			Quantity (short tons)	Value (thousands)
Barium acetate	1	W	W	W	1	W	W	W
Barium carbonate	2	W	W	W	2	W	W	W
Barium chloride	2	W	W	W	2	W	W	W
Barium nitrate	1	W	W	W	1	W	W	W
Barium sulfide, gray	1	W	W	W	1	W	W	W
Black ash	1	W	W	W	1	W	W	W
Blanc fixe	1	W	W	W	1	W	W	W
Total	3	26,075	25,446	$16,871	3	28,447	28,008	$16,466

W Withheld to avoid disclosing company proprietary data.
[1]Data reported by plants that consume either barite or precusors are included.
[2]A plant producing more than 1 product is counted only once.

Table 7.—U.S. hydrocarbon well drilling and barite consumption

Year	Barite used for well drilling (thousand short tons)	Wells drilled (thousands)[1]				Successful wells (percent)	Average depth per well (feet)	Average barite per well (short tons)
		Oil	Gas	Dry holes	Total			
1967	965	15.33	3.66	13.23	32.22	58.9	4,385	29.95
1968	1,006	14.33	3.46	12.81	30.60	58.1	4,738	32.88
1969	1,235	14.37	4.08	13.74	32.19	57.3	4,881	38.37
1970	1,119	13.02	3.84	11.26	28.12	60.0	4,952	39.79
1971	1,044	11.86	3.83	10.16	25.85	60.7	4,806	40.39
1972	1,183	11.31	4.93	11.06	27.30	59.5	4,932	43.33
1973	1,326	9.90	6.39	10.31	26.60	61.2	5,129	49.85
1974	1,440	12.78	7.24	11.67	31.69	63.2	4,750	45.44
1975	1,638	16.41	7.58	13.25	37.24	64.4	4,685	43.98
1976	1,986	17.06	9.09	13.62	39.77	65.7	4,571	49.94
1977	2,372	18.91	11.38	14.69	44.98	67.3	4,687	52.73
1978	2,632	17.76	12.93	16.25	46.94	65.4	4,829	56.07
1979	2,967	19.38	14.68	15.75	49.81	68.4	4,791	59.57
1980	3,385	26.99	15.74	18.09	60.82	70.3	4,675	55.66
1981	4,526	37.67	17.89	22.97	78.53	70.8	4,602	57.63
1982	4,048	40.30	18.95	26.55	85.80	69.1	4,616	47.18
1983	2,648	37.21	15.63	23.49	76.33	69.2	4,268	34.69
1984	2,695	41.10	15.71	25.23	82.04	69.5	4,246	32.85
1985	2,042	26.24	10.15	15.97	52.36	69.5	4,658	39.00
1986	1,097	15.27	5.53	10.28	31.08	66.9	4,716	35.30
1987	1,294	12.13	4.97	9.04	26.14	65.4	4,779	49.50

[1]Includes exploratory and development wells; excludes service wells, stratigraphic tests, and core tests.

Source: American Petroleum Institute.

PRICES

Price quotations in trade publications for barite remained unchanged. These prices may serve as a general guide but do not reflect actual transactions.

The reported average value per ton of domestic barite, based on reported value or direct-ship, beneficiated, and floated material, decreased slightly, f.o.b. plant, from $41.50 per ton in 1986 to $35.29. This decline in value for domestic concentrate was attributed to a greater percentage of lower valued drilling-mud-grade material in the total. The average reported value per ton of ground drilling-mud-grade barite from Louisiana and Texas was $67.90; the average value of that from California, Nevada, and Utah was $62.76. The value of the Louisiana and Texas ground material, in direct response to steadily improving market conditions, rose about 11%. Material from the other major grinding States, supplied largely by domestic mines, declined slightly. The average customs value of barite exported to Canada and Mexico was about $325 per ton; the customs value of material exported to Latin America was about $100 per ton.

Table 8.—Barite price quotations

Item	Price per short ton[1] 1986	Price per short ton[1] 1987
Barite:[2]		
Chemical, filler, glass grades, f.o.b. shipping point, carlots:		
Handpicked, 95% $BaSO_4$, not over 1% Fe	$90.00	$90.00
Magnetic or flotation, 96% to 98% $BaSO_4$, not over 0.5% Fe	106.00	116.00
Water-ground, 95% $BaSO_4$, 325 mesh, 50-pound bags	$70.00-165.00	$70.00-165.00
Drilling-mud-grade:		
Dry-ground, 83% to 93% $BaSO_4$, 3% to 12% Fe, specific gravity 4.20 to 4.30, f.o.b. shipping point, carlots	60.00- 90.00	60.00- 90.00
Crude, imported, specific gravity 4.20 to 4.30, f.o.b. shipping point	40.00- 55.00	40.00- 55.00
Barium chemicals:[3]		
Barium carbonate:		
Precipitated, bulk, carlots, freight equalized (per pound)	.25	.25
Electronics-grade, bags	510.00	510.00
Barium chloride:		
Technical crystals, bags, carlots, works	470.00	470.00
Anhydrous, bags, carlots, same basis	590.00	590.00
Barium hydrate: Mono, 55-pound bags, carlots, delivered (100 pounds)	46.00	46.00
Barium sulfate:		
Blanc fixe, technical-grade, bags, carlots	400.00	400.00
U.S.P., X-ray diagnosis-grade, powder, 25-kilogram bags, 10,000-kilogram lots (per pound)	.59	.59
Barium sulfide (black ash), drums, carlots, works	460.00	460.00

[1]Unless otherwise specified.
[2]Engineering and Mining Journal. V. 187, No. 12, Dec. 1986, p. 19; and v. 188, No. 12, Dec. 1987, p. 27.
[3]Chemical Marketing Reporter. V. 230, No. 26, Dec. 29, 1986, pp. 24-25; and v. 232, No. 26, Dec. 28, 1987, pp. 28-29.

FOREIGN TRADE

Exports of natural barium sulfate or barite increased about 30% from nearly 7,000 tons to more than 9,000 tons. This represented a third year increases in exports after 6 consecutive years of decline from the record high of 1979 when 109,000 tons was exported. Export and import data provided by the Bureau of the Census did not indicate the grades of barite traded; however, based on the value of individual shipments, an estimated 97% was ground drilling-mud grade, and the remaining 3% was chemical-, filler-, or glass-grade. Minor amounts of witherite (natural barium carbonate), precipitated barium carbonate, and sulfate were also exported. Crude barite was not exported. Canada and Mexico, traditionally either first or second among export recipients, were buyers of U.S. ground barite. Those two countries consumed about 89% of the total exports. Canada and Mexico received only about 2% of the total. Exports to Mexico, a major oil-producing country, declined to only 13 tons from a high of 18,000 tons in 1983. Both Canada and Mexico continued to rely more on domestic production. During the year, the weakening U.S. dollar had little effect on trade because of continuing Canadian and Mexican financial or economic problems.

Imports for consumption of crude barite increased 11% from 745,000 tons in 1986 to more than 825,000 tons. The 1987 barite import figure was nearly 65% below the record high of 2.32 million tons set in 1982. The c.i.f.[7] value of this material dropped 9% to $32.91 per ton, indicating that prices of foreign ores continued to decline in response to oversupply and lower ocean shipping rates. At yearend, an earlier cutback in foreign production, notably in China and India, due to an absence of forward commitments, saw a firming of both crude barite prices and shipping rates. Shipping rates were influenced, in part, because the abrogated charters for barite were unavailable at previous rates during the yearend upturn because of more profitable competing foodstuff cargoes such as wheat. Domestic producers and consumers, faced with relatively high rail rates to ship from domestic drilling-quality barite mines in Nevada to gulf coast-area grinding plants, continued to take advantage of the lower priced foreign ores to meet their demands in this highly competitive gulf coast area. Based on an average value per ton of material shipped, the principal source countries, in descending order, were Mexico, India, Morocco, and China.

The high-priced Mexican material was chiefly crude filler- and extender-quality barite. The costlier high-quality barite, generally material with a specific gravity greater than 4.2, is usually blended with lower grade ore, foreign or domestic, during grinding to meet American Petroleum Institute specifications for 4.2-drilling-mud-grade barite. Crude barite, for the most part, entered through customs districts near most drilling-mud markets along the gulf coast for delivery to grinding plants in the area. The import distribution by customs districts in 1987 (1986) was New Orleans, LA, 68% (58%); Houston, TX, 21% (34%); and Laredo, TX (Port of Brownsville, TX), 11% (8%). Small amounts were also received, in decreasing amounts, in Great Falls, MT, and Detroit, MI.

Imports for consumption of ground barite decreased about 50% to more than 11,000 tons from nearly 22,000 tons in 1986; of this, Canada and Mexico supplied about 80%. Prior to 1984, ground barite imports had been limited to premium-quality pharmaceutical grades, which were unavailable domestically. In recent years, this market has been dwindling because certain medical X-ray diagnostic procedures employing barium compounds have been largely replaced with computer-assisted tomography (CAT) scanners or imaging techniques. Sources of medical-grade barite were Belgium-Luxembourg, Canada, France, the Federal Republic of Germany, and the Netherlands. Prices averaged $1,500 per ton. The average c.i.f. value of Moroccan imports, $115 per ton, suggested that this barite was probably drilling-mud-grade material. The increase in imports of mud-grade ground barite noted during the last 4 years appears to be ending because of increasing competition from domestic grinders in both price and quality. The continued imports of ground drilling-mud-grade barite, in a slowly recovering market situation, will probably hamper the recovery at the grinding plants and domestic mines that still can supply ore for blending. The value of imports from other countries, about $300 per ton, indicated that this ground material was probably destined for the domestic filler and/or extender markets that usually are supplied by U.S. producers.

Imports for consumpton of barium chemicals and unwrought and/or waste and scrap barium metal, for the most part, increased in quantity and value.

Table 9.—U.S. exports of natural barium sulfate, by country

Country	1986		1987	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Argentina	80	$42	85	$37
Canada	878	284	196	194
Chile	1,950	178	--	--
Ecuador	--	--	508	46
Mexico	53	27	13	6
Nigeria	--	--	1,655	147
Paraguay	--	--	150	14
Philippines	23	12	5	3
Venezuela	3,787	192	6,386	249
Zaire	--	--	85	9
Other	199	285	1	11
Total[1]	6,969	1,021	9,083	716

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

Source: Bureau of the Census.

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

Country	1986 Quantity (short tons)	1986 Value[1] (thousands)	1987 Quantity (short tons)	1987 Value[1] (thousands)
Crude barite:				
Canada	--	--	100	$7
Chile	29,248	$877	--	--
China	429,196	15,019	636,336	20,483
India	114,685	4,419	56,520	1,867
Ireland	12,731	224	--	--
Mexico	34,045	1,314	75,405	2,812
Morocco	81,963	2,862	56,890	1,993
Thailand	39,956	1,430	--	--
Other	3,163	225	--	--
Total[2]	744,986	26,369	825,251	27,162
Ground barite:				
Belgium-Luxembourg	--	--	22	8
Canada	5,019	860	8,480	1,751
China	273	32	--	--
France	102	30	456	121
Germany, Federal Republic of	436	186	206	85
Mexico	237	4	--	--
Morocco	12,457	947	1,598	184
Netherlands	194	70	526	198
Thailand	3,126	358	--	--
Other	1	2	44	10
Total[2]	21,845	2,489	11,333	2,357

[1]C.i.f. value.
[2]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

Table 11.—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 (precipitated barium sulfate) Value (thousands)	Barium chloride Quantity (short tons)	Barium chloride Value (thousands)	Barium hydroxide Quantity (short tons)	Barium hydroxide Value (thousands)
1983	NA	NA	9,087	$5,911	3,402	$1,016	4,799	$3,751
1984	NA	NA	9,302	6,381	3,680	1,576	5,452	3,973
1985	NA	NA	8,971	6,295	2,839	1,125	5,708	3,959
1986	NA	NA	10,449	8,530	1,919	733	4,925	3,960
1987	NA	NA	11,469	8,586	1,979	775	5,247	4,147

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)
1983	777	$275	8,821	$3,884	946	$1,256
1984	1,278	478	14,476	7,269	1,020	847
1985	1,339	643	12,457	5,400	1,593	2,556
1986	1,143	504	11,365	4,809	1,802	3,197
1987	1,459	579	12,851	5,485	9,442	2,500

NA Not available.

Source: Bureau of the Census.

Table 12.—U.S. imports for consumption of crude, unground, and crushed or ground witherite[1]

Year	Crude, unground		Crushed or ground	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1983	1	$4	49	$12
1984	41	24	185	129
1985	1	6	141	68
1986	2	8	145	70
1987	364	97	72	47

[1]Barium carbonate.

Source: Bureau of the Census.

WORLD REVIEW

Australia.—The main barite workings were centered around the underground mines of Commercial Minerals Ltd. at Oraparinna, approximately 300 miles north of Adelaide in the Flinders Ranges of South Australia.[8] The ore lies within steeply dipping veins up to 5 meters in width, hosted by purple slates and shales. The Oraparinna ore is high grade and marketed chiefly for paint and other industrial uses. Drilling-mud grades were from open pit mines at nearby Dunbar.

India.—The floor prices of specialty whiter grades of barite powders were lowered by Krishnappar Asbestos and Barytes Pvt. Ltd. following consultation with the Government. The new floor prices per metric ton bagged, f.o.b. Madras, were super snow white, $110; snow white, $100; and white, $88. The old floor prices were $165, $155, and $138, respectively. Shipments also incurred a Government fixed price of $8 per metric ton for palletizing.

Korea, Republic of.—Korfran Chemical Co., an equal joint venture between France's Rhône-Poulenc S.A. and Oriental Chemical Industry Ltd., received governmental approval to construct a $20 million barium and strontium carbonate plant at Inchon, about 50 miles from Seoul.[9] The plant would have a 22,000-ton-per-year capacity of both carbonates. The strongest markets for these salts were in the manufacture of black and white and color TV tubes and/or envelopes. In another similar project Kali-Chemie, a West German subsidiary of the Solvay Group, and Samsung Corning Co. Ltd., Republic of Korea, agreed to a 50-50 joint venture for additional production of barium and strontium chemicals.[10] The joint venture company, Daehan Specialty Chemicals Co. Ltd., will build a 45,000-ton-per-year production facility on the southeast coast for completion by early 1989. Kali-Chemie is the world's largest producer of barium and strontium compounds while Samsung Corning is a leading television glassmaker.

Mexico.—The decline of national barite production was caused largely by the cutback in oil- and gas-drilling exploration programs by its main customer, Petróleos Mexicanos (PEMEX), in response to depressed worldwide oil prices.[11]

Pakistan.—The Baluchistan Development Authority (BDA) began supplying barite to its new chemical plant at Hub Chanki from its Lasbela District deposits. The plant was to run as a joint venture, Minchem, by BDA (51%) and a private party (49%) with the latter managing and controlling chemical production and BDA supplying the raw materials. Barium chemical production, by the black-ash process, was targeted for about 20,000 tons per year including 3,000 tons per year of lithopone and 3,500 tons per year of barium carbonate, barium nitrate, nonbarium chemicals. A second chemical plant, to be run by the private sector, was to be assembled near Islamabad by midyear. The venture, known as Sihala Chemical Complex, was to consist essentially of an imported Chinese barium chemicals plant and Bolan Mining Enterprises Ltd. (BME). BME was to supplying about 5,000 tons per year of barite to manufacture barium chemicals, some of which were to be exported back to China. Both the process and barium chemicals to be manufactured were unspecified.[12]

Table 13.—Barite: World production, by country[1]

(Thousand short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Afghanistan[e 3]	2	2	2	2	2
Algeria	[e]120	97	66	66	66
Argentina	67	49	57	65	64
Australia	13	22	25	6	17
Belgium[e]	44	43	44	44	44
Bolivia	1	1	1	(4)	2
Brazil	140	158	157	[r e]165	165
Burma[5]	11	11	9	9	9
Canada	50	52	78	[r e]44	45
Chile	126	24	60	59	55
China[e]	1,100	1,100	1,100	1,100	1,100
Colombia	4	4	6	5	[6]5
Czechoslovakia[e]	67	66	66	66	66
Egypt	4	6	5	[e]5	5
Finland	4	10	10	8	[6]12
France	168	163	[e]165	[e]160	155
German Democratic Republic[e]	39	39	37	37	35
Germany, Federal Republic of	181	184	189	222	200
Greece[7]	33	3	4	3	3
Guatemala[e]	(4)	(4)	[6]3	[r]2	--
India	356	492	639	379	300
Iran[e]	94	100	100	100	100
Ireland	220	243	236	141	165
Italy	153	118	141	124	125
Japan	77	73	85	58	35
Kenya	(4)	(4)	(4)	(4)	1
Korea, Republic of	1	3	3	4	4
Malaysia	24	26	26	19	44
Mexico	394	470	516	354	[6]445
Morocco	318	619	551	209	[6]158
Pakistan	29	30	33	43	14
Peru	122	51	24	33	33
Philippines	1	1	--	--	--
Poland	89	89	100	108	65
Portugal[e]	[6]1	(4)	(4)	(4)	(4)
Romania[e]	86	80	80	80	80
South Africa, Republic of	7	5	5	10	[6]9
Spain	58	76	74	[e]74	75
Thailand	207	193	255	157	[6]37
Tunisia	22	13	[e]22	[e]22	22
Turkey	87	218	183	[e]193	193
U.S.S.R.[e]	570	580	595	595	595
United Kingdom	40	69	118	96	[6]99
United States[8]	754	775	739	297	[6]448
Yugoslavia	39	45	[e]40	[e]40	40
Zimbabwe	1	1	(4)	(4)	(4)
Total	5,924	[r]6,404	6,649	5,204	5,137

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through June 17, 1988.
[2]In addition to the countries listed, Bulgaria also produces barite, but available information was inadequate to make reliable estimates of output levels.
[3]Data are for fiscal year beginning Mar. 21 of that stated.
[4]Less than 1/2 unit.
[5]Data are for fiscal year beginning Apr. 1 of that stated.
[6]Reported figure.
[7]Barite concentrates.
[8]Sold or used by producers.

Turkey.—The Paleozoic formations in Konya, Maras, Antalya, Kutahya, and Mus Provinces contained the country's major barite deposits.[13] The total mine production capacity was reported to be over 650,000 tons per year with proven reserves at 6 million tons, probable reserves at nearly 9 million tons, and total reserves assumed to be over 25 million tons.

TECHNOLOGY

A remarkable new perovskite-structure material, yttrium-barium-copper oxide ($YBa_2Cu_3O_7$), was synthesized and found to be fully superconductive at about 90 K.[14] This new material, made from relatively inexpensive raw materials, is capable of conducting electricity with virtually no resistance at readily attainable nitrogen temperatures. The crystallography,[15] physical and chemical properties,[16] and the Raman spectroscopy of phases[17] for this superconducting phase and its analogs were discussed. The discovery, long sought by scientists and engineers, should eventually lead to less costly electrical transmission over great distances, miniature computers more powerful than any now in existence, and certainly many other uses not yet conceived. The high-purity requirements for these electroceramics by the electronic and optical glass industries are largely responsible for the worldwide resurgence in barium chemicals manufacturing in general and high-purity salts in particular.

Comprehensive reviews published on the industrial minerals of Australia[18] and Pakistan[19] included detailed sections on barite, local geology, mineralogy, mining and milling flowsheets, and indigenous mining methods. The review of Pakistan included a separate section on the major barite mining and milling companies and their capacities, along with a map pinpointing their locations. The growing Pakistani barium chemicals industry, offsetting the depressed drilling-mud industry, was singled out for special attention.

The mining and geology of the barite deposits of the Alwar District, Rajasthan, India,[20] and the Yugoslav barite industry[21] also were published. The Rajasthan report highlights not only the barite mining and geology of the area but also a case study of a typical underground mine in the district. The mines are in a region where electric power is available only from portable generators. The Yugoslav paper presents a concise review of its domestic barite deposit, methods for barite ore dressing, and the technology for its consumption patterns. A section emphasizing the type of deposits—vein, sedimentary (bedded), or residual—along with geology and mining techniques, and processing, washing, and flotation flowsheets for the Lokve Mine and mill complex were most informative.

Two articles reviewed the uses of mineral fillers and extenders in the growing domestic plastics markets, both resins and thermosets. One paper examined the selected market sectors technically, relating their consumption of mineral fillers in reinforcements and pigments for interior and exterior applications.[22] The role of barite in plastisols for carpet-backing, where it imparts sound-deadening characteristics, in fillers for non-asbestos brake lining as a heat sink, and in polyurethane foam used in furniture manufacture for recoil and density properties was highlighted in a feature section dealing with special applications. The other paper stressed the technical challenge of product modifications by employing selected minerals and surface-modified minerals.[23] The unique chemical inertness of barite in combination with its high density should play a major role in the future design of advanced plastic products.

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Bauxite and Alumina

By Luke H. Baumgardner[1] and Ruth A. Hough[2]

World bauxite production increased significantly in 1987 and exceeded 90 million tons[3] for the first time. Mine production was reported from 27 countries. Bauxite production in the United States increased only slightly, although domestic alumina production from imported bauxite rose nearly 34% above 1986 output in response to increased primary aluminum demand. A moderate decrease in the unit value of crude and dried bauxite imports from 1986 to 1987 was reflected in the Bureau of the Census trade data.

Domestic Data Coverage.—Domestic production and consumption data for bauxite and alumina are developed by the Bureau of Mines from five separate voluntary surveys of U.S. operations. Typical of these quarterly and annual surveys is the "Consumption of Alumina" survey. Of the 24 operations canvassed, 23 responded, representing a 96% response rate.

Table 1.—Salient bauxite statistics

(Thousand metric tons and thousand dollars)

	1983	1984	1985	1986	1987
United States:					
Production: Crude ore (dry equivalent)	679	856	674	510	576
Value	$11,309	$15,643	$12,855	r$10,361	$10,871
Exports (as shipped)	74	82	56	69	201
Imports for consumption[1]	7,601	9,435	7,158	6,456	9,156
Consumption (dry equivalent)	9,100	10,519	8,206	6,901	9,548
World: Production	r78,687	r87,799	84,496	p86,093	e90,302

eEstimated. pPreliminary. rRevised.
[1]Excludes calcined bauxite. Includes bauxite imported to the U.S. Virgin Islands.

Legislation and Government Programs.—At yearend, the General Services Administration reported the following deficits in bauxite stockpile goals: 631,000 tons, calcined abrasive grade; 8.679 million tons, Jamaica-type metallurgical grade; 813,000 tons, Suriname-type metallurgical grade; and 1.144 million tons, calcined refractory grade.

DOMESTIC PRODUCTION

Bauxite was produced from surface mining operations in Alabama, Arkansas, and Georgia. Three companies in central Arkansas processed bauxite for diverse end-use markets, a limited amount of which went to primary metal production. At Benton, AR, the Aluminum Co. of America (Alcoa) calcined bauxite for the abrasive and proppant industries and processed crude ore at the company's local Bayer refinery to produce specialty aluminum oxides and hydroxides. Bauxite mined and calcined by the American Cyanamid Co. at Bryant, AR, was shipped to out-of-State plants for production of aluminum sulfate and proppants. Bauxite purchased from a local supplier was used by Porocel Corp. at Berger, AR, to produce activated bauxite chiefly for use in the refining of petroleum. Bauxite from Alabama and Georgia mines, because of its very low iron oxide content, was used solely for the manufacture of high-alumina refractory products.

Demand for domestic refractory grade ore remained weak during 1987 and mine output was intermittent. In the mining district west of Eufaula, AL, the Harbison-Walker Refractories Div. of Dresser Industries Inc., produced bauxite for the company's local calcining plant and also supplied bauxitic clay to the Carbo Ceramic Co.'s (formerly Standard Oil Proppants Co.) proppant plant at Eufaula. Mullite Co. of America (Mulcoa), an operating unit of C-E Minerals Inc., produced bauxite in Henry County, AL, and Sumter County, GA, for calcining at Mulcoa's plant near Andersonville, GA. The mines and calcining plant of A. P. Green Refractories Co. in the Baker Hill, AL, area were inactive during the year, and the plant and bauxite reserves were sold to C-E Minerals late in the year.

Domestic capacity to produce alumina remained unchanged at 4.57 million tons per year, although Alcoa announced at yearend the planned permanent closing of its Bauxite, AR, mine and 340,000-ton-per-year Bayer alumina plant in October 1988. U.S. alumina production increased substantially compared with 1986 output as it moved in consort with the rise in demand for primary metal. Apparent refinery capacity utilization was about 91%.

Table 2.—Mine production of bauxite and shipments from mines and processing plants to consumers in the United States

(Thousand metric tons and thousand dollars)

Year	Mine production			Shipments from mines and processing plants to consumers[1]		
	Crude	Dry equivalent	Value[2]	As shipped	Dry equivalent	Value[2]
1985	787	674	$12,855	993	989	$34,506
1986	617	510	r10,361	r776	r740	r36,276
1987	689	576	10,871	756	680	22,173

rRevised.
[1]May exclude some bauxite mixed in clay products.
[2]Computed from values assigned by producers and from estimates of the Bureau of Mines.

Table 3.—Recovery of dried, calcined, and activated bauxite in the United States

(Thousand metric tons)

Year	Crude ore treated	Total processed bauxite recovered[1]	
		As recovered	Dry equivalent
1986	250	128	196
1987	131	62	102

[1]Dried, calcined, and activated bauxite. May exclude some bauxite mixed in clay products.

Table 4.—Percent of domestic bauxite shipments, by silica content

SiO_2 (percent)	1983	1984	1985	1986	1987
Less than 8	--	11	74	77	70
From 8 to 15	75	55	14	--	7
More than 15	25	34	12	23	23

Table 5.—Production and shipments of alumina in the United States

(Thousand metric tons)

Year	Calcined alumina	Other alumina[2]	Total[1]: As produced or shipped[3]	Total[1]: Calcined equivalent
Production:[e]				
1983	3,540	680	4,220	4,000
1984	4,160	560	4,720	4,545
1985	2,860	860	3,725	3,465
1986	2,570	750	3,320	3,105
1987	3,555	830	4,385	4,150
Shipments:[e]				
1983	3,480	670	4,150	3,945
1984	4,230	570	4,800	4,620
1985	2,890	760	3,650	3,425
1986	2,590	740	3,330	3,120
1987	3,530	845	4,375	4,135

[e]Estimated.
[1]Data may not add to totals shown because of independent rounding.
[2]Trihydrate, activated, tabular, and other aluminas. Excludes calcium and sodium aluminates.
[3]Includes only the end product if one type of alumina was produced and used to make another type of alumina.

Table 6.—Capacities of domestic alumina plants,[1] December 31

(Thousand metric tons per year)

Company and plant	1985	1986	1987
Aluminum Co. of America:			
Bauxite, AR	340	340	340
Point Comfort, TX	1,600	1,735	1,735
Total	1,940	2,075	2,075
Kaiser Aluminum & Chemical Corp.: Gramercy, LA	770	795	795
Reynolds Metals Co.: Corpus Christi, TX	1,700	1,700	1,700
Grand total	4,410	4,570	4,570

[1]Capacity may vary depending upon the bauxite used.

CONSUMPTION AND USES

Bauxite consumption rose in 1987 compared with that of 1986, with significant gains in calcined refractory grades and crude and dried metallurgical grades. Domestic producers benefited little as the increase was supplied largely from imports. Consumption by the chemical industries was unchanged, while calcined abrasive grade bauxite, including feedstocks to the proppants industries, continued a declining trend begun in 1985. Low world oil prices removed the incentives for petroleum producers to use proppants. About 90% of the bauxite consumed in the United States was refined to alumina and an estimated average of 2.07 tons of dried bauxite was required to produce 1 ton of calcined alumina. Twenty-one primary aluminum smelters consumed 7.5 million tons of calcined alumina. An estimated 84% of alumina shipped by U.S. refineries went to domestic primary smelters. Consumption by abrasives, chemicals, refractories, and other industries accounted for the balance of the alumina in calcined, hydroxide, activated, tabular, and other forms.

Table 7.—U.S. consumption of bauxite, by industry

(Thousand metric tons, dry equivalent)

Industry	Domestic	Foreign	Total
1986:			
Alumina	[1]460	[1]5,779	5,980
Abrasive[2]	W	W	259
Chemical	[3]37	[3]253	231
Refractory	80	292	372
Other	W	W	59
Total[1 3]	577	6,324	6,901
1987:			
Alumina	[1]490	[1]8,335	8,601
Abrasive[2]	W	W	224
Chemical	[3]34	[3]267	243
Refractory	68	354	422
Other	W	W	58
Total[1 3]	592	8,956	9,548

W Withheld to avoid disclosing company proprietary data; included with "Other" or "Total."
[1]Includes "Abrasive."
[2]Includes consumption by Canadian abrasive industry.
[3]Includes "Other."

Table 8.—U.S. consumption of crude and processed bauxite

(Thousand metric tons, dry equivalent)

Type	Domestic origin	Foreign origin	Total
1986:			
Crude and dried	W	W	6,305
Calcined and activated	W	W	597
Total	577	6,324	[1]6,901
1987:			
Crude and dried	W	W	8,924
Calcined and activated	W	W	624
Total	592	8,956	9,548

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1]Data do not add to total shown because of independent rounding.

Table 9.—Production and shipments of selected aluminum salts in the United States in 1986

Item	Number of producing plants	Production (thousand metric tons)	Total shipments including interplant transfers: Quantity (thousand metric tons)	Total shipments including interplant transfers: Value (thousands)
Aluminum sulfate:				
Commercial and municipal (17% Al_2O_3)	82	1,109	1,060	$129,361
Iron-free (17% Al_2O_3)	26	109	103	13,872
Aluminum chloride:				
Liquid and crystal	3	5	W	W
Anhydrous (100% $AlCl_3$)	4	W	W	W
Aluminum fluoride, technical	3	W	W	W
Aluminum hydroxide, trihydrate (100% $Al_2O_3 \cdot 3H_2O$)	7	479	540	126,639
Other aluminum compounds[1]	NA	NA	NA	61,013

NA Not available. W Withheld to avoid disclosing company proprietary data.
[1]Includes sodium aluminate, light aluminum hydroxide, cryolite, and alums.

Source: Data are based upon Bureau of the Census 1986 Current Industrial Reports, Series MA-28A, "Inorganic Chemicals."

Table 10.—Stocks of bauxite in the United States,[1] December 31

(Thousand metric tons, dry equivalent)

Sector	1986[r]	1987
Producers and processors	186	212
Consumers	3,133	2,824
Government	18,472	18,472
Total	21,791	21,508

[r]Revised.
[1]Domestic and foreign bauxite; crude, dried, calcined, activated; all grades.

Table 11.—Stocks of alumina in the United States,[1] December 31

(Thousand metric tons, calcined equivalent)

Sector	1986[r]	1987
Producers[e]	148	141
Primary aluminum plants	1,888	2,685
Total[e]	2,036	2,826

[e]Estimated. [r]Revised.
[1]Excludes consumers' stocks other than those at primary aluminum plants.

PRICES

Contract terms for the purchase of metal grade bauxite and cell grade alumina in world markets are not normally made public, and consequently, prices for these commodities are not published by trade journals. Price quotes are generally limited to certain specialty forms of bauxite and alumina for nonmetallurgical uses.

In 1987, the Bureau of Mines estimated the average value of domestic crude bauxite shipments, f.o.b. mine or plant, to be $15.79 per ton. The average value of calcined domestic bauxite was estimated to be $128 per ton. Quoted base prices for imported calcined refractory grade bauxite were: Chinese, typical 85% Al_2O_3, f.o.b. barge, Burnside, LA, $95 to $120 per ton; Guyanese, minimum 86% Al_2O_2, f.o.b. railcar, Baltimore, MD, or f.o.b. barge, Burnside, LA, or Mobile, AL, $164.76 per ton. These base prices were subject to adjustment for grain-size specifications, size of order, and fuel cost factors.

The average value of domestic calcined alumina shipments was estimated to be $143 per ton. The average value of imported calcined alumina indicated by trade data of the Bureau of the Census was $141 per ton, f.a.s. port of shipment, and $152 per ton, c.i.f. U.S. ports.

Table 12.—Average value of U.S. imports of crude and dried bauxite[1]

(Per metric ton)

Country	1986		1987	
	Port of shipment (f.a.s.)	Delivered to U.S. ports (c.i.f.)	Port of shipment (f.a.s.)	Delivered to U.S. ports (c.i.f.)
To U.S. mainland:				
Australia	$15.43	$23.43	$13.96	$22.45
Brazil	24.58	27.53	24.14	29.24
Guinea	25.98	32.73	19.66	26.88
Guyana	34.02	45.45	31.89	44.20
Jamaica	30.93	34.99	30.54	34.24
Suriname	37.36	47.35	23.77	32.22
Weighted average	27.54	33.66	23.32	29.48

[1]Computed from quantity and value data reported to U.S. Customs Service and compiled by the Bureau of the Census, U.S. Department of Commerce. Not adjusted for moisture content of bauxite or differences in methods used by importers to determine value of individual shipments.

Table 13.—Market quotations on alumina and aluminum compounds

(Per metric ton, in bags, carlots, freight equalized)

Compound	Dec. 30, 1986	Dec. 31, 1987
Alumina, calcined	$418.88	$418.88
Alumina, hydrated, bulk	209.44	209.44
Alumina, activated, granular, works	905.00	905.00
Aluminum sulfate, commercial, ground (17% Al_2O_3)	225.97	225.97
Aluminum sulfate, iron-free, dry (17% Al_2O_3)	330.69	330.69

Source: Chemical Marketing Reporter.

FOREIGN TRADE

Exports of dried bauxite totaled 146,000 tons in 1987, nearly quadruple the quantity exported in 1986. Venezuela received 101,000 tons, Canada, 38,000 tons, and Suriname, 7,000 tons. Of the total 55,000 tons of calcined bauxite exported, Mexico received 52,000 tons and Canada, 3,000 tons.

Ghana became a major destination of U.S. alumina exports because of the closure of the Alpart refinery in Jamaica, its usual source. Alumina exports to Canada, Ghana, and Mexico were more than double the quantities shipped in 1986 and accounted for 88% of the 1987 exports.

Imports for consumption of crude and dried bauxite increased significantly over 1986 receipts, and the three traditional principal suppliers, Australia, Guinea, and Jamaica provided 90% of the total.

Ghana became a new supplier of metal grade bauxite to the United States. Imports from all source countries increased compared with those of 1986, with the exception of those from Suriname, where guerrilla action by insurgents shut down that country's largest bauxite mine for most of the year.

Australia continued to be the dominant source of U.S. alumina imports for consumption (83% of the total), and imports from all sources except Jamaica increased with respect to 1986 receipts.

Table 14.—U.S. exports of alumina,[1] by country

(Thousand metric tons, calcined equivalent, and thousand dollars)

Country	1985		1986		1987	
	Quantity	Value	Quantity	Value	Quantity	Value
Argentina	(2)	$178	1	$624	1	$629
Belgium-Luxembourg	2	2,209	2	3,485	2	2,543
Brazil	1	770	--	593	75	10,789
Canada	126	30,561	263	47,491	575	89,890
France	(2)	747	--	1,259	1	2,005
Germany, Federal Republic of	3	4,958	3	4,379	1	2,989
Ghana	--	--	77	12,540	270	38,942
Japan	1	2,443	21	6,426	24	8,162
Mexico	104	28,451	91	23,627	150	32,431
Netherlands	1	r2,476	1	2,365	2	2,274
Norway	45	7,417	11	645	(2)	13
Sweden	22	2,546	--	456	(2)	106
United Kingdom	3	4,803	2	2,441	2	2,134
Venezuela	1	1,138	1	1,573	2	1,512
Other	6	11,133	14	17,416	22	13,617
Total[3]	316	99,829	487	125,322	1,127	208,037

rRevised.

[1]Includes exports of aluminum hydroxide (calcined equivalent) as follows: 1985—16,700 tons; 1986—12,199 tons; and 1987—18,727 tons.

[2]Less than 1/2 unit.

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

Source: Bureau of the Census.

Table 15.—U.S. imports for consumption of bauxite, crude and dried,[1] by country

(Thousand metric tons)

Country	1985	1986	1987
Australia	829	579	1,167
Brazil	560	100	451
China	9	21	5
Dominican Republic[2]	6	1	70
Ghana	--	--	36
Guinea	3,752	3,356	4,256
Guyana	225	169	244
Jamaica[2]	1,540	2,119	2,799
Sierra Leone	56	--	--
Suriname	176	112	104
Other	[r]5	([3])	24
Total[4]	7,158	6,456	9,156

[r]Revised.
[1]Includes bauxite imported to the U.S. Virgin Islands from foreign countries.
[2]Dry equivalent of shipments to the United States.
[3]Revised to zero.
[4]Data may not add to totals shown because of independent rounding.

Note.—Total U.S. imports of crude and dried bauxite (including the U.S. Virgin Islands) as reported by the Bureau of the Census were as follows: 1985—7,257,840 tons; 1986—6,854,083 tons; and 1987—9,827,818 tons.

Source: Bureau of the Census and the Jamaican Bauxite Institute.

Table 16.—U.S. imports for consumption of calcined bauxite, by country

(Thousand metric tons and thousand dollars)

Country	1986				1987			
	Refractory grade		Other grade		Refractory grade		Other grade	
	Quantity	Value[1]	Quantity	Value[1]	Quantity	Value[1]	Quantity	Value[1]
Australia	--	--	14	$1,110	--	--	6	$416
China	112	$8,958	48	3,881	163	$10,708	10	714
Guyana	109	14,232	9	935	107	14,995	22	1,230
Suriname	--	--	11	558	--	--	4	160
Other	--	--	([2])	41	--	--	([2])	26
Total[3]	221	23,190	83	6,526	270	25,703	43	2,545

[1]Value at foreign port of shipment as reported to U.S. Customs Service.
[2]Less than 1/2 unit.
[3]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

Table 17.—U.S. imports for consumption of alumina,[1] by country

(Thousand metric tons, calcined equivalent, and thousand dollars)

Country	1985		1986		1987	
	Quantity	Value[2]	Quantity	Value[2]	Quantity	Value[2]
Australia	3,014	$564,212	3,051	$458,965	3,361	$431,041
Brazil	48	9,280	20	4,720	25	4,977
Canada	42	16,958	42	16,109	59	25,078
France	5	11,046	5	12,019	7	13,825
Germany, Federal Republic of	11	13,896	13	14,924	14	20,922
Jamaica	372	66,171	140	20,370	90	13,107
Japan	4	4,112	3	3,371	6	6,688
Suriname	326	42,949	[r]268	[r]30,465	324	40,568
Venezuela	--	--	55	9,712	111	13,936
Other	5	6,614	[r]6	[r]3,555	71	11,719
Total	3,827	735,238	3,603	574,210	4,068	[3]581,864

[r]Revised.
[1]Includes imports of aluminum hydroxide.
[2]Value at foreign port of shipment as reported to U.S. Customs Service.
[3]Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

WORLD REVIEW

Bauxite mines and alumina plants raised production levels during the last quarter of 1987 to meet the rising demand for alumina to make primary aluminum metal. Venezuela joined the ranks of world bauxite producers with the opening of mining operations in the State of Bolívar, and the Dominican Republic reopened bauxite mines that had been shut down in 1982. China reported the discovery of a large bauxite deposit. The Governments of Guinea, Jamaica, and Suriname were reported to have reached tentative agreements with the bauxite-producing companies to revise or rescind bauxite production levies.

Australia.—The world's largest bauxite- and alumina-producing country set new production records for the fifth consecutive year. Comalco Ltd. reported bauxite production and shipments of 8.02 and 7.81 million tons, respectively, from its mining complex at Weipa, Queensland. In addition to the production of metal grade bauxite, in other operations at Weipa the company calcined bauxite for use in abrasives and proppants and mined and processed kaolin clay from deposits underlying the bauxite ore. Queensland Alumina Ltd., at Gladstone, Queensland, owned by Comalco (30.3%), Kaiser Aluminum and Chemical Corp. (28.3%), Alcan Australia Ltd. (21.4%), and Pechiney Corp. (20%) produced about 2.77 million tons of alumina.

At Gove, in the Northern Territory, the alumina plant owned by Swiss Aluminium Australia Ltd. (Austraswiss) (70%) and Gove Alumina Ltd. (30%), also operated at full capacity with production close to 1.4 million tons. Bauxite exports declined as Japan continued to shut down alumina plants. In July, Austraswiss announced that it had successfully resolved the 1986 dispute in which the Australian Government claimed that the company was underpricing its alumina sales to gain tax benefits.

In Western Australia, Alcoa of Australia Ltd. operated the Kwinana, Pinjarra, and Wagerup alumina plants at capacity, as did the Worsley Alumina Pty. Ltd., owned jointly by Reynolds Alumina Australia Ltd. (40%), Shell Co. of Australia Ltd. (30%), The Broken Hill Pty. Co. Ltd. (BHP) (20%), and Kobe Alumina Associates (Australia) Pty. Ltd. (10%). Western Australia's bauxite and alumina operations were overshadowed by news reports on the development of gold deposits associated with the bauxite in the Boddington area. The Worsley group poured the first commercial gold at its Boddington mine and plant in August, and Alcoa of Australia sought mining rights to the gold reserves on its bauxite lands adjoining the Boddington deposits. BHP announced that it intended to sell its share of Worsley Alumina to Hydro Aluminium A/S, a subsidiary of Norsk Hydro A/S, Norway.

Brazil.—Sales of bauxite by Mineração Rio do Norte S.A. (MRN) from its mining operations at Trombetas reached a record high of 5.3 million tons. Participants in the consortium included state-owned Companhia Vale do Rio Doce (CVRD) holding a 46% interest, Alcan Alumínio do Brasil S.A. (24%), Companhia Brasiliera de Aluminio (10%), Billiton Metais S.A. (10%), Norsk Hydro (5%), and Reynolds Aluminio S.A. (5%). The bauxite sales-price dispute that began in 1986 continued through 1987 as the private commercial partner-customers argued against CVRD's move to increase the price. The $25.68 per ton price at the beginning of the year was raised to $28.50 on April 1, and then reduced to provisional prices of $26.97 in August and $26.68 in October. Most of the bauxite exported by MRN was shipped to Canada, the United States, and Venezuela.

The proposed Aluminio do Norte do Brasil S.A. alumina plant to be built on the Amazon River near Belém by CVRD (60%), and the Japanese consortium, Nippon Amazon Aluminium Co. (NAAC), was stalled in the early construction stages by NAAC's decision at yearend 1986 not to provide additional capital to cover its 40% interest in the 800,000-ton-per-year plant. The refinery was sited next to the newly completed ALBRAS aluminum smelter, owned jointly by CVRD and NAAC, and was designed to supply the smelter's alumina requirements. A drought-related electrical power shortage during 1987 forced cutbacks in smelter production at Alcan's Aratu plant and at the Alumínio do Maranhão plant owned by Alcoa Alumínio S.A. (60%) and Billiton Metais (40%), thus reducing bauxite and alumina consumption at these facilities.

China.—The discovery of a 500-million-ton bauxite deposit in Shanxi Province was reported by the Ministry of Geology and Mineral Resources. The verified ore reserves were stated to be of high grade and to be near the surface, and the deposit was estimated to contain more than 40% of the known bauxite reserves in China. A primary aluminum complex is planned at Yumenkou, on the Yellow River in the southwest region of Shanxi Province. The first stage, a 200,000-ton-per-year alumina plant, was nearing completion after more than 3 years of construction and was expected to be in production late in 1987. A coal-fired powerplant and a limestone mine were also to be completed in the first stage, the latter to supply lime for the combination Bayer/lime-soda-sinter process. Second and third stages were expected to increase progressively annual alumina capacity to 2 million tons and complete a 300,000-ton-per-year aluminum smelter by the year 2000. China has been a net importer of aluminum, but development of the aluminum industry has been given high priority in anticipation of rapid growth in domestic consumption.

India.—The largest bauxite mine in Asia was opened by the National Aluminium Co. Ltd. (NALCO) in February at Panchpatmali in Orissa State. Bauxite reserves were reported to be 317 million tons and the annual capacity of the mining operation was about 2.4 million tons. The mine was part of a complex that included a 600-megawatt power facility, a 218,000-ton-per-year primary aluminum smelter, and an 800,000-ton-per-year alumina plant at Damanjodi. Pechiney of France provided the design technology. Contracts were signed by NALCO to sell 50,000 tons of alumina to Poland and 100,000 tons of alumina to Norsk Hydro ASV. Initial shipments to each were to commence in 1987.

Jamaica.—In 1987, Jamaica was the second largest supplier of metal grade bauxite and fourth largest supplier of alumina to the United States. Although four of the world's largest aluminum companies have bauxite mining and refining operations on the island, fuel costs, bauxite production levies, and a depressed aluminum market from 1984 through early 1987 combined to hold production levels down and reduce revenue to the Government. Increased bauxite exports to the United States and the U.S.S.R. were insufficient to offset the continued low exports of alumina. The Jamaican Government continued production at Alcoa's Clarendon alumina plant under a 2-year lease signed in mid-1985 and sold the alumina through Clarendon Ltd., a Swiss trading company. Jamaica's efforts to purchase the plant were unsuccessful and in October, Alcoa announced that it would resume full control of the plant when the lease contract expired in February 1988. Alcan was urged by the Government to restart idled capacity at the Ewarton refinery, and Kaiser and Reynolds were pressured to reopen the Alpart refinery. Negotiations between Jamaica and the companies were in progress at yearend, and they had reached a tentative agreement that bauxite levies would be adjusted downward in exchange for increased alumina production.

Suriname.—Bauxite and alumina production problems continued throughout the year for the Suriname Aluminum Co. (Suralco), the wholly owned Alcoa subsidiary. The Moengo bauxite mine was closed by insurgent rebel action in November 1986, and remained shut down for most of 1987. Emergency arrangements were made to import bauxite ore to supply the 1.4-million-ton-per-year Paranam alumina plant owned by Suralco (55%) and Billiton International Metals BV (45%), but the plant was forced to close in February 1987 when equipment was damaged by idled workers. Suralco's aluminum smelter was closed in January after antigovernment rebels blew up the powerlines to the plant. Although the power supply was repaired, the smelter could not be restarted in 1987 owing to low water levels at the hydroelectric plant.

Venezuela.—After 20 years of importing raw materials for the production of primary aluminum, Venezuela became a fully integrated metal producer with the opening in June 1987 of Los Pijiguaos bauxite mine on the Orinoco River. Beginning in September, 134,000 tons of ore was barged 650 kilometers down the Orinoco to the Interamericana de Alúmina C.A. (INTERALUMINA) plant at Puerto Ordaz, where the bauxite was refined to alumina to supply the two adjacent primary metal smelters. C.V.G. Bauxita Venezolana C.A., the state-controlled operating company in which Alusuisse holds a 3.5% interest, planned to raise the mine capacity to 3 million tons per year in 1988. Capacity increases for INTERALUMINA and both smelters were also scheduled for 1988-89. The Government was seeking joint-venture participation with the world's major aluminum producers and fabricators. The availability of low-cost hydroelectric power should prove a strong incentive to new industry.

Table 18.—Bauxite: World production, by country[1]

(Thousand metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
Australia	24,372	31,537	31,839	32,384	34,000
Brazil	7,199	6,433	5,846	6,544	7,250
China[e]	1,600	1,600	1,650	1,650	2,400
Dominican Republic[2]	--	--	--	--	[3]211
France	1,663	1,607	1,530	1,379	[3]1,271
Germany, Federal Republic of	(4)	(4)	(4)	(4)	(4)
Ghana	70	[r]44	170	226	[3]230
Greece	2,455	2,296	2,453	2,230	2,400
Guinea[5]	12,421	13,160	13,100	12,130	13,400
Guyana[2]	1,087	1,333	[e]1,675	1,466	2,200
Hungary	2,917	2,994	2,815	3,022	[3]3,101
India	[r]1,976	[r]2,093	2,281	2,322	[3]2,685
Indonesia	778	1,003	830	650	[3]635
Italy	13	--	--	--	--
Jamaica[2 6]	7,683	8,937	5,975	6,944	[3]7,775
Malaysia	502	680	492	559	[3]482
Mozambique	--	--	5	4	5
Pakistan	3	3	2	3	4
Romania[e]	650	620	600	600	600
Sierra Leone	785	1,040	1,184	1,242	[3]1,390
Spain	5	7	2	[e]7	4
Suriname	3,400	3,454	[e]3,000	3,847	1,200
Turkey	306	132	214	291	[3]247
U.S.S.R.[e 7]	4,600	4,600	4,600	4,600	4,600
United States[2]	679	856	674	510	[3]576
Venezuela[8]	--	--	--	--	[3]217
Yugoslavia	3,500	3,347	3,538	3,459	[3]3,394
Zimbabwe	23	23	21	24	25
Total	[r]78,687	[r]87,799	84,496	86,093	90,302

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through July 8, 1988.
[2]Dry bauxite equivalent of crude ore.
[3]Reported figure.
[4]Less than 1/2 unit.
[5]Dry bauxite equivalent of ore processed by drying plant.
[6]Bauxite processed for conversion to alumina in Jamaica plus kiln-dried ore prepared for export.
[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 nepheline syenite concentrate production was as follows, in thousand metric tons: 1983—2,500; 1984—2,500; 1985—2,500; 1986—2,500; and 1987—2,500. Estimated alunite ore production was as follows, in thousand metric tons: 1983—615; 1984—615; 1985—615; 1986—620; and 1987—625. Nepheline syenite concentrate grades 25% to 30% alumina, and alunite ore grades 16% to 18% alumina; these commodities may be converted to their bauxite equivalent by using factors of 1 ton of nepheline syenite concentrate equals 0.55 ton of bauxite and 1 ton of alunite equals 0.34 ton of bauxite.
[8]The new Los Pijiguaos Mine came on-stream in mid-1987.

Table 19.—Alumina: World production,[1] by country[2]

(Thousand metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
Australia	7,231	8,781	8,792	9,423	[3]10,105
Brazil	787	891	1,096	1,258	1,200
Canada	1,116	1,126	1,019	[e]1,100	[3]953
China[e]	800	800	825	825	1,200
Czechoslovakia	80	85	[e]85	[e]85	85
France	853	898	734	740	[3]711
German Democratic Republic	42	43	47	46	46
Germany, Federal Republic of[4]	[r]1,346	[r]1,417	1,368	1,250	[3]1,017
Greece	410	482	380	470	480
Guinea	[r]573	[r]538	572	556	543
Hungary	836	811	798	856	[3]858
India	[e]450	588	587	[e]600	700
Ireland	66	653	555	686	[3]784
Italy	466	607	555	618	585
Jamaica	1,851	1,749	1,513	1,575	1,610
Japan	1,065	1,172	978	607	[3]358
Romania	512	552	548	555	550
Spain	737	742	725	[e]725	812
Suriname	1,129	1,208	[e]1,000	1,471	[3]1,370
Turkey	57	75	113	144	[3]95

See footnotes at end of table.

Table 19.—Alumina: World production,[1] by country[2] —Continued

(Thousand metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
U.S.S.R.[e]	3,200	3,300	3,500	3,700	3,700
United Kingdom	93	105	110	[e]110	110
United States[e]	4,000	4,545	3,465	[r]3,105	4,150
Venezuela	560	1,139	[e]1,085	[r e]1,300	[3]1,381
Yugoslavia	1,010	1,135	1,138	1,130	1,135
Total	[r]29,270	[r]33,442	31,588	[5]32,936	[5]34,539

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Figures presented generally represent calcined alumina; exceptions are noted individually.
[2]Table includes data available through July 8, 1988.
[3]Reported figure.
[4]Series revised to reflect calcined alumina; previously shown as hydrate output.
[5]Data do not add to total shown because of independent rounding.

Table 20.—World annual alumina capacity, by country

(Thousand metric tons, yearend)

Country	1985	1986	1987
Australia	9,750	9,750	10,000
Brazil	1,150	1,150	1,150
Canada	1,225	1,225	1,225
China	850	850	1,300
Czechoslovakia	100	100	100
France	1,040	1,040	1,040
German Democratic Republic	65	65	60
Germany, Federal Republic of	1,745	1,745	1,745
Greece	500	500	500
Guinea	700	700	700
Guyana	355	355	355
Hungary	895	920	920
India	675	675	1,000
Ireland	800	800	800
Italy	920	920	720
Jamaica	2,825	2,825	3,100
Japan	1,060	975	550
Romania	540	540	540
Spain	800	800	800
Suriname	1,350	1,350	1,350
Turkey	200	200	200
U.S.S.R.	4,500	4,600	4,600
United Kingdom	140	120	120
United States	4,410	4,570	4,570
Venezuela	1,000	1,000	1,300
Yugoslavia	1,635	1,635	1,635
Total	39,230	39,410	40,380

TECHNOLOGY

The Bureau of Mines described research on the recovery of alumina from domestic alunite ($KAl_3(SO_4)_2(OH)_6$) deposits.[4] In the initial step of the process, the alunite was sulfated by treating it with hot, concentrated sulfuric acid. Hot water was used to leach out the acid-insoluble aluminum sulfate that was precipitated out as crystals, as the solution cooled. By calcining the aluminum sulfate crystals, cell-grade alumina could be produced. The potassium compounds that accumulated in the sulfuric acid were retained for subsequent recovery.

A number of advanced ceramics, including aluminum oxide (alumina), have recently been developed for surgical implants. These new "bioceramics" were reviewed in January 1987.[5] Alumina powder, with a purity ranging from 99.5% to 99.9%, is compressed isostatically and fired at 1,500° C to 1,700° C to produce a hard, inert ceramic of high density. The monocrystalline form is similar to single-crystal sapphire with a hardness of nine on Mohs scale. A polycrystalline form of alumina ceramic, though not as dense or as hard as the single crystal form, is better suited to some implant applications. For tooth implants, the transparent monocrystalline alumina is preferred for the root section inserted into the jaw bones. The softer white polycrystalline alumina, which can be more readily shaped and contoured to match the natural teeth, works well as the exposed crown section. The extreme hardness, resistance to wear and chemical attack, and low coefficient of friction make monocrystalline alumina an excellent material for the ball and socket of artificial hip and knee joints.

Awareness of the limited domestic bauxite resources has led to extensive research programs for more than 40 years by industry and the Bureau of Mines to develop alternate sources of aluminum oxide for the production of primary aluminum. The presence of extensive clay resources has made these aluminum silicates a prime target of research, and the more recent work has centered on various processes for recovering the aluminum as a trichloride compound. The Toth Aluminum Corp. has reported commercial production of high purity $AlCl_3$ from Georgia kaolin at its Vacherie, LA, plant. The details of the carbochlorination process employed in the 5,000-ton-per-year plant were described.[6] The company was initially selling an aluminum chloride product rather than the proposed aluminum oxide. However, discussions have been reported between Toth and Alcoa regarding the possible sale to Toth of Alcoa's now-closed experimental smelter at Palestine, TX, designed to produce primary aluminum by direct reduction of aluminum chloride feed using the Alcoa Smelting Process.

Among the relatively low-cost mineral fillers used in plastics, rubber, wire insulation, and synthetic marble and onyx, alumina trihydrate (ATH) is unique in that it is compatible with most polymers, has a bright white color, and acts as a flame retardant and smoke suppressant. In the specialty alumina markets, growth in demand for ATH as a filler was second only to that of alumina in ceramics.[7] For the production of polyester-based synthetic onyx, Na_2O content, color, particle size, and particle size distribution of the ATH are all critical elements. The quality of the synthetic onyx can be improved in brightness, translucency, and color if the ratio of ground to unground ATH crystals and the specific surface area of the particles are closely controlled.

At the MRN-operated Trombetas bauxite mine on the Amazon River, Brazil, washing operations generate an annual tailings volume of about 18 million cubic meters with a solids content of 7% to 9%.[8] Mine capacity is 5 million tons per year of beneficiated bauxite after approximately 1.7 million tons of -400 mesh solids are removed in the washing plant. The handling and disposal of such a large volume of material required careful testing and planning. The plan selected used an intermediate settling pond where the tailings were allowed to thicken before being recovered by a dredge and pumped to the final impoundment cells in the mined-out areas. The cells were to be filled in two stages and after settling for 2 years, topsoil was to be spread and new vegetation started.

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[1]Physical scientist, Branch of Nonferrous Metals.

[2]Supervisory mineral data assistant, Branch of Nonferrous Metals.

[3]All quantities in this chapter are given in metric tons unless otherwise specified.

[4]Wouden, M. L., L. J. Froisland, and M. B. Shirts. Recovery of Alumina From Alunite by Acid Sulfation. Metall. Soc. AIME Tech. Paper A87-22, 1987, 10 pp.

[5]Boretos, J. W. Advances in Bioceramics. Adv. Ceram. Mater., v. 2, No. 1, Jan. 1987, pp. 15-22.

[6]McCallion, J. Carbo-chlorination of Georgia Clay Yields High Purity $AlCl_3$. Chem. Process., v. 50, No. 2, Feb. 1987, pp. 53-54.

[7]Sato, C., S. Kazama, and Y. Oda. New Developments in Alumina Trihydrate for Flame Retardant Filler. Paper in Light Metals 1987, ed. by R. D. Zabrezrik. Metall. Soc. AIME, Denver, CO, 1987, pp. 99-104.

[8]Lapa, R. P., and W. Cardoso. Tailings Disposal at the Trombetas Bauxite Mine. Paper in Light Metals 1988, ed. by L. G. Boxall. Metall. Soc. AIME, Phoenix, AZ, 1988, pp. 65-76.

Beryllium

By Deborah A. Kramer[1]

Domestic production of beryllium ore decreased slightly in 1987, but consumption of beryllium materials increased, particularly beryllium-copper alloys. Growth in the automotive electronics, computer electronics, and telecommunications markets was partially responsible for increased beryllium demand. Developmental work and feasibility studies were conducted on three beryllium ore properties in the United States and Canada, which, if successful, could increase the North American supply of beryllium raw materials. Exports of beryllium metal and imports of beryl ore increased significantly from those of 1986. Over 75% of the metal exports was shipped to Taiwan.

Beryllium materials continued to be used in advanced technology applications such as defense electronics, computers, microwave radar devices, and lasers. However, other materials were substituted for beryllium in aircraft brakes, one of its traditional applications.

Domestic Data Coverage.—Domestic production data for beryllium are developed by the Bureau of Mines from two separate, voluntary surveys of U.S. operations. Typical of these surveys is the "Beryllium Mineral Concentrate and Beryllium Ore" survey. Of the 11 operations to which a survey request was sent, all responded, representing 100% of the total mine shipments shown in tables 1 and 5.

Table 1.—Salient beryllium mineral statistics

(Short tons of beryllium metal equivalent unless otherwise specified)

	1983	1984	1985	1986	1987
United States:					
Beryllium-containing ores:					
Mine shipments	267	241	230	261	242
Imports for consumption, beryl[1]	88	53	66	60	92
Consumption, reported	280	360	316	318	356
Price, approximate, per short ton unit BeO, imported cobbed beryl at port of exportation	$126	$88	$87	$88	$84
Stocks, Dec. 31	281	226	199	195	181
World: Production[1]	[r]403	394	359	[p]396	[e]379

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Based on a beryllium metal equivalent of 4% in beryl.

Legislation and Government Programs.—In June, the General Services Administration (GSA) solicited bids to supply 60,000 pounds of beryllium metal to the National Defense Stockpile (NDS). GSA reportedly received bids from two companies, Brush Wellman Inc. and Advanced Metallurgy and Testing Corp. (AMT), to supply all or part of the 11,150 pounds of grade-A structural beryllium and 48,850 pounds of instrument-grade metal. At yearend, no contract to supply the metal had been awarded. Government stocks of beryllium materials in the NDS at yearend were beryl, 17,987 short tons; beryllium-copper master alloy, 7,387 tons; and beryllium metal, 290 tons. Stockpile goals for these materials were beryl, 18,000 tons; beryllium-copper master alloy, 7,900 tons; and beryllium metal, 400 tons.

The 100 most hazardous substances found in Superfund sites reportedly were ranked in 4 priority groups, based on chemical toxicity, frequency of occurrence at Superfund sites, and potential for human exposure. Beryllium was included in the first group of substances. Under section 110 of the Superfund Amendments and Reauthorization Act, 1986 (Public Law 99-499), the Environmental Protection Agency and the Department of Health and Human Services were required to develop toxicological profiles for the substances on the priority lists. A draft toxicological profile for beryllium was issued in October 1987. The profile was intended to characterize the toxicological and health effects information for beryllium and to identify and review pertinent literature.[2]

DOMESTIC PRODUCTION

Beryllium ore shipments declined from those of 1986. Production of beryllium metal and beryllium-copper master alloy increased significantly, but beryllium oxide ceramic production declined slightly.

The only major domestic producer of beryllium ores was Brush Wellman. The company mined bertrandite from its open pit in Spor Mountain, UT, and processed bertrandite, imported beryl, and domestic beryl into beryllium hydroxide at its mill in Delta, UT. Small quantities of beryl were recovered in the United States, principally as a byproduct during the mining of pegmatite minerals.

Drilling began early in the year at the Sierra Blanca Prospect near El Paso, TX, which was a joint venture operation between Cabot Corp. and Cyprus Minerals Co.

Cominco American Incorporated announced that it would spend up to $600,000 over the next 2 years to study the feasibility of its joint venture property in Juab County, UT. Cominco American's partner in the joint venture was Beryllium International Corp. Cominco American estimated that it would cost about $15 to $16 million to bring the property into production.

Cyprus and Cabot reportedly formed a new company, AMT, to produce beryllium metal. AMT would lease facilities from NGK Metals Corp. at Temple, PA, to produce beryllium metal for a small market segment. AMT also planned to develop new near-net-shape production technology and provide testing services for beryllium metal consumers. Plant startup was scheduled for yearend 1987.

CONSUMPTION AND USES

Consumption of beryllium in 1987 increased from that of 1986 because of strong demand in the electronics industry. Increased growth of the automotive electronics, telecommunications, and computer markets, which use beryllium components, were important in boosting domestic beryllium consumption.

Three principal products accounted for most of the beryllium consumed in the United States—beryllium-copper alloys, beryllium metal, and beryllium oxide. Beryllium-copper alloys, containing from 0.5% to 2.0% beryllium, represented the most widely used beryllium product, and they were used in applications such as aerospace, computer, defense, electrical machinery, oil and gas exploration, automotive electronics, and telecommunications. The principal use of beryllium metal was in aerospace and defense systems. Specific uses of beryllium include rocket motors, aircraft brakes, military targeting systems, inertial guidance systems, and infrared satellite surveillance. High-power electronic circuits, microwave radar devices, and lasers were some of the uses for beryllium oxide ceramics. All of these applications utilize the high-strength, lightweight, and high-thermal-conductivity properties of the metal and the oxide. Small quantities of beryllium were consumed in the form of aluminum- and nickel-base alloys.[3]

PRICES AND SPECIFICATIONS

Throughout the year, the price range for beryl ore quoted in Metals Week was $78 to $85 per short ton unit (20 pounds) of contained beryllium oxide. At yearend, the following prices for beryllium materials were quoted in American Metal Market, in dollars per pound, except for beryllium-copper master alloy, which was given in dollars per pound of contained beryllium:

Vacuum cast ingot, 97% pure	$225
Metal powder, in 5,000-pound lots and 97% pure	196
Beryllium-copper master alloy	160
Beryllium-copper casting alloy	$5.52- 6.30
Beryllium-copper in rod, bar, wire	8.90
Beryllium-copper in strip	8.00
Beryllium-aluminum alloy, in 100,000-pound lots	260
Beryllium oxide powder	55.70

Brush Wellman reportedly increased prices on beryllium oxide powder twice since January 1985, when the $55.70 price was effective, but it did not announce them in the press. Effective January 1, 1986, the price for beryllium oxide powder was $59.30 per pound; effective January 1, 1987, this price increased to $61.35 per pound.

FOREIGN TRADE

Exports of beryllium metal more than doubled from those of 1986. Exports of beryllium-copper alloys were combined with data for other copper alloy exports by the Bureau of the Census and could not be separately identified. Some beryllium-copper alloy exports were identified through the Journal of Commerce Trade Information Service-PIERS. This computer data base service reports materials transported by ship and may not reflect the total quantity of beryllium-copper alloys exported. According to PIERS, 261,788 pounds (gross weight) of beryllium-copper alloys was exported, principally to France and Taiwan.

Table 2.—U.S. exports of beryllium alloys, wrought or unwrought, and waste and scrap,[1] by country

Country	1986		1987	
	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)
Belgium-Luxembourg	560	$56	105	$68
Brazil	--	--	183	19
Canada	6,471	224	10,799	469
China	--	--	110	5
Finland	53	5	--	--
France	7,817	1,264	5,590	1,243
Germany, Federal Republic of	8,527	2,066	4,699	555
Hong Kong	--	--	6,000	26
Ireland	113	3	--	--
Israel	53	28	1,323	130
Jamaica	164	2	--	--
Japan	3,530	477	3,551	887
Korea, Republic of	2,253	22	1,063	48
Mexico	126	4	164	4
Netherlands	2,540	320	2,672	212
Pakistan	182	2	--	--
South Africa, Republic of	--	--	493	5
Spain	30,038	90	--	--
Switzerland	753	105	470	52
Taiwan	4,400	21	128,777	390
United Kingdom	11,363	2,697	4,371	886
Venezuela	587	4	--	--
Other	[r]26	[r]4	38	14
Total	79,556	7,394	170,408	5,013

[r]Revised.
[1]Consisting of beryllium lumps, single crystals, powder; beryllium-base alloy powder; and beryllium rods, sheets, and wire.

Source: Bureau of the Census.

Table 3.—U.S. imports for consumption of beryl, by country

Country	1986 Quantity (short tons)	1986 Value (thousands)	1987 Quantity (short tons)	1987 Value (thousands)
Argentina	20	$18	35	$33
Brazil	759	646	883	748
China	502	497	509	490
France	153	112	721	552
Hong Kong	--	--	50	49
Macao	6	4	--	--
Madagascar	13	8	--	--
Mozambique	18	12	--	--
South Africa, Republic of	39	27	--	--
United Kingdom	--	--	23	8
Zimbabwe	--	--	81	64
Total	1,510	1,324	2,302	1,944

Source: Bureau of the Census.

Table 4.—U.S. imports for consumption of beryllium metal and compounds

Year	Beryllium-copper master alloy		Beryllium, wrought		Beryllium, unwrought and waste and scrap		Beryllium oxide and carbonate		Beryllium compounds n.s.p.f.	
	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)	Qunatity (pounds)	Value (thousands)
1985	15,930	$67	769	$176	110,689	$89	2,532	$123	7,332	$135
1986	24,160	114	20,467	50	22,487	55	248	3	2,010	42
1987	53,802	246	92,422	290	18,294	159	6,669	99	29,424	90

Source: Bureau of the Census.

WORLD REVIEW

Brazil.—Brazil's Institute of Nuclear Energy (IEN) planned to begin small-scale production of beryllium metal by yearend. The proposed plant was expected to produce beryllium for use as a neutron moderator in a reactor that the IEN planned to construct to produce radioisotopes. Raw material for the beryllium plant reportedly will be provided by the Farquhar Foundation in the State of Minas Gerais. After an initial pilot-scale plant is completed and the operating parameters determined, the IEN planned to double the plant's capacity to 264 pounds per year. When in operation, it will be the only beryllium metal plant in market economy countries outside the United States.

Canada.—Hecla Mining of Canada Ltd. reportedly completed a market analysis and process development to recover beryllium from ore at the Thor Lake property in the Northwest Territories, which Hecla planned to develop in a joint venture with Highwood Resources Ltd. of Canada. Hecla approved the expenditure of $2.5 million in 1988 to construct a pilot plant to generate detailed engineering data for commercial plant development. The Thor Lake property contains approximately 1.8 million tons of ore reserves with an average grade of 0.76% beryllium oxide.

Zimbabwe.—CRM (Pvt.) Ltd. reportedly took over the activities of Mitmar (Pvt.) Ltd., the sole producer of beryl and mica. CRM planned to expand its beryl production and continue its exploration program for beryl.[4]

Table 5.—Beryl: World production, by country[1]

(Short tons)

Country	1983	1984	1985	1986[p]	1987[e]
Argentina	26	28	[e]17	[e]35	33
Brazil	1,039	1,551	967	[e]1,050	1,100
Madagascar[2]	[r]133	51	[e]55	[e]55	55
Mozambique	7	8	[e]7	[e]7	7
Portugal	3	11	2	(3)	--
Rwanda	35	49	30	(3)	--
South Africa, Republic of	23	1	6	3	3
U.S.S.R.[e]	2,100	2,100	2,100	2,100	2,100
United States[4] (mine shipments)	6,665	6,030	5,738	6,533	[5]6,062
Zimbabwe	52	21	42	114	120
Total	[r]10,083	9,850	8,964	9,897	9,480

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

[1]In addition to the countries listed, China produced beryl, and Bolivia and Namibia may also have produced beryl, but available information is inadequate to formulate reliable estimates of production. Nepal reports producing small amounts. Table includes data available through Apr. 29, 1988.

[2]Includes ornamental and industrial products.

[3]Revised to zero.

[4]Includes bertrandite ore, calculated as equivalent to beryl containing 11% BeO.

[5]Reported figure.

TECHNOLOGY

Research personnel at Los Alamos National Laboratory reportedly constructed a prototype laser-spark-source spectrometer that can detect as low as 10 billionths of a gram of beryllium in a small sample in less than 3 minutes. Conventional filter analyses may take up to 8 hours. A patent for the laser-spark-analysis method used in the instrument was issued to the U.S. Department of Energy. Los Alamos reportedly is seeking companies to commercially manufacture and market the new detectors.

Brush Wellman announced that it began a $4.3 million expansion of its facility for forming near-net-shape beryllium parts directly from powder. The expansion was intended to make the metal more cost competitive with competing materials. When the expanded facility becomes operational in early 1988, Brush Wellman will be capable of producing near-net-shape parts by combinations of cold die pressing, cold isostatic pressing, vacuum sintering, and/or hot isostatic pressing.

The National Aeronautics and Space Administration planned to replace the beryllium heat sink component in the brakes of the space shuttle with carbon. Carbon materials reportedly can withstand braking temperatures up to 3,000° F compared with beryllium, which can withstand temperatures up to 1,000° F. A carbon heat sink also was claimed to be lighter, less costly, and longer lasting than a beryllium heat sink. Substitution of carbon for beryllium in the space shuttle followed the changing specifications in braking systems for heavier aircraft; the C-5B cargo aircraft, F-14 fighter aircraft, and 757 passenger aircraft were equipped with carbon brakes.

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[1]Physical scientist, Branch of Nonferrous Metals.

[2]Toxicological Profile for Beryllium (U.S. EPA contract 68-03-3228, Syracuse Res. Corp.). Oak Ridge Natl. Lab., Oct. 1987, 94 pp.

[3]Taylor, B. A Review of Beryllium—The Metal, Its Oxide and Alloys. Ind. Miner. (London), No. 235, Apr. 1987, pp. 67-73.

[4]Industrial Minerals (London). Beryl and Mica Takeover. No. 234, Mar. 1987, p. 15.

Bismuth

By James F. Carlin, Jr.[1]

Domestic production of bismuth was derived by processing bismuth-rich residues extracted during the processing of intermediate smelter products, such as lead bullion, which contain bismuth as a minor constituent. One company accounted for all primary refinery production in the United States. The aluminum, chemical, cosmetic, pharmaceutical, and steel industries were major users. As world demand for bismuth increased, bismuth-rich feedstocks for the single U.S. refinery became scarcer, causing a decline in production. Domestic consumption rose substantially to the highest level recorded, reflecting the general economic improvement, especially in capital goods markets. Prices rose through most of the year owing to increasing world consumption.

The potential for the use of bismuth in advanced-materials applications was increased through research on medical applications and free-machining stainless steels.

Domestic Data Coverage.—Domestic production data for bismuth are developed by the Bureau of Mines from a voluntary survey of the only U.S. bismuth refinery. To avoid disclosing company proprietary information, production data are not published.

Legislation and Government Programs.—Government stocks remained at 2,081,298 pounds. The National Defense Stockpile goal remained at 2,200,000 pounds.

Federal laws provided a depletion allowance of 22% for domestic operations and 14% for U.S. companies producing in other countries.

Table 1.—Salient bismuth statistics

(Thousand pounds unless otherwise specified)

	1983	1984	1985	1986	1987
United States:					
Consumption	2,285	2,648	2,644	2,919	3,521
Exports[1]	306	312	269	93	84
Imports, general	1,972	1,948	1,999	2,490	3,485
Price, average, domestic dealer, per pound	$1.72	$4.27	$5.18	$3.25	$3.65
Stocks, Dec. 31: Consumer	577	480	507	763	648
World: Mine production[2]	8,777	8,256	10,452	[p]8,711	[e]8,956

[e]Estimated. [p]Preliminary.
[1]Includes bismuth, bismuth alloys, and waste and scrap.
[2]Excludes the United States.

DOMESTIC PRODUCTION

One primary refinery operated by ASARCO Incorporated at Omaha, NE, accounted for all primary production. Production declined in 1987. Small quantities of secondary bismuth were produced by several firms from bismuth scrap materials.

CONSUMPTION AND USES

Domestic consumption rose more than 21% to 3.5 million pounds, a new record high, reflecting a continuation of the general economic improvement and favorable demand in specific end-use markets. The category of bismuth metallurgical additives, especially free-machining stainless steels, experienced particularly strong demand growth.

Table 2.—Bismuth metal consumed in the United States, by use

(Thousand pounds)

Use	1983	1984	1985	1986	1987
Chemicals[1]	1,104	1,573	1,325	1,462	1,650
Fusible alloys	623	609	610	639	736
Metallurgical additives	523	424	668	772	1,088
Other alloys	20	20	21	28	24
Other[2]	15	22	20	18	23
Total	2,285	2,648	2,644	2,919	3,521

[1]Includes industrial and laboratory chemicals, comestics, and pharmaceuticals.
[2]Includes experimental.

PRICES

Prices for bismuth quoted by Metals Week at the beginning of the year ranged from $2.65 to $2.80 per pound, and rose generally throughout the year. By yearend, price quotes increased to a range of $4.70 to $4.80 per pound. The price increase was attributed to increased demand for bismuth in the industrialized countries.

FOREIGN TRADE

Exports of bismuth remained in the lower range that prevailed in the early 1980's. Imports rose significantly, in line with the increased usage, and continued to be the major source of supply for domestic consumption. Peru emerged as the leading U.S. supplier, as the result of a substantial increase over 1986 shipments. Belgium-Luxembourg and Mexico ranked close behind as import suppliers.

Starting January 1, 1987, the U.S. import duties for bismuth were unwrought metal (TSUS 632.10), free for most favored nations (MFN) and 7.5% ad valorem for non-MFN; alloys (TSUS 632.66), 5.5% ad valorem for MFN and 45% ad valorem for non-MFN; and compounds (TSUS 418.00 and 423.80), 7% ad valorem for MFN and 35% ad valorem for non-MFN.

Table 3.—U.S. exports of bismuth, bismuth alloys, and waste and scrap, by country

Country	1986 Quantity (pounds)	1986 Value (thousands)	1987 Quantity (pounds)	1987 Value (thousands)
Australia	--	--	22	$2
Belgium-Luxembourg	216	$1	--	--
Brazil	3,613	26	--	--
Canada	33,719	252	37,509	337
Egypt	2,211	15	--	--
France	--	--	256	25
Germany, Federal Republic of	730	7	6,468	29
Greece	--	--	25	2
Hong Kong	37	3	2,223	15
India	--	--	132	5
Ireland	98	1	--	--
Israel	--	--	63	2
Italy	--	--	12	2
Japan	4,804	29	189	7
Korea, Republic of	--	--	1,381	13
Malaysia	--	--	1,049	104
Mexico	100	7	1,070	7
Netherlands	1,602	15	--	--
Peru	104	1	--	--
Singapore	2,600	11	1,729	11
Switzerland	--	--	68	6
Taiwan	3,206	16	6,100	19
Thailand	509	3	--	--
United Arab Emirates	--	--	440	2
United Kingdom	39,357	28	24,949	53
Total	92,906	415	83,685	641

Source: Bureau of the Census.

Table 4.—U.S. general imports[1] of metallic bismuth, by country

Country	1986 Quantity (pounds)	1986 Value (thousands)	1987 Quantity (pounds)	1987 Value (thousands)
Belgium-Luxembourg	847,465	$2,526	959,030	$2,866
Canada	73,138	381	114,996	288
China	54,249	150	16,529	52
France	4,409	31	--	--
Germany, Federal Republic of	4,739	29	20,307	22
Hong Kong	11,229	34	4,741	14
Italy	--	--	7,176	26
Japan	219,634	581	35,840	69
Korea, Republic of	48,490	141	119,550	281
Mexico	800,049	1,955	862,597	2,359
Netherlands	12,126	39	55,453	230
Peru	235,849	387	971,003	1,559
United Kingdom	178,257	641	317,491	1,003
Total	2,489,634	6,895	3,484,713	8,769

[1]General imports and imports for consumption were the same in 1986 and 1987.

Source: Bureau of the Census.

WORLD REVIEW

World mine production of bismuth contained in lead and other metal ores increased slightly. Bismuth was produced primarily as a byproduct of other metals, mostly lead, and only in Bolivia was bismuth actually mined for itself. All bismuth-rich mine-source materials in Australia have been stockpiled there in recent years. Mexico experienced a significant increase in output, as production problems of the prior year were reportedly solved.

Major world refiners of bismuth included Dowa Mining Co. Ltd., Mitsui Mining & Smelting Co. Ltd., and Nippon Mining Co. Ltd. in Japan; Empresa Minera del Centro del Péru in Peru; Industria Minera México S.A. and Industrias Peñoles S.A. de C.V. in Mexico; Korea Tungsten Mining Co. Ltd. in the Republic of Korea; Mining and Chemical Products Ltd. in the United Kingdom; and Métallurgie Hoboken-Overpelt S.A. and Société Industrielle d'Etudes et d'Exploitations Chimique in Belgium.

Table 5.—Bismuth: World mine production, by country[1]

(Thousand pounds)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Australia (in concentrates)[e 3]	3,110	2,980	3,090	2,200	2,400
Bolivia (in concentrates)	13	7	351	95	5
Canada[4]	445	366	443	573	490
China (in ore)[e]	570	570	570	570	570
Japan (metal)	1,263	1,241	1,415	1,411	1,200
Korea, Republic of (metal)	220	278	298	300	220
Mexico[5]	1,202	955	2,039	1,651	2,150
Peru[5]	1,495	1,433	1,731	[e]1,500	1,400
Romania (in ore)[e]	180	180	180	180	170
U.S.S.R. (metal)[e]	180	180	185	185	190
United States (metal)	W	W	W	W	W
Yugoslavia (metal)	99	66	150	46	[6]161
Total	8,777	8,256	10,452	8,711	8,956

[e]Estimated. [p]Preliminary. W Withheld to avoid disclosing company proprietary data; not included in "Total."
[1]Table includes data available through Apr. 8, 1988. Bismuth is produced primarily as a byproduct of other metals, mostly lead, and only in Bolivia is it mined for itself.
[2]In addition to the countries listed, Brazil, Bulgaria, France, the German Democratic Republic, the Federal Republic of Germany, Mozambique, and Namibia are believed to have produced bismuth, but available information is inadequate for formulation of reliable estimates of output levels.
[3]In recent years all bismuth-rich residues have reportedly been stockpiled owing to relatively low prices. Data are for fiscal years ending June 30 of that stated.
[4]Refined metal and bullion plus recoverable bismuth content of exported concentrate.
[5]Bismuth content of refined metal, bullion, and alloys produced indigenously plus recoverable bismuth content of ores and concentrates exported for processing.
[6]Reported figure.

TECHNOLOGY

Research at the University of Virginia identified a bacterium, campylobacter pyloridis, that appears to cause gastric inflammations leading to ulcers. The research indicated that ulcer patients given bismuth-containing drugs show a markedly better recovery rate than those given other traditional ulcer medications.[2]

A major producer of stainless steels in Japan developed a new stainless steel grade, Super Starcut, with a small amount of bismuth added, that reportedly imparts excellent free-machining properties as well as improved mechanical properties, corrosion resistance, and hot and cold workability.[3]

[1]Physical scientist, Branch of Nonferrous Metals.
[2]Business Week. Aug. 3, 1987, p. 46.
[3]The Bulletin of the Bismuth Institute. No. 50, 1986, pp. 1-5.

Boron

By Phyllis A. Lyday[1]

U.S. production and sales of boron minerals and chemicals increased during the year. Glass fiber insulation was the largest use for borates, followed by sales to distributors, textile-grade glass fibers, and borosilicate glasses.

California was the only domestic source of boron minerals. The United States continued to provide essentially all of its own supply while maintaining a strong position as an exporter of sodium borate products and boric acid to foreign markets.

Supplementary U.S. imports of Turkish calcium borate and calcium-sodium borate ores and boric acid, primarily for various glass uses, continued.

Domestic Data Coverage.—Domestic data for boron are developed by the Bureau of Mines from two separate, voluntary surveys of U.S. operations. Of the three operations to which a production survey request was sent, all responded, representing 100% of the total boron sold or used shown in tables 1 and 7. A Bureau canvass of the three U.S. companies also collected data on domestic sales of boron minerals and compounds shown in tables 2 and 3.

Table 1.—Salient statistics of boron minerals and compounds

(Thousand short tons and thousand dollars)

	1983	1984	1985	1986	1987
United States:					
Sold or used by producers:					
Quantity:					
Gross weight[1]	1,303	1,367	1,269	1,251	1,385
Boron oxide (B_2O_3) content	637	667	636	629	689
Value	$439,181	$456,687	$404,775	$426,086	$475,092
Exports:					
Boric acid:					
Quantity[2]	38	45	49	42	67
Value	$20,688	$24,402	$21,598	$23,562	$34,180
Sodium borates:					
Quantity[3]	[4]225	576	623	624	609
Value[e]	$51,000	$134,000	$151,000	$161,000	$243,600
Imports for consumption:[5]					
Boric acid:					
Quantity	4	4	10	6	2
Value	$3,456	$3,449	$5,121	$3,824	$2,900
Colemanite:					
Quantity	16	20	33	16	8
Value	$8,309	$12,123	$24,620	$8,770	$2,763
Ulexite:					
Quantity	11	47	31	42	52
Value	$3,116	$10,202	$11,120	$17,766	$20,597
Consumption: Boron oxide (B_2O_3) content	341	375	360	338	369
World: Production	2,464	2,776	2,727	[p]2,687	[e]2,898

[e]Estimated. [p]Preliminary.
[1]Minerals and compounds sold or used by producers, including both actual mine production and marketable products.
[2]Includes orthoboric and anhydrous boric acid.
[3]1982-83, U.S. Exporters; 1984-87, The Journal of Commerce Port Import/Export Reporting Service.
[4]Refined.
[5]Boron oxide (B_2O_3) content. Data for 1983-84 revised to indicate conversion to B_2O_3 content. A small amount of borax was also imported.

Legislation and Government Programs.—Boric acid is a component of cosmetics and pharmaceuticals and is also used in numerous industrial processes. A 2-year study by the U.S. Department of Health and Human Services revealed that there was no evidence of carcinogenicity in mice fed 99.7%-pure boric acid at doses of 2,500 or 5,000 parts per million.[2]

The U.S. Department of Transportation published final rules entitled "Hazardous Substances." A list of materials and their reportable quantities that would be regulated as hazardous materials included zinc borate. Because the role of the Research and Special Programs Administration of Transportation in regulating hazardous substances is directly tied to the Environmental Protection Agency's ongoing hazardous substances responsibility, amendments would be made in Hazardous Materials Regulations as necessary to satisfy the intent of Congress expressed in the Superfund Amendments and Reauthorization Act (SARA) of 1986 (Public Law 99-499). Because the amendments adopted were mandated by SARA, Transportation determined that notice and public procedure were contrary to the public interest.[3]

On January 1, 1985, the California Assembly bill No. 3497 transferred jurisdiction over the Insulation Program from the California Energy Commission to the Bureau of Home Furnishings and Thermal Insulation. This law stated that no material shall be sold or installed in the State that is not certified by the manufacturer to have been tested and passed in accordance with the Bureau of Home Furnishings and Thermal Insulation standards. The State set up its National Voluntary Laboratory Accreditation Program, National Bureau of Standards, to perform fire-related tests on 13 generic types of insulation products, including cellulose. Two important types of fire-related tests for cellulose insulation included the critical radiant flux test and the smoldering resistance test. Chemicals used most often by cellulose insulation manufacturers in California are boric acid and borax.[4]

Insulation must meet standards for thermal resistance, fire safety, corrosion, and fungi resistance; for dimensional stability, odor, pliability, settling, bond strength, and deflection; and for air erosion, as appropriate. The Bureau of Home Furnishings and Thermal Insulation periodically publishes a Directory of Insulation Materials that have been certified by the Bureau, on the basis of approved laboratory tests, to be in compliance with the State law. The May 1987 directory listed numbers of certified companies in the following areas: 10 companies in cellulose insulation, 6 in mineral fiber, and 9 in mineral fiber blanket.[5]

The National Strategic Materials and Minerals Program Advisory Committee, consisting of 26 advisors, recommended to the Secretary of the U.S. Department of the Interior that the California Desert Protection Act withdraw excessive desert land from mining. The committee stated that the unique geologic terrain has tremendous potential for the discovery of additional boron, gold, and rare-earth deposits.[6]

DOMESTIC PRODUCTION

The majority of the boron production continued to be from Kern County, CA, with the balance from San Bernardino County.

American Borate Co., a wholly owned subsidiary of Owens-Corning Fiberglas Corp., continued sales of colemanite and probertite-ulexite.

Kerr-McGee Chemical Corp. operated the Trona and Westend plants at Searles Lake, San Bernardino County, to produce refined sodium borate compounds and boric acid from the mineral-rich lake brines. At the Trona plant, a differential evaporative process was used to produce boric acid, pentahydrate borax, and anhydrous borax. Byproducts included potassium compounds. The Westend plant continued production of sodium borates by a carbonation process that also produced lime, soda ash, and sodium sulfate. Kerr-McGee produced boron specialty chemicals at other locations in the form of boron trichloride, boron tribromide, and elemental boron. Boron trichloride is the raw material required to manufacture boron filaments that strengthen aerospace products and sporting goods.

United States Borax & Chemical Corp., a subsidiary of RTZ Corp. PLC, United Kingdom, continued to be the primary world supplier of sodium borates. U.S. Borax mined and processed refined hydrated sodium borates, its anhydrous derivatives, and anhydrous boric acid at Boron, in Kern County, CA.

A second plant at Boron used a proprietary process to produce technical-grade and textile-fiberglass-grade (TFG) boric acid from U.S. Borax's extensive kernite ore reserves. Kernite required less energy than borax because it was processed from an ore, rather than a processed sodium borate. The TFG boric acid was produced to compete with imported colemanite used in textile fiberglass manufacture.

The majority of material was shipped to U.S. Borax's storage, Wilmington, CA, which also produced some boron specialty chemicals and borated soap products.

U.S. Borax announced that Ottawa Silica Co., acquired by RTZ Borax Ltd. in 1986, was to merge with Pennsylvania Glass Sand Corp., acquired in 1985, to form a subsidiary, US Silica, the largest silica sand producer in the United States.

Development of the Fort Cady colemanite deposit in the Mojave Desert near Barstow, CA, continued. Mountain States Mineral Enterprises Inc., Tucson, AZ, which acquired the project from Duval Corp., concluded process confirmation work in 1987, which was started earlier by Duval. The process involves using in situ leach of the colemanite deposit to recover boric acid. Mountain States Mineral Enterprises with Blackbird Resources Inc., Toronto, Canada, began a pilot commercial plant and a multiwell test program in 1987. Following completion of the test program in early 1988, a feasibility study containing a comprehensive marketing study will be accomplished prior to proceeding to commercial production. In excess of $50 million is expected to be expended in bringing the property into production at an approximate rate of 100,000 short tons of boric acid per annum. Blackbird Resources has an agreement with Mountain States Mineral Enterprises to acquire rights to the project after completion of the feasibility study. Blackbird Resources merged with Galveston Resources Ltd., Vancouver, Canada, in 1987.

CONSUMPTION AND USES

U.S. consumption of borates increased. Glass fiber insulation and glass fiber primarily used as reinforcement for plastics continued to be the largest consuming industries.

The use of borates in glass fiber thermal insulation, primarily used in new construction, was the largest area of demand for borates. Cellulosic insulation, the seventh largest area of demand, decreased in demand.

The second major market for borates, manufacturing high-tensile-strength glass fiber materials for use in a range of products, showed an apparent decrease in demand possibly because of lower colemanite imports and usage of domestic stocks. Fiberglass accounts for approximately 90% of the reinforced plastic market. The two most common reinforcement grades of glass fiber are "E," electrical, and "S," high strength, grades. E-glass provides a high strength-to-weight ratio, good fatigue resistance, outstanding dielectric properties, retention of 50% tensile strength to 650° C, and excellent chemical, corrosion, and environmental resistance. The properties are made even more attractive by the price, which is often less than $1 per pound. S-glass offers some strength advantages, but at up to four times the price of E-glass.[7]

Omni Fiberglas Corp., Chino, CA, a Koppers Co. Inc. subsidiary, began supplying fiberglass during 1987. Established makers of the glass reinforcing agents were CertainTeed Corp., Manville Corp., Owens-Corning, and PPG Industries Inc. Thermoset unsaturated polyester and epoxy resins reinforced with glass in the form of chop, filament, or flake were used as high-performance composite materials. High-volume composite applications are replacing traditional metals in automobiles.

New fabricating processes have made expensive boron containing reinforced resin systems competitive. Carbon and glass-fiber-reinforced high-temperature thermoplastics have replaced steel and specialty alloys in four components of the Ferrari Formula I engine: the oil pump, turbo inlet, turbo impeller, and the water-pump impeller. The composites were selected because of their inherent high-temperature resistance, high mechanical strength, wear resistance, and resistance to oil, grease, and corrosion. Additional factors were the design flexibility allowed by the use of plastics and the high-speed production of complex parts via injection molding.[8]

Shortages of glass fiber supplies affected fabricators in the marine and construction markets during 1987. Suppliers' plans for additional capacity include greater manufacturing efficiencies, conversion of furnaces to produce the reinforcements for which demand is greatest, and diverting capacity from overseas plants to the United States. Owens-Corning planned an expansion of capacity at the Anderson, SC, and Amarillo, TX, plants. The expansion, to be achieved by improving manufacturing efficiency, will increase capacity by an estimated 6%. If demand warrants, Owens-Corning could restart the Jackson, TN, plant that was closed in February, which could supply 11% of the industry's capacity. PPG announced plans to rebuild furnaces at Shelby, NC, to gain incremental capacity.[9]

One study predicted that advanced polymer composites will increase at an annual rate of 10%, rising to $3.4 billion in 1996. Matrix materials for the advanced polymer composites included a variety of thermoplastic and thermosetting resins. The matrix is reinforced with fibers of carbon or graphite, high-performance glass, aramid, boron, quartz, ceramic, or metal.[10]

The Ceramic Industry magazine canvassed 260 companies that participated in a survey to provide actual and estimated figures for the "5th Annual Giants in Ceramics/USA" survey. Sales in 1986 in glass were $17,462 million. Fiberglass was estimated to be 23% of the value of sales. PPG and Owens-Corning were estimated as having the highest sales value.[11]

Consumption of borates in borosilicate glasses remained the third major end use and demand decreased. Boron added to glass reduced the viscosity of the melt and assisted with fiber formation. In 1989, the Defense Waste Processing Facility will begin testing, and by 1990, it planned to be mixing 33 million gallons of radioactive liquid and sludge with borosilicate glass and pouring the material into stainless steel canisters. The canisters will be stored in racks cooled by air circulation, until a permanent site can be approved.[12]

The fourth major end use of boron compounds was cleaning and bleaching. Boron compounds continued to find application in the manufacture of biological growth control chemicals for use in water treatment, algicides, fertilizers, herbicides, and insecticides. Boron can be applied as a spray and incorporated in herbicides, fertilizers, and irrigation water.

Boron compounds were also used in metallurgical processes as fluxes, as shielding slag in the nonferrous metallurgical industry, and as components in electroplating baths. Small amounts of boron and ferroboron were constituents of certain nonferrous alloys and specialty steels, respectively.

During 1987, two companies produced neodymium-iron-boron magnets, which have one-half the size and weight, but with equivalent induction and magnetic field, of samarium-cobalt magnets. Sumitomo Special Metals of Japan first began commercial production of their Neomax magnets in 1983. Neomax is produced by a powder metallurgy route similar to the technique used to produce the samarium-cobalt magnets. General Motors Corp. produces the Magnaquench magnets by a spin-melting method, which was expected to prove more cost effective and efficient, although initial development capitalization cost was high. The melt spin route has the advantage of being a continuous operating process providing a greater flexibility in alloy formulations. The resulting alloys tend to have an improved coercive force, fewer effects from corrosion, and better yields. General Motors installed the smaller starter motors without sacrificing power. General Motors invested $60 million in production of the magnets and uses about 20% of production.[13]

Major producers of fluoboric acid and its tin and lead salts were General Chemical Corp., Chemtech Industries Inc.'s Harstan Div., CP Chemicals, Harshaw/Filtrol Partnership, and Fidelity Chemical Products Corp. Primary usage was in printed circuit boards where fluoborate is used in solder plating applications.[14]

Miscellaneous uses of boron included high-quality filament, such as that produced by Avco Specialty Materials Div. that reported its Lowell, MA, facility can produce 35,000 pounds per year of boron filament and over 50,000 pounds per year of boron-epoxy tape. A tungsten substrate wire undergoes vapor-deposition from boron trichloride and hydrogen to produce boron filaments. These filaments are used in a variety of products, primarily aircraft structures, which include the F-15 horizontal and vertical stabilizers, the F-14 horizontal stabilizer, the B-1B *Longeron, Hawk* series and *Sea Stallion* helicopters, the *Mirage* 2000 and 4000, and the space shuttle. The relatively high cost and large diameter of boron fibers limited the application of this material.[15]

S. B. Chemicals Ltd. began production of elemental amorphous boron at a new plant in Franklin Park, IL. Two grades of material will be produced, a 90% to 92% purity and a 95% purity, using a proprietary technology.[16]

Covan Ltd. announced construction of a 3-million-pound-per-year sodium borohydride facility at its plantsite and corporate headquarters in Conshohocken, PA. Covan is a limited partnership recently formed by members of the bleaching and specialty chemicals industries to provide a second source of sodium borohydride in North America. The Ventron Div. of Morton Thiokol Inc. is also a producer. Sodium borohydride is a strong reducing agent whose special formulations are used for producing bleaching solutions at pulp and textile mills, for cleaning metal surfaces, and for purifying and manufacturing chemicals in specialty chemical processes. Another significant application is in the cleaning of process waste streams. Sodium borohydride is also used to produce diborane, which is used to produce high-energy fuels.[17]

U.S. Borax marketed disodium octaborate tetrahydrate as a specially formulated wood preservative (EPA Reg. No. 1624-39), which protects wood from fungal and insect attack in above-ground uses. The material can be handled without special precautions. The wood can be treated with the borate by natural diffusion or through pressure treatment.

Table 2.—U.S. consumption of boron minerals and compounds, by end use

(Short tons of boron oxide content)[1]

End use	1986	1987
Agriculture	14,821	14,821
Borosilicate glasses	30,761	30,818
Enamels, frits, glazes	11,755	12,365
Fire retardants:		
Cellulosic insulation	18,917	12,971
Other	417	1,065
Glass fiber insulation	118,162	123,165
Metallurgy	3,089	4,223
Miscellaneous uses	27,601	20,735
Nuclear applications	1,079	590
Soaps and detergents	24,498	24,251
Sold to distributors, end use unknown	37,268	85,067
Textile-grade glass fibers	49,632	38,445
Total	338,000	368,516

[1]Includes imports of borax, boric acid, colemanite, and ulexite.

Table 3.—U.S. consumption of orthoboric acid, by end use

(Short tons of boron oxide content)[1]

End use	1986	1987
Agriculture	251	74
Borosilicate glasses	8,564	4,432
Enamels, frits, glazes	1,199	1,959
Fire retardants:		
Cellulosic insulation	3,882	1,220
Other	402	1,065
Insulation-grade glass fibers	134	125
Metallurgy	138	400
Miscellaneous uses	10,405	9,598
Nuclear applications	897	590
Soaps and detergents	539	333
Sold to distributors, end use unknown	16,358	29,090
Textile-grade glass fibers	25,242	26,764
Total	68,011	75,650

[1]Includes imports.

PRICES

Prices for borax pentahydrate and decahydrate borax decreased. Other prices remained at 1986 levels.

Table 4.—Borate prices per short ton[1]

Product	Price, Dec. 31, 1987 (rounded dollars)
Borax, technical, anhydrous, 99%, bulk, carlots, works[2]	602
Borax, technical, anhydrous, 99%, bags, carlots, works[2]	647
Borax, technical, granular, decahydrate, 99.5%, bags, carlots, works[2]	243
Borax, technical, granular, decahydrate, 99.5%, bulk, carlots, works[2]	198
Borax, technical, granular, pentahydrate, 99.5%, bags, carlots, works[2]	271
Borax, technical, granular, pentahydrate, 99.5%, bulk, carlots, works[2]	226
Boric acid, technical, granular, 99.9%, bags, carlots, works[2]	614
Boric acid, technical, granular, 99.9%, bulk, carlots, works[2]	569
Boric acid, United States Borax & Chemical Corp., high-purity anhydrous, 99% B_2O_3, 100-pound bags, carlots, Boron, CA	2,300
Colemanite, American Borate Co., calcined, minus 70-mesh, 45% B_2O_3, bulk, f.o.b. railcars, Dunn, CA	502
Colemanite, American Borate Co., concentrate (uncalcined), minus 70-mesh, 38% B_2O_3 f.o.b., Dunn, CA	327
Colemanite, Turkish, 40% to 42% B_2O_3, ground to a minus 70-mesh, f.o.b. railcars, Kings Creek, SC	420

[1]U.S. f.o.b. plant or port prices per short ton of product. Other conditions of final preparation, transportation, quantities, and qualities not stated are subject to negotiation and/or somewhat different price quotations.
[2]Chemical Marketing Reporter. Current Prices of Chemicals and Related Materials. V. 226, No. 27, Dec. 28, 1987, p. 29.

FOREIGN TRADE

Industry sources estimate that over 100,000 tons of borax decahydrate, pentahydrate, and boric acid was shipped to China in 1987. Owing to the lack of adequate bulk handling facilities in China, the product was bagged for shipment by the borate producers and by independent distributors. The reasons for the unprecedented demand remain obscure.

The decrease in value of the U.S. dollar on the world market is expected to have a positive effect on the export of borates to Europe. The major competitor, Turkey, has a currency linked with the European currencies, and has less of a competitive position with exports because of currency differences; thereby giving U.S. exports an advantage.

Table 5.—U.S. exports of boric acid and refined sodium borate compounds, by country

Country	1986			1987		
	Boric acid[1]		Sodium borates[2] (short tons)	Boric acid[1]		Sodium borates[2] (short tons)
	Quantity (short tons)	Value (thousands)		Quantity (short tons)	Value (thousands)	
Argentina	--	--	20	--	--	--
Australia	1,230	$575	7,406	1,877	$899	8,762
Bangladish	--	--	--	30	18	39
Belgium-Luxembourg	--	--	148	63	42	175
Brazil	12	10	2,545	72	49	5,184
Canada	5,426	2,892	[3]55,205	5,736	2,889	[3]36,600
Chile	--	--	111	3	4	18
China	--	--	--	2,703	1,365	52,422
Colombia	118	59	4,121	185	124	2,625
Costa Rica	1	3	375	12	7	303
Denmark	--	--	3	--	--	--
Dominican Republic	--	--	109	2	2	5
Ecuador	--	--	719	--	--	906
El Salvador	--	--	460	12	4	6
France	2,794	1,767	--	622	373	57
Germany, Federal Republic of	--	--	661	--	--	--
Guatemala	--	--	65	7	3	80
Haiti	13	5	133	--	--	134
Honduras	--	--	140	--	--	70
Hong Kong	277	161	2,974	15,446	7,009	49,203
India	--	--	17,423	--	--	5,424
Indonesia	179	97	4,051	214	123	5,271
Israel	60	34	413	57	50	262

See footnotes at end of table.

Table 5.—U.S. exports of boric acid and refined sodium borate compounds, by country —Continued

Country	1986 Boric acid[1] Quantity (short tons)	1986 Boric acid[1] Value (thousands)	1986 Sodium borates[2] (short tons)	1987 Boric acid[1] Quantity (short tons)	1987 Boric acid[1] Value (thousands)	1987 Sodium borates[2] (short tons)
Jamaica	--	--	--	$9	3	--
Japan	22,266	$12,611	55,242	25,265	13,903	$54,891
Korea, Republic of	2,294	1,326	18,662	3,662	1,710	21,591
Malaysia	9	18	5,004	130	75	4,602
Mexico	2,968	1,322	[3]17,076	3,734	1,707	[3]73,970
Netherlands	494	287	355,003	335	188	225,935
New Zealand	797	403	2,132	918	454	3,166
Pakistan	--	--	471	6	2	271
Panama	3	5	54	18	8	47
Papua New Guinea	131	60	253	110	51	514
Peru	11	10	61	39	18	104
Philippines	92	80	1,310	114	87	2,053
Romania	--	--	--	371	224	--
Saudi Arabia	8	5	268	4	5	480
Singapore	24	12	1,607	278	172	3,808
South Africa, Republic of	111	98	4,389	146	101	1,876
Spain	--	--	46,190	--	--	28,447
Sri Lanka	11	6	20	21	12	20
Sweden	21	12	--	--	--	1
Taiwan	2,195	1,241	14,977	2,690	1,215	15,720
Thailand	198	129	1,137	158	108	1,246
Trinidad and Tobago	--	--	3	--	--	--
United Kingdom	69	124	1,731	--	--	89
Uruguay	4	4	39	7	4	20
Venezuela	312	185	1,283	1,528	1,154	1,999
Zimbabwe	4	3	33	10	6	--
Other	25	16	30	21	9	496
Total[4]	42,178	23,562	624,057	66,614	34,180	608,893

[1]Bureau of the Census.
[2]The Journal of Commerce Port Import/Export Reporting Service data.
[3]U.S. exporters of sodium borates.
[4]Data may not add to totals shown because of independent rounding.

Table 6.—U.S. imports for consumption of boric acid, by country

Country	1986 Quantity (short tons)	1986 Value[1] (thousands)	1987 Quantity (short tons)	1987 Value[1] (thousands)
Brazil	16	$13	--	--
Canada	25	29	18	$13
Chile	--	--	23	11
China	1	1	--	--
France	218	261	40	39
Germany, Federal Republic of	68	109	2	10
Italy	2,342	1,371	2,094	1,460
Japan	([2])	2	25	29
Turkey	3,461	1,480	--	--
United Kingdom	9	558	39	1,338
Total	[3]6,141	3,824	2,241	2,900

[1]U.S. Customs declared values.
[2]Less than 1/2 unit.
[3]Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

WORLD REVIEW

Owens-Corning, based in Toledo, OH, is the world's largest producer of glass fibers, with more than 80 plants worldwide that use boron in glass manufacture. Glass wool insulation products are manufactured in Vice, Belgium, through a wholly owned subsidiary, Deutsche Owens-Corning Glasswool, with headquarters at Taunusstein, Federal Republic of Germany. European Owens-Corning has six European subsidiaries manufacturing glass fiber, NV Owens-Corning SA at Battice, Belgium; Owens-Corning Fiberglas S.A. at L'Ardoise Laudun, France; Norsk Glassfiber A/S at Birkeland, Norway; Owens-Corning Fibreglas España S.A. at San Vicente, Spain; Owens-Corning Fiberglas Netherlands BV at Apeldoorn, Netherlands; and Scandinavian Fiberglas A/B, Sweden.[18]

China.—About 2,000 tons per year of ulexite is produced at Da Qaidam Lake, primarily for export to Japan. Brine in the Xiao Qaidam Lake was reported to contain 3 to 4 grams per liter of boron oxide over a 13.5-square-mile area. In addition, ulexite deposits containing between 1% and 30% boron oxide are found at the lake. The source of the borates is hot springs and mud volcanoes that drain into the Tatalin River. Concentrations of spring waters in the area contain between 55 and 470 milligrams per liter of boron oxide.[19]

Europe.—Boron oxide used in glass in Europe was reported to be used in glass wool, 34%; reinforced glass fibers, 33%; borosilicate glass, 32%; and other, 1%. Consumption of boron oxide in borosilicate glass has risen between 1981 and 1986, while consumption for glass wool decreased in the same period. About 80% of reinforcement glass fibers is consumed in plastics.[20]

France.—The second largest glass producer in the world, the Saint-Gobain Group, headquartered in Paris, has five glass fiber operations (using boron in glass production) at various locations in Europe in addition to Pilkington Insulation Ltd. in the United Kingdom. Glass wool was produced by Isover Saint-Gobain of France, Balzaretti Modigliani S.p.A. in Italy, Isover-Glaceries de Saint-Roch of the Netherlands, Grunzweig und Hartmann Glasfaser AG of the Federal Republic of Germany, and Cristaleria Espanola S.A. of Spain. Three other operating subsidiaries also produce glass fibers: Vetrotex Italia S.p.A. near Milan, Italy; Gevetex Textilglas GmbH at Herzogenrath, the Federal Republic of Germany, and Vetrotex Saint-Gobain, based at Chambery, France.[21]

Italy.—Società Chimica Larderello S.p.A. (SCL), part of the EniChem Group through EniChem Anic, was a producer of boric acid and borates at two plants in Larderello, Tuscany. EniChem coordinates the chemical activities of Ente Nazionale Idrocarburi. Larderello exported about 50% of production to more than 30 countries worldwide, primarily for use in ceramics, borosilicate glasses, fluoborates, and other boron compounds. The company was founded in 1818 and extracted boric acid from the geothermal sources. These fumaroles now supply electrical energy and chemicals, such as carbon dioxide and ammonia, to the plant. The first chemical plant in Italy to produce boric acid from colemanite ores was built in 1963 and has a capacity of 11,000 tons per year. A newer plant was built in 1981 with a capacity of more than 66,000 tons per year of refined boric acid and approximately 16,500 tons per year of high-purity sodium borate pentahydrate, decahydrate, and other boron specialties. The Larderello plant was the first to introduce 99.9%-pure granular technical boric acid of extremely low sulfate and chloride impurities to the market. In 1984, SCL developed Boric Acid NS 99.99% (nuclear grade), which has been marketed to the nuclear power companies because of its unique purity characteristics. This boric acid exceeds PD Specification 52205 AP Revision F. No. 79500 for use in powerplant applications.

Turkey.—Proven reserves of borax were reported at 519 million tons. In 1986, production of boron products was reported to be 98,400 tons and 1,113,100 tons of concentrates.

The most recent boron mineral reserve distribution in Turkey is summarized below:

Area of reserves	Quantity (thousand tons)	Boron oxide (thousand tons)	Boron oxide (percent)
Balikesir-Bigadic	724	217	30-34
Bursa-Kestelek	9	3	30-35
Eskisehir-Kirka	573	143	25-26
Kutahya-Emet	683	205	30-40
Total	1,989	568	

Deposits found north of the town of Bigadic in Balikesir Province produce colemanite and ulexite, whereas, deposits in Kutahya Province, produce mainly colemanite. The Kirka Mine, between Afyon and Eskisehir Provinces, contains the only commercial sodium borate deposit in Turkey.[22]

At yearend 1986, Etibank's boron operations had the following annual salable production capacities and manpower:

Mine	Capacity (thousand tons)	Employees
Bigadic Mining Co	200	1,950
Emet Colemanite Co	500	1,950
Kestelek Mining Co	100	550
Kirka Boraks Co	500	900
Total	1,300	5,350

Production capacities of compounds at Eskisehir in thousand tons was as follows: pentahydrate borax, 176; anhydrous borax, 66; and decahydrate borax, 19. Capacities at the Bandirma borax and boric acid plants were reported in thousand tons as follows: decahydrate borax, 61; boric acid, 36; and sodium perborate, 22. In 1986, production was reported in thousand tons as follows: decahydrate borax, 55.7; boric acid, 24; and sodium perborate, 19.[23]

In 1987, Etibank commissioned a hydrogen peroxide plant at its Bandirma boron processing complex. At full capacity, the plant was to produce 15,000 tons of hydrogen peroxide per year. It is planned that the hydrogen peroxide will be combined with a metaborate produced from a sodium tetraborate to produce a perborate. Sodium perborate was used in Europe as the primary type of washing powder.

Private companies, which had earlier been forced to sell or trade their stockpiles of boron because of the changes in Turkish mining regulations, were allowed to reprocess their old tailings, although they were required to sell the output to Etibank.[24]

Table 7.—Boron minerals: World production, by country[1]

(Thousand short tons)

Country	1983	1984	1985	1986[p]	1987[e]
Argentina	125	157	140	[e]145	145
Chile	1	4	5	7	7
China[e]	30	30	30	30	30
Peru[e]	11	11	11	11	11
Turkey	774	987	1,052	1,023	1,100
U.S.S.R.[e]	220	220	220	220	220
United States[2]	1,303	1,367	1,269	1,251	[3]1,385
Total	2,464	2,776	2,727	2,687	2,898

[e]Estimated. [p]Preliminary.
[1]Table includes data available through May 27, 1988.
[2]Minerals and compounds sold or used by producers, including both actual mine production and marketable products.
[3]Reported figure.

TECHNOLOGY

Zinc borate is an effective and economic fire retardant synergist of organic halogens in polymers. It has been used extensively as a flame retardant, smoke suppressant, and afterglow suppressant. A study on the use of alumina trihydrate (ATH) and zinc borate as halogen-free fire retardants concluded the following: promotion of a strong char that suppresses smoke; formation of a porous and hard residue that can insulate the unburned polymer substrate; and effective flame retardant and smoke suppressant in a variety of polymers with ATH or in some silicone rubbers when only zinc borate was used.[25]

Scientists at the National Institute for Research in Inorganic Materials in Tsukuba Science City, Japan, reported fabrication of a boron-nitride diode that operates at temperatures as high as 530° C. Cubic boron nitride can be made into semiconductors when suitable impurities are added. These semiconductors could be used in high-temperature devices that could monitor performance inside engines where silicon-based electronic circuits would fail.[26]

A study by the U.S. Department of Agriculture indicates that boron can prevent osteoporosis. Boron had the effect of conserving calcium, that is, preventing bone demineralization. Hormone levels, thought to be important for maintaining bone and calcium levels, doubled. Additional studies were planned on the subtlety of boron's function in the body.[27]

A residential development outside Orlando, FL, became the first fiber optic wiring in new residential application. Fiber optics use borosilicate glass consisting of a core within cladding that has a lower index of refraction. Boron lowers the index, but compounds of aluminum, germanium, phosphorus, or titanium raise the index. Although the use of these materials in fiber optics is small, fiber optics represent a high value use of boron.[28]

Impregnating graphite intercalated with aluminum oxide with boric acid and heating to 1,250° C yielded a fiber with a continuous hollow core. The material has possible application in filtration or catalyst supports.[29]

The majority of ceramics are good insulators, however, a large class of ceramic materials offers properties of low to high conductivity such as titanium diboride. Although these materials pose little competition for metals in conventional applications, they excel where other material would be satisfactory, such as in reversal of the electrical current so that scale can be dissolved by electrolysis.[30]

Production of glass reinforced plastic composite engines was planned to begin by Polimotor Research Inc. at a plant in Canton, OH, in 1988 and would increase demand for reinforcers using fiberglass, and thus increase demand for boron. The initial capacity will be 2,500 engines per year, with expansion possible to 50,000 units. The advantages include savings of 175 pounds for an equivalent metal engine.[31]

Nippon Kokan K.K., Tokyo, Japan, has developed a titanium diboride composition that is less brittle yet stronger than conventionally produced material. Titanium diboride combines a high melting point, 2,871° C, with hardness and resistance to corrosion and erosion. The new material can be conventionally sintered or hot-isostatically pressed.[32] The new material could replace some electrodes used in aluminum production.

During 1985, at the request of manufacturers of cellulose insulation, using borax and boric acid as a flame retardant, the California Bureau of Home Furnishing and Thermal Insulation set up an interlaboratory roundrobin testing program for loose-fill cellulosic insulation material.[33] A second round during 1987, verified that the electric radiant panel test procedure was reliable in 75% of the tests as a screening test for in-house laboratories to predict the results of the full gas radiant panel apparatus.[34] The approval of a method to test the permanency of cellulosic insulation could potentially increase the demand for borax and boric acid as flame retardants in cellulose insulation worldwide.

A range of borates exhibit nonlinear optical properties and could be utilized for integrated optic components. The theory predicts that an ionic boron oxide group is responsible for properties in these materials.[35] Although the use of boron material in optic components is a small portion of demand, this use would represent a high value product.

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Bromine

By Phyllis A. Lyday[1]

Of the 847 million pounds of bromine produced worldwide in 1987, the United States produced 40%, followed by Israel, 27%; the U.S.S.R., 17%; the United Kingdom, 6%; and other countries, 10%. The U.S. portion of world production has decreased steadily since 1973, when the United States produced 71% of the world supply. The decrease in world share has been a result of environmental constraints

Table 1.—Salient bromine and bromine compound statistics

(Thousand pounds and thousand dollars)

	1983	1984	1985	1986	1987
United States:					
Bromine sold or used:[1]					
Quantity	370,000	385,000	320,000	310,000	[e]335,000
Value	$91,000	$95,000	$80,000	$93,000	[e]$107,000
Exports:					
Elemental bromine:					
Quantity	[2]4,500	[3]68,200	[3]6,252	[2]17,900	[2]7,380
Value	[2]$1,000	[e]$15,200	[e]$1,400	[2]$8,170	[2]$3,526
Bromine compounds:[4]					
Gross weight	61,300	53,200	61,000	28,000	48,300
Contained bromine	52,000	45,100	51,900	23,000	41,100
Value	$21,600	$16,200	$23,400	$23,900	$18,000
Imports:[2]					
Elemental bromine:					
Quantity	([5])	9	11	342	547
Value	$5	$17	$9	$87	$166
Compounds:					
Ammonium bromide:					
Gross weight	1,634	1,450	2,786	5,721	4,946
Contained bromine	1,333	1,183	2,729	4,667	3,778
Value	$962	$854	$1,593	$2,994	$2,257
Calcium bromide:					
Gross weight	1,722	1,598	5,093	6,218	8,075
Contained bromine	1,377	1,278	4,072	4,972	6,456
Value	$900	$203	$917	$741	$833
Potassium bromate:					
Gross weight	679	661	1,069	641	3,063
Contained bromine	325	350	512	340	1,466
Value	$572	$610	$899	$669	$849
Potassium bromide:					
Gross weight	436	367	968	697	1,910
Contained bromine	293	246	650	468	1,282
Value	$303	$268	$685	$486	$1,122
Sodium bromide:					
Gross weight	2,534	1,916	2,901	467	1,448
Contained bromine	1,927	1,488	2,253	364	1,124
Value	$971	$851	$1,108	$217	$507
Other:					
Gross weight	12,070	15,150	10,087	10,112	18,286
Contained bromine	10,241	11,535	6,863	8,004	11,220
Value	$8,105	$8,210	$5,863	$4,627	$13,669
World: Production	801,863	875,150	839,982	[p]824,380	[e]846,530

[e]Estimated. [p]Preliminary.

[1]Elemental bromine sold as such to nonproducers, including exports, or used in the preparation of bromine compounds by primary U.S. producers.

[2]Bureau of the Census.

[3]The Journal Commerce Port Import/Export Reporting Service.

[4]Bureau of the Census. Includes methyl bromide and ethylene dibromide.

[5]Less than 1/2 unit.

and the emergence of Israel as a major producer. The quantity of bromine sold or used in the United States was about 335 million pounds valued at $107 million. Exports of bromine compounds amounted to 41.1 million pounds. The price of elemental bromine in bulk was 35 cents per pound. Primary uses of bromine compounds were as a scavenger for lead in gasoline, oil and gas well fluids, and flame retardants.

Domestic Data Coverage.—Domestic production data for bromine are developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the eight operations to which a survey request was sent, all responded, representing 100% of total elemental bromine sold or used.

Legislation and Government Programs.—The Environmental Protection Agency (EPA) undertook a special review of the ethylene dibromide fungicides: Mancozeb, Maneb, Metiram, Nabam and Zineb.[2]

An amendment to the New York State Fire Prevention and Building Code went into effect at yearend. New York was the first State to require all plastic products marketed in the State, regardless of where manufactured, to be tested for toxicity before being sold. Major products being tested were electrical conduit wire, pipe, and duct insulation, which can use brominated flame retardants to meet building codes.[3]

Great Lakes Chemical Corp. and the Arkansas State Pollution Control and Ecology Department agreed to a number of environmental improvements at the El Dorado plant over a 3-1/2-year period. The agreement was a result of an October 1985 notice of violation. Improvements included repairing or closing some waste collection ponds, treating waste water in a new facility, cleaning up ground water contamination, and increasing ground water monitoring. Great Lakes constructed a new facility for treating waste water. Additional recovery wells will pump contaminated water from the ground to be treated in the new waste water facility. Additional monitoring wells will also be installed. If any parts of the plan are not completed on time, Great Lakes will pay penalties from $500 to $2,500 per day.[4]

EPA approved the registration of bromine chloride, EPA Reg. No. 5785-68, and bromine chloride technical, EPA Reg. No. 337-20. Both products are classified for general use as a algicide, bactericide, disinfectant, and slimicide in waste water, commercial, and industrial recirculation cooling water systems.[5]

A final test rule was issued by EPA that required manufacturers and processors of tetrabromobisphenol-A, a major brominated flame retardant, to perform testing for chemical and environmental effects. The testing requirements included biodegradation studies in sediment/water and soil, an acute toxicity study in a freshwater alga, acute and early life state toxicity studies in fish, a partial life-cycle toxicity study in a benthic invertebrate, a chronic toxicity study in an aquatic invertebrate, and bioconcentration studies in fish and invertebrate.[6]

The incineration of 328,000 gallons of ethylene dibromide (EDB) was being considered by EPA as a method to dispose of the chemical. A test was planned in December of the incineration process. EDB was banned as a fumigant in September 1983, and manufacturers and distributors quickly surrendered all stocks of the chemical for disposal.[7]

Ten brominated chemicals were controlled for national security reasons under Export Control Commodity No. 5799D. The U.S. Department of Commerce undertook a review of the rationale for the controls and decided to terminate the control of these chemicals on the grounds that the availability of these chemicals would no longer make a significant contribution to the military potential. The decision was made in consultation with the U.S. Departments of Defense, Energy, and State. The chemicals remain subject to export controls to Country Groups S and Z for foreign policy reasons.[8]

In California, 1,2 dibromo-3-chloropropane was listed as 1 of 29 toxic substances under proposition 65, the Safe Drinking Water & Toxic Enforcement Act (Superfund) of 1986. Under the provisions of the law, businesses are prohibited from discharging listed chemicals into drinking water unless the discharged amounts can be shown to be safe. Businesses are also prohibited from exposing individuals to listed chemicals at unsafe levels without first warning them of the risk.[9]

The U.S. Department of Health and Human Services and the EPA published a priority list for toxicological profiles of 100 hazardous substances found at Superfund sites. The list included four brominated compounds in priority groups 2, 3, and 4. The list was prepared from 717 hazardous substances currently identified at Superfund sites.[10]

The Arkansas State Plant Board, the

Mississippi Department of Agriculture and Commerce, and the Louisiana Agriculture Department granted a section 18 exemption for bromoxynil for control of hemp sesbania, morning glory, and cocklebur in rice. The exemption expired August 1, 1987.[11]

The Office of the Governor, Territory of Guam, granted a section 18 quarantine exemption for the use of methyl bromide to control western flower thrips and cabbage aphids on several vegetables. The exemption expires January 12, 1991.[12]

DOMESTIC PRODUCTION

Three companies representing the U.S. Bromine Alliance accounted for about 95% of U.S. elemental bromine capacity. Plant capacity did not reflect production capacity, which was dependent upon brine supplies, concentration of the bromine in the brine, and individual plant extraction processes. Arkansas brines contained about 6,000 parts per million and Michigan brines about 2,600 parts per million of bromine.

Ethyl Corp. concluded an agreement with The Dow Chemical Co. to purchase Dow's facility in Magnolia, AR, and other bromine assets. Included was the brine field leases in the Magnolia area, distribution equipment, facilities, and inventories worldwide, as well as certain patents pertaining to Dow's bromine chemical technology. Under a consent decree reached with the U.S. Department of Justice, Dow and Ethyl agreed to exclude Dow's brominated clear brine fluids business from the transaction. As part of the consent decree, Dow will attempt to sell its brominated clear brine fluids business to a qualified purchaser. Dow will continue to operate a plastic foam plant on the Magnolia site until the plant can be relocated.

Ethyl assumed sales activities for Dow's elemental bromine, flame retardants, organic bromides, and sodium hydrosulfide. Ethyl will integrate operations for the former Dow bromine chemical facility with its existing operations in Magnolia and will construct new facilities at both sites to manufacture products Dow produced in Midland, MI. New facilities are also under construction at Magnolia to produce flame retardants formerly produced in Sayreville, NJ.

Morton Thiokol Inc. produced small quantities for captive use in inorganic bromides. Rhône-Poulenc S.A. through its subsidiary, the France-based inorganic bromide producer Potasse et Produits Chimiques (PPC), bought Morton's current inventory and technology for inorganic bromides, which are primarily used in photography. Rhône-Poulenc Inc. (USA) will function as PPC's U.S. sales agent.[13]

Great Lakes, which operated three bromine plants in Union County, announced a 50% expansion of a plant in Adrian, MI, that produces bromochlorodimethylhydantoin, a bromine-containing biocide used in a variety of applications, including swimming pools, spas, cooling towers, and waste water treatment.[14]

Great Lakes purchased QO Chemical Inc., a wholly owned subsidiary of Pentech Corp. QO produced furfural from agricultural waste and then manufactured furyl alcohol and other specialty products used in building materials, chemical intermediates, flame retardants, foundry resins, oil refining, plastics, and urethane systems. The new company will use many of the brominated flame retardants that Great Lakes produce.

Table 2.—Bromine-producing plants in the United States in 1987

State and company	County	Plant	Production source	Elemental bromine plant capacity[1] (million pounds)
Arkansas:				
Arkansas Chemicals Inc	Union	El Dorado	Well brines	50
The Dow Chemical Co	Columbia	Magnolia	do	110
Ethyl Corp	do	do	do	160
Great Lakes Chemical Corp	Union	El Dorado	do	105
Do	do	Marysville	do	80
Do	do	El Dorado	do	50
Michigan:				
The Dow Chemical Co	Mason	Ludington	do	20
Morton Thiokol Inc	Manistee	Manistee	do	5
Total				580

[1]Chemical Marketing Reporter. Chemical Profile. V. 228, No. 4, July 22, 1985, pp. 53-54.

CONSUMPTION AND USES

The U.S. International Trade Commission publication, "Synthetic Organic Chemicals, 1986" reported that the Dyes & Pigments Div. of Mobay Chemical Corp. produced Pigment Red No. 168, dibromoanthranthrone orange. Red No. 168 was used in automotive metallic applications because of its transparency.

Demand for EDB, primarily as a gasoline additive, reached a low of about 10% of total consumption. Fire retardants were estimated to be about 30% of consumption, primarily as tetrabromobisphenol-A and decabromodiphenyl oxide. Agriculture uses were about 10% of consumption, principally as methyl bromide used as a soil fumigant. Bromine is used in water treatment as a slime and biocidal control product. Sodium bromide was estimated at about 5% of consumption. About 30% of bromine consumption was as calcium bromide in workover and completion fluids. Other uses were estimated at approximately 15% of consumption.[15]

According to data from the Bureau of the Census, 1 billion pounds of bisphenol-A was produced in 1987, up 21% from production in 1986. The demand was strong in the polycarbonate resin sector, which amounts to approximately one-half of the market. Epoxy resins, which account for about one-third of the market, were also strong.[16] Tetrabromobisphenol-A is a major flame retardant produced from bisphenol-A, used in epoxy, polyester, and other polymers where low color and high clarity are mandatory.[17] A study of flame retardants consumption by polymers estimated 36 million pounds of bromine additives was used in 1986. The majority was in polyacrylonitrile-butadiene-styrene and polystyrene products.[18]

Bromine was used in biocides in recirculatory cooling systems. Formulated alone or with other active ingredients, bromine compounds are regarded by the water treatment industry as cost-effective biocides. Some compounds have both bacteriostatic and fungistatic properties at low concentrations.[19]

Bromine added as a bromide salt with chlorine or hypochlorine leaches gold as well as platinum in acid, neutral, or alkaline water. A product marketed under the name "Bio-D Leachant", being distributed in North America, has been reported as a better reagent than bromocide, a disinfectant, because it is readily recycled for reuse. About 20 small operators were reported to be using bromine. Three larger companies were testing bromine on 5,000-short-ton heap-leaching operations. The advantages of bromine are rapid extraction, nontoxicity, and adaptability to a wide range of conditions. Disadvantages are high reagent consumption and interferences in standard assay techniques.[20]

PRICES

Bromine was sold under contracts negotiated between buyer and seller. Price quotations do not necessarily represent prices at which transactions actually occurred, nor do they represent bid and asked prices. They were quoted here to serve only as a guide to yearend price levels.

Table 3.—Yearend 1987 prices for elemental bromine and selected compounds

Product	Value per pound (cents)
Ammonium bromide, National Formulary (N.F.), granular, drums, carlots, truckloads, freight equalized, f.o.b. works	131
Bromine, purified:	
Purifed, truckloads, delivered	77
Drums, truckloads, works[1]	87
Bulk tank car, tank trucks (45,000-pound minimum), delivered east of the Rocky Mountains[1]	35
Bromochloromethane, drums, carlots, f.o.b. Midland, MI	112
Calcium bromide, bulk, 14.2 pounds per gallon at 60° F, f.o.b. works[2]	20- 21
Ethyl bromide, technical, 98%, drums, carlots, freight allowed, East	76
Ethylene dibromide, drums, carlots, freight equalized	38- 46
Hydrobromic acid, 48%, drums, carlots, truckloads, f.o.b	38.5
Hydrogen bromide, anhydrous, cylinders, extra 30,000 pounds, f.o.b. works	700
Methyl bromide, distilled, tanks, 140,000-pound minimum, freight allowed	56.75
Potassium bromate, granular, powdered, 200-pound drums, carlots, f.o.b. works	106
Potassium bromide, N.F., granular, drums, carlots, f.o.b. works	112
Sodium bromide, 99% granular, 400-pound drums, freight, f.o.b. works	104

[1]Delivered prices for drums and bulk shipped west of the Rocky Mountains, 1 cent per pound higher. Bulk truck prices 1 to 2.5 cents per pound higher for 30,000-pound minimum and 4 to 5.5 cents per pound higher for 15,000-pound minimum.
[2]Reported to the Bureau of Mines by primary producers.

Source: Chemical Marketing Reporter. Current Prices of Chemicals and Related Materials. V. 232, No. 26, Dec. 28, 1987, pp. 28-36.

FOREIGN TRADE

AmeriBrom Inc., a member of the Israeli Dead Sea Bromine Co. Ltd., a part of Israel Chemicals Ltd., began to ship larger quantities of elemental bromine to the United States because of an increase in demand. Previous market commitments to Europe and Japan limited the amount of bromine that could be shipped to the United States. Imports from Israel and from Broomchemie BV in the Netherlands had been primarily in the form of derivatives in previous years. Morre-Tec Industries Inc. of Union, NJ, was appointed distributor of calcium bromide for AmeriBrom.

WORLD REVIEW

Canada.—In Alberta, formation waters with bromide contents greater than 1,000 milligrams per liter are confined to small areas in the Upper Devonian Winterburn and Woodbend Groups of central Alberta; the Upper Devonian Beaverhill Lake Formation of southern Alberta; the Middle Devonian Elk Point Group of north-central Alberta; and the Granite Wash, northern Alberta. Formation water from the Beaverhill Lake Formation of southern Alberta contained nearly 2,790 milligrams per liter of bromide, which corresponds to the concentration of brines at Midland, MI, but less than the 5,000 parts per million for Arkansas brines and the 12,000 parts per million for bitterns from potash production from the Dead Sea.[21]

China.—An underground deposit near Laizhou Bay, Shandon, reported reserves at 600 million cubic meters of brine.[22]

Europe.—An expert panel was studying ways to curb salt spills into the Rhine from French sources. France (30%), the Federal Republic of Germany (30%), the Netherlands (34%), and Switzerland (6%) will split the budget of the panel. One plan suggested doubling existing storage facilities to cope with the 16 million tons of salt coming from the Mines de Potasse d'Alsace S.A., at Amelie. Bromine is produced as a byproduct of potash production in France and the Federal Republic of Germany.[23]

France.—Mines de Potasse d'Alsace was in the process of building an additional bromine column to bring the total columns to 10. The glass columns are about 4 feet wide and produce a combined total of 13 tons per day of elemental bromine.

Germany, Federal Republic of.—Kali und Salz AG reported that the only potash mine in production was the Salzdetfurth Mine with an annual bromine capacity of 5.5 million pounds. The mine is north of Kassel between the Leine and Oker Rivers.

Because of concern by the Green Party, the Verband Der Chemische Industrie announced in 1985 a voluntary, precautionary action to reduce and possibly eliminate the use of brominated flame retardants in plastics. A group of world producers formed the Brominated Flame Retardant Industry

Panel (BFRIP) to investigate reports that researchers in the Federal Republic of Germany, Switzerland, and the United States had reported finding significant quantities of brominated dioxins and furans in brominated diphenyl oxide flame retardants. To address the issues, BFRIP developed a program to test the animal toxicity of the solid decomposition products of polymers containing brominated flame retardants under combustion conditions.[24]

Other studies released during 1987 complement the work being funded by the BFRIP. Dow, a member of the BFRIP, released a study that indicates humans exposed to dioxins generally experienced death rates at or below those of a corresponding United States population.[25] Scientists report no evidence of an increase in birth defects following a 1976 accident in Seveso, Italy, that exposed the surrounding population to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). Several small animals were found dead at the time of the TCDD exposure but, other than choracne, a severe form of acne, no other effects were observed in exposed humans. The study concluded that the rates of both major and minor malformations are the same in TCDD-exposed areas as in nonexposed areas.[26]

Israel.—Dead Sea Bromine Co. Ltd., Sdom, announced a proposed expansion of 265 million pounds costing $150 million.[27] Israel Chemicals, the parent of Dead Sea Bromine, was developing a new calcium bromide process to extract calcium bromide directly from brines. In addition, a process for organic solvent extraction of calcium bromide from potash bitterns was being developed to delete an intermediate energy consuming step. Conventional methods react hydrogen bromide with calcium hydroxide. The Israelis have operated a pilot plant of 2 to 4 million pounds per year since 1984. It was reported that a demonstration facility was being built to test the new calcium bromide process.[28]

Table 4.—World bromine plant capacities and sources

Country and company	Location	Capacity (million pounds)	Source
China:			
Laizhou Bromine Works	Shandong	1	Underground brines.
France:			
Atochem	Port-de-Bouc	30	Seawater.
Mines de Potasse d'Alsace S.A	Mulhouse	19	Bitterns of mined potash production.
German Democratic Republic:			
Government	Bleicherode	NA	Do.
	Sondershausen	NA	Do.
Germany, Federal Republic of:			
Kali und Salz AG: Salzdetfurth Mine	Bad Salzdetfurth.	5.5	Do.
India:			
Hindustan Salts Ltd	Jaipur	} 1.6	Seawater bitterns from salt production.
Mettur Chemicals	Mettur Dam		
Tata Chemicals	Mithapur		
Israel:			
Dead Sea Bromine Co. Ltd	Sdom	220	Bitterns of potash production from surface brines.
Italy:			
Società Azionaria Industrial Bromo Italiana	Margherita di Savoia.	2	Seawater bitterns from salt production.
Japan:			
Asahi Glass Co. Ltd	Kitakyushu	9	Seawater bitterns.
Toyo Soda Manufacturing Co. Ltd	Tokuyama	44	Do.
Spain:			
Derivados del Etilo S.A	Villaricos	2	Seawater.
U.S.S.R.:			
Government	NA	150	Well brines.
United Kingdom:			
Associated Octel Co. Ltd	Amlwch	66	Do.

NA Not available.

Table 5.—Bromine: World production, by country[1]

(Thousand pounds)

Country[2]	1983	1984	1985	1986[p]	1987[e]
France[e]	35,000	38,600	44,000	42,000	41,000
Germany, Federal Republic of	6,914	7,288	6,784	[e]5,500	5,500
India[e]	770	770	770	770	770
Israel[e]	154,000	198,400	220,000	231,500	231,500
Italy[e]	1,100	1,100	1,320	990	1,100
Japan[e]	26,500	26,500	26,500	[r]33,000	33,000
Spain[e]	700	660	800	620	660
U.S.S.R.[e]	150,000	154,000	154,000	143,000	143,000
United Kingdom	56,879	62,832	65,808	[r] [e]57,000	55,000
United States[3]	370,000	385,000	320,000	310,000	[4]335,000
Total	801,863	875,150	839,982	824,380	846,530

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

[1]Table includes data available through May 6, 1988.

[2]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.

[3]Sold or used by producers.

[4]Reported figure.

TECHNOLOGY

Greater solubilities for some metals occur in the metal bromide-hydrogen, bromide-water system. Stricter control of effluents and declining ore grades have caused an increase in interest in hydrometallurgical processing. Bromide reagents are more costly than chloride reagents, but recycling the reagents would minimize the difference and increase demand for bromine compounds for use in metallurgical processing. Solubility studies of various metal bromides reported crystallization was almost total at hydrogen bromide saturation for aluminum bromide, potassium bromide, and sodium bromide.[29]

The bromine number is defined as the number of grams of bromine that reacts with 100 grams of a substance under certain conditions. The ASTM D 1159-77 method for determining the bromine number of petroleum products with boiling points to 327° C was modified to make it suitable for products up to 550° C.[30]

A radioactive bromine had been used to treat ovarian and estrogen-dependent cancers. The treatment employs an estrogen-like drug to which the radioactive bromine is attached. The drug binds to a cell that locates bromine close to the genetic material. As the bromine decays, it destroys the cell's structure. The drug will undergo animal tests before human trials.[31]

Interest has intensified in annual shrinkage of the stratospheric ozone layer over the Antarctic. Bromine and bromine monoxide are two of the halogen species being studied by scientists around the world for their part in the reactions that destroy ozone. If bromine is determined to be a major factor, the demand for bromine could be affected by world bans, such as those placed on chlorofluorocarbons (CFC).[32] A draft treaty was reached by 28 countries during negotiations sponsored by the United Nations Environmental Program. Halons 1211 and 1301, both containing bromine, are not covered by the proposal.[33] The U.S. Congress was considering legislation to curb further use of CFC, including Halons 1211 and 1301, thus decreasing demand for bromine.

A method for classificiation and identification of air pollutants, including brominated hydrocarbons, was developed. The compounds are identified by comparing their data with the three nearest neighbors in the set. The classification accuracy was 85%.[34] This method could increase the accuracy of identification of brominated compounds for making policy decisions on polluting compounds.

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Cadmium

By Thomas O. Llewellyn[1]

U.S. imports for consumption of cadmium metal decreased considerably, but exports increased dramatically over those of 1986 and reached their highest level in the last 7 years. The producer-price range of cadmium metal, at $1.20 to $1.50 per pound at the beginning of the year, more than doubled by yearend. The flourishing Japanese nickel-cadmium battery industry, labor disputes, and the excess of world demand over production contributed to both the increase in U.S. exports and the rise in metal prices.

A low-temperature chemical vapor deposition process for producing thin-filmed cadmium was developed. Potential applications for these fabricated thin films included photodetectors and transparent conductors.

Domestic Data Coverage.—Domestic production data for cadmium metal and compounds are developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the four metal-producing plants to which a survey request was sent, all responded, representing 100% of the total cadmium metal production shown in tables 1 and 3. Of the 11 operations that produced cadmium compounds to which a survey request was sent, all responded, representing 100% of the cadmium content of production of cadmium compounds shown in table 2.

Table 1.—Salient cadmium statistics

	1983	1984	1985	1986	1987
United States:					
Production[1] metric tons	1,052	1,686	1,603	1,486	1,515
Shipments by producers[2] do.	1,495	1,811	1,791	2,030	1,916
Value thousands	$1,786	$2,581	$2,436	$1,883	$1,861
Exports metric tons	170	106	86	38	241
Imports for consumption, metal do.	2,196	1,889	1,988	3,174	2,701
Consumption, apparent do.	3,763	3,300	3,720	4,385	4,178
Price: Average per pound[3]	$1.13	$1.69	$1.21	$1.25	$1.99
World: Refinery production metric tons	[r]17,636	[r]19,463	18,723	[p]18,525	[e]18,566

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Primary and secondary cadmium metal. Includes equivalent metal content of cadmium sponge used directly in production of compounds.
[2]Includes metal consumed at producer plants.
[3]Average quoted price for cadmium sticks and balls in lots of 1 to 5 tons.

Legislation and Government Programs.—The Superfund Amendments and Reauthorization Act (SARA) of 1986 (Public Law 99-499) extended and amended the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA or Superfund). Certain requirements were established for the Environmental Protection Agency (EPA) and the Agency for Toxic Substances and Disease Register (ATSDR) with regard to the hazardous substances most commonly found at facilities on the CERCLA National Priorities List (NPL) and pose the most significant potential threat to human health. Section 110 of SARA amends section 104(i) of CERCLA by establishing requirements for the preparation of (1) a list of hazardous substances found at NPL sites (in order of priority), (2) toxicological profiles of those substances, and (3) a research program to improve or expand the information available on these substances. The EPA and ATSDR published the first priority list of 100 hazardous substances, in compliance with the law, on April 17, 1987. The list is divided into 4 priority groups of 25 substances each. In this list, cadmium was among the hazardous substances of the first priority group.[2]

On August 19, 1987, the EPA issued notice of final determination and intent to cancel registration and to deny applications for all pesticide products that contain cadmium compounds (salts of chloride, sebacate, succinate, carbonate, and anilino cadmium dilactate) as active ingredients that were used on turf of golf courses and home lawns. The cancellation and denial were based on the EPA's findings that the use of cadmium fungicides would result in unreasonable adverse effects to applicators of the products for these uses. This notice announced the EPA's final determination to (1) cancel registrations and to deny applications of all pesticide products containing any of the five cadmium compounds as active ingredients that are registered for use on golf course fairways and home lawns, and (2) to modify the terms and conditions of registration of cadmium products for use on golf course greens and tee areas.[3]

DOMESTIC PRODUCTION

St. Joe Resources Co., a subsidiary of Fluor Corp., was bought by Horsehead Industries Inc. The St. Joe operations were combined with those of Horsehead's New Jersey Zinc Co. Inc. to form a new company called Zinc Corp. of America. The sale was part of Fluor's continuing program to sell its assets of St. Joe Minerals Corp.

Cadmium metal was produced by AMAX Inc., Sauget, IL; ASARCO Incorporated, Denver, CO; Jersey Minière Zinc Co., Clarksville, TN; and Zinc Corp. of America, Bartlesville, OK.

Table 2.—U.S. production of cadmium compounds

(Metric tons, cadmium content)

Year	Cadmium sulfide[1]	Other cadmium compounds[2]
1983	670	1,024
1984	771	1,510
1985	477	1,021
1986	645	1,459
1987	540	1,511

[1]Includes cadmium lithopone and cadmium sulfoselenide.
[2]Includes plating salts and oxide.

CONSUMPTION AND USES

Consumption in 1987 was estimated as follows: batteries, 32%; coating and plating, 29%; pigments, 15%; plastic stabilizers, 15%; and alloys and other uses, 9%.

SAFT America Inc. announced the introduction of a newly designed Polytemp Plus NiCad battery. The company claimed that the new battery was capable of long-lasting high performance for applications at temperatures up to 70° C on continuous charge. This reportedly would make the batteries ideal for computers, medical electronics, and other standby uses.[4]

Table 3.—Supply and apparent consumption of cadmium

(Metric tons)

	1985	1986	1987
Stocks, Jan. 1	901	686	923
Production	1,603	1,486	1,515
Imports for consumption, metal	1,988	3,174	2,701
Total supply	4,492	5,346	5,139
Exports	86	38	241
Stocks, Dec. 31	686	923	720
Consumption, apparent[1]	3,720	4,385	4,178

[1]Total supply minus exports and yearend stocks.

STOCKS

The decrease in stocks held by both metal producers and distributors reflected the excess worldwide demand over world production.

Table 4.—Industry stocks, December 31

(Metric tons)

	1986		1987	
	Cadmium metal	Cadmium in compounds	Cadmium metal	Cadmium in compounds
Metal producers	303	W	126	W
Compound manufacturers	73	481	98	457
Distributors	65	1	37	2
Total	441	482	261	459

W Withheld to avoid disclosing company proprietary data; included with "Compound manufacturers."

PRICES

At the beginning of 1987, AMAX published a domestic producer price of $1.20 per pound for cadmium metal, and St. Joe Resources' National Zinc Div.'s published price was $1.50 per pound. In March, AMAX lowered its price to $1.00 per pound, but by April again quoted a price of $1.20 per pound. Cadmium metal prices during the remainder of 1987 followed a steep upward trend. AMAX raised its price from the $2.25-per-pound level of September to $2.75 for October, and by November it was $3.00 per pound where it remained at yearend. National Zinc increased its price from $2.30 per pound in September to $2.90 in early October, and finally boosted it to $3.50 per pound late the same month; this price prevailed through yearend. The steep price increase of cadmium metal was attributed, in part, to the flourishing Japanese nickel-cadmium battery industry, labor disputes such as the 4-month strike at Cominco Ltd.'s lead-zinc operation in Canada, and the excess of world demand over production.

The New York dealer price for cadmium metal in January ranged from $0.97 to $1.05 per pound. The published New York dealer price range increased steadily throughout the first 4 months of 1987, and by the end of April was $1.20 to $1.30 per pound. The dealer price range for cadmium metal fluctuated slightly during the last 8 months of 1987, but followed the same upward trend as the producers' price quotations, and closed the year in the range of $3.00 to $3.20 per pound.

FOREIGN TRADE

Exports of cadmium increased dramatically in 1987 compared with those of 1986 and reached their highest level in the last 7 years. Japan, the United Kingdom, Taiwan, and Mexico, in descending order of receipts, received approximately 95% of the total exports. Cadmium metal imports for consumption decreased considerably in 1987 compared with those of 1986.

The Bureau of the Census reported that the United States exported nearly 11.6 million nickel-cadmium batteries in 1987, most of which went to Hong Kong. Imports of nickel-cadmium batteries, including those incorporated into other products, totaled about 89 million batteries. Japan and Mexico supplied approximately 84% of the total battery imports.

Table 5.—U.S. exports of cadmium metal and cadmium in alloys, dross, flue dust, residues, and scrap

Year	Quantity (metric tons)	Value (thousands)
1985	86	$342
1986	38	188
1987	241	660

Source: Bureau of the Census.

Table 6.—U.S. imports for consumption[1] of cadmium metal, by country

Country	1986 Quantity (metric tons)	1986 Value (thousands)	1987 Quantity (metric tons)	1987 Value (thousands)
Australia	[2]589	[2]$1,143	427	$1,201
Belgium-Luxembourg	29	84	18	36
Canada[2]	1,221	2,571	1,164	3,503
China	[2]76	[2]143	117	283
Finland	46	83	25	62
France	[2]21	[2]43	6	19
Germany, Federal Republic of	227	390	272	764
Hong Kong	[2]22	[2]34	--	--
Japan	--	--	3	8
Korea, Republic of	59	121	10	44
Mexico	441	782	496	1,524
Namibia	--	--	5	22
Netherlands	54	106	5	13
Norway	40	79	27	54
Peru	[2]141	[2]255	70	188
Spain	40	69	--	--
Sweden	15	30	--	--
Taiwan	--	--	[2]37	[2]57
United Kingdom[2]	144	257	20	40
Yugoslavia	10	17	--	--
Total[3]	3,174	6,208	2,701	7,818

[1]General imports and imports for consumption were the same in 1986 and 1987.
[2]Includes waste and scrap (gross weight).
[3]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

WORLD REVIEW

The European Economic Community proposed better control of emissions from industrial processes, waste, incineration, and coal burning; reduction of cadmium use in manufactured products; and the establishment of stricter limits for cadmium in fertilizers to reduce cadmium pollution. The proposals for control of cadmium emissions were expected to be completed by 1989.

Société d' Accumulateurs Fixés et de Traction (SAFT) of France and Licencintorg, the Soviet Central Purchasing Organization for Technology Acquisitions, announced the signing of an agreement in Moscow by which SAFT will provide the Soviet Union with a nickel-cadmium battery manufacturing facility. Under the agreement, SAFT will supply all required processing, production, and laboratory testing equipment. In the past, SAFT operated through subsidiaries in foreign countries. It is anticipated that this new factory will produce batteries to be used as power supply for telecommunications, electronics, and instrumentation.[5]

The British battery company, ALCAD,

previously owned by Marathon Manufacturing Companies Inc., a subsidiary of Penn Central Corp., was bought by SAFT. ALCAD produced pocket-plate nickel-cadmium storage batteries for industrial and railroad uses, and its share of the world market was 15%. SAFT's world market for this line of batteries was also 15%.[6]

Table 7.—Cadmium: World refinery production,[1] by country

(Metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
Algeria	([2])	80	128	124	125
Argentina	21	46	46	47	45
Australia	[r]1,121	1,082	910	[e]1,000	1,000
Austria	46	49	52	52	53
Belgium	1,260	1,472	1,252	1,374	1,300
Brazil	189	225	124	136	140
Bulgaria[e]	200	200	200	200	180
Canada	1,456	1,605	1,717	1,421	1,500
China[e]	300	300	300	300	300
Finland	616	614	565	522	650
France	513	568	337	431	300
German Democratic Republic[e]	15	15	15	[r]18	18
Germany, Federal Republic of	1,094	1,111	1,095	1,218	1,200
India	131	148	194	[r e]160	180
Italy	385	452	526	411	325
Japan	2,214	2,423	2,535	2,489	2,440
Korea, North[e]	100	100	100	100	100
Korea, Republic of	320	320	--	([2])	--
Mexico	[r]847	[r]838	905	1,016	1,000
Namibia	51	40	58	61	50
Netherlands	513	636	594	557	560
Norway	117	150	159	154	150
Peru	451	390	[e]420	387	400
Poland[e]	570	570	600	600	600
Romania[e]	80	75	75	75	75
Spain	278	290	268	247	300
U.S.S.R.[e]	3,000	3,000	3,000	3,000	3,000
United Kingdom	340	390	370	380	500
United States[3]	1,052	1,686	1,603	1,486	[4]1,515
Yugoslavia	48	270	279	259	260
Zaire	308	318	296	[e]300	300
Total	[r]17,636	[r]19,463	18,723	18,525	18,566

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

[1]This table gives unwrought 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 found 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 reported in this table to avoid double counting. Table includes data available through Apr. 8, 1988.

[2]Revised to zero.

[3]Includes secondary.

[4]Reported figure.

TECHNOLOGY

It was reported that chemists at the University of Kyoto, Japan, developed a fully rechargeable, all-plastic battery with electrodes made of plastic, instead of metal, and with a lifespan of about 80 minutes. The doped polymers used for the electrodes are usually unstable and, due to the solvent action of the battery electrolyte, their conductivity deteriorates rapidly. An improved battery performance was achieved using polymeric dopants such as polypyrrole-polyvinyl sulfate for anodes and oxidized polypyrrole doped with chloride for cathodes. The electrolyte consisted of a potassium chloride solution. It was also reported that the University of Kyoto researchers planned to make better plastic anodes using other conducting polymers to obtain a longer lasting battery. Reportedly, these batteries with electrodes made of cheap and lightweight plastic might someday replace lead and nickel-cadmium batteries.[7]

Spray pyrolysis processing (SPP), also called low-temperature chemical vapor deposition, of cadmium sulfide and other optoelectronic materials was discussed in a review article that examined the major processing variables, equipment requirements, and chemical solutions utilized. Likely applications for the SPP-fabricated thin films included photodetectors, transparent conductors, and bandpass windows. The relative simplicity and low cost of the SPP technique reportedly made it quite promising because SPP thin films had properties equivalent to those of thin films fabricated by conventional techniques. The process was expected to be a good candidate for large-scale industrial utilization.[8]

Developments in cadmium technology during the year were abstracted in Cadscam, a quarterly publication available through the Cadmium Association, 34 Berkeley Square, London, W1X 6AJ, England.

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[1]Physical scientist, Branch of Nonferrous Metals.

[2]Federal Register. Notice of the First Priority List of Hazardous Substances That Will Be the Subject of Toxicological Profiles. V. 52, No. 74, Apr. 17, 1987, pp. 12866-12874.

[3]———. Cadmium: Intent To Cancel Registration of Pesticide Products Containing Cadmium; Denial of Applications of Registration of Pesticide Products Containing Cadmium; Conclusion of Special Review. V. 52, No. 160, Aug. 19, 1987, pp. 31076-31083.

[4]Advanced Battery Technology. V. 23, No. 12, Dec. 1987, p. 8.

[5]———. V. 23, No. 6, June 1987, pp. 1-2.

[6]———. V. 23, No. 5, May 1987, p. 1.

[7]New Scientist. A Step Closer to Plastic Batteries. V. 113, No. 1553, Mar. 26, 1987, p. 34.

[8]Albin, S. A., and S. H. Risbud. Spray Pyrolysis Processing Optoelectronic Materials. Advanced Ceramic Mater., v. 2, No. 3A, 1987, pp. 243-251.

Calcium and Calcium Compounds

By David E. Morse[1]

Calcium, the fifth most abundant element in the earth's crust, is chemically very active and is found in nature in a host of minerals that occur in nearly every geologic environment. The Bureau of Mines publishes reports for a variety of calcium-containing minerals and compounds because of their commercial significance and contribution to the quality of human life. The commercial name for calcium fluoride is fluorspar; calcium carbonate is sold as either limestone, marble, calcareous marl or shell; calcium sulfate is gypsum or anhydrite; calcium oxide and hydroxide are called lime; and calcium phosphate (apatite) is known as phosphate rock. Information on these products can be obtained in the chapters of the Bureau of Mines Minerals Yearbook entitled "Fluorspar," "Gypsum," "Lime," "Phosphate Rock," "Crushed Stone," and "Dimension Stone." Other calcium compounds are discussed in the chapter concerning the element with which calcium is combined; for example, calcium bromide is covered in the "Bromine" chapter. This chapter includes calcium metal, calcium chloride, and various other calcium compounds not covered elsewhere.

Calcium metal was manufactured by one company in Connecticut. Natural calcium chloride was produced by three companies in California, two companies in Michigan, and one company in Washington. Synthetic calcium chloride was manufactured by two companies in Louisiana and one company in Washington.

Domestic Data Coverage.—Domestic production data for calcium chloride are developed by the Bureau of Mines from a voluntary survey of U.S. operations entitled "Calcium Chloride and Calcium-Magnesium Chloride." Of the 10 operations to which a survey request was sent, 9 responded, representing less than one-half of the total production shown in table 1. Production for the single nonrespondent, Dow Chemical Co. at Ludington, MI, was estimated using published plant capacity and information reported in trade journals and research reports.

DOMESTIC PRODUCTION

Pfizer Inc. produced calcium metal at Canaan, CT, by the Pidgeon process, an aluminothermic process in which high-purity calcium oxide (produced by calcining limestone) and aluminum powder are briquetted and heated in vacuum retorts. The vaporized calcium metal product is collected as a crown in a water-cooled condenser.

Pfizer produced commercial-grade calcium containing 98.5% calcium in seven shapes, high-purity redistilled metal containing 99.2% calcium in four shapes, and an 80% calcium-20% magnesium alloy. Pfizer also produced an alloy consisting of 75% calcium and 25% aluminum for use in maintenance-free batteries, and a pure calcium wire used in the steel industry to modify inclusions. Elkem Metals Co., a Norwegian-owned company with headquarters at Pittsburgh, PA, produced calcium alloys at its plant in Alloy, WV, including a calcium-silicon alloy containing about 30% calcium, 65% silicon, and 5% iron, and two proprietary alloys that contain barium, and barium and aluminum. The Foote Mineral Co., ASARCO Incorporated, and The Pesses Co. also produced calcium alloys.

National Chloride Co. of America, Cargill Inc.'s Leslie Salt Co., and Hill Bros. Chemical Co. produced calcium chloride from dry-lake brine wells in San Bernardino County, CA. Hill Bros. Chemical also produced from a second operation near Cadiz Lake. Natural calcium chloride production in California was much less than the quantity produced in Michigan. Dow and Wilkinson Chemical Corp. recovered calcium chloride from brines in Lapeer and Mason Counties, MI. Dow's Ludington plant produced calcium chloride pellets and flake; Wilkinson marketed calcium chloride solutions only. Tahoma Chemical Co. Inc. produced natural calcium chloride in Washington.

Allied Signal Inc. recovered synthetic calcium chloride as a byproduct at its Baton Rouge, LA, plant using hydrochloric acid and limestone; Texas United Chemical Corp. produced calcium chloride from purchased hydrochloric acid and limestone at its plant near Lake Charles, LA; and Occidental Chemical Corp. manufactured calcium chloride at Tacoma, WA, using limestone and hydrochloric acid.

Texas United Chemical produced granular calcium chloride at Lake Charles, LA. Total capacity was reported to be 40,000 short tons per year of liquid and dry calcium chloride, 100% basis.

Calcium hypochlorite was produced by Olin Corp. and PPG Industries Inc. Total domestic calcium hypochlorite capacity was 165,000 tons per year.

Table 1.—U.S. production of calcium chloride (75% $CaCl_2$ equivalent)

Year	Natural		Synthetic		Total	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1983	663,949	$71,330	192,688	$29,727	856,637	$101,057
1984[e]	838,000	93,000	198,000	31,500	1,036,000	124,500
1985	W	W	W	W	940,000	135,200
1986	W	W	W	W	780,000	[r]109,294
1987[e]	W	W	W	W	772,776	87,353

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data.

CONSUMPTION AND USES

Calcium metal was used in the manufacture of batteries, as an aid in removing bismuth in lead refining, as a desulfurizer and deoxidizer in steel refining, and as a reducing agent to recover refractory metals such as chromium, rare earths, and thorium from their oxides. Some minor uses were in the preparation of vitamin B and chelated calcium supplements and as a cathode coating in some types of photoelectric tubes. The nuclear applications of calcium metal give it strategic significance; foreign sales must be approved by the U.S. Department of State. State Department approval had been denied to countries that were not signatory to the United Nations Nuclear Nonproliferation Treaty. Calcium metal is used to reduce uranium dioxide, a fuel element utilized in some types of fission reactors.

Calcium chloride was used for road and pavement deicing, dust control and road base stabilization, coal and other bulk material thawing, oil and gas drilling, concrete-set acceleration, tire ballasting, and miscellaneous uses.

The principal use of calcium chloride was to melt snow and ice from roads. Calcium chloride is more effective at lower temperatures than rock salt and has been used mainly in the Northern and Eastern States. Because of its considerably higher price, it was used in conjunction with rock salt for maximum effectiveness and economy.

Calcium hypochlorite was used to disinfect swimming pools, which accounted for 85% of domestic demand, and in other municipal and industrial bleaching and sanitation processes. It was used as an algicide, bactericide, deodorant, water purifier, disinfectant, fungicide, and bleaching agent.

Calcium nitrate was used as a concrete additive to inhibit corrosion of steel reinforcement bars, accelerate setting time, and enhance strength.

Calcium carbide and calcium-silicon alloy were used to remove sulfur from molten pig iron as it was carried in transfer ladles from the blast furnace to the steelmaking furnace.

Precipitated calcium carbonate was used as a pigment for brightness and opaqueness in premium-quality coated and uncoated papers.

PRICES AND SPECIFICATIONS

The published price of calcium metal crowns in quantities greater than 20,000 pounds was unchanged from that established November 1, 1985. The published price of calcium-silicon alloy remained unchanged. Yearend published prices and specifications were as follows:

	Value per pound	
	1986	1987
Calcium metal, 1-ton lots, 50-pound full crowns, 10 by 18 inches, Ca+Mg 99.5%, Mg 0.7%	$3.92	$3.92
Calcium-silicon alloy, 32% calcium, carload lots, f.o.b. shipping point	.72	.72

Source: Metals Week. V. 57, No. 52, 1986, p. 5; v. 58, No. 52, 1987, p. 5.

Calcium metal was usually sold in the form of crowns, broken crown pieces or nodules, or billets, which are produced by melting crowns in an argon atmosphere. The metal purity in these forms was at least 98%. Higher purity metal was obtained by redistillation.

Calcium metal was usually shipped in polyethylene bags under argon in airtight 55-gallon steel drums.

Calcium chloride was sold as flake or pellet averaging about 75% $CaCl_2$, or as a liquid concentrate averaging 40% $CaCl_2$. Yearend 1987 published prices and specifications were as follows:

	Value per ton
Calcium chloride concentrate, regular grade, 77% to 80%, flake, bulk, carload, works	$153.00
100-pound bags, carload, same basis	196.00
Anhydrous, 94% to 97%, flake or pellet, bulk, carload, same basis	217.00
80-pound bags, carload, same basis	279.00
Brining grade, 80-pound bags	285.00
Calcium chloride liquid, 100% basis, tank car, tank truck, barge	99.75
45%, same basis	118.00
Calcium chloride, United States Pharmacopeia, granular, 225-pound drums, truckload, freight equalized	1,800.00

Source: Chemical Marketing Reporter. Dec. 28, 1987, p. 29.

FOREIGN TRADE

U.S. exports of calcium chloride increased significantly in quantity; exports to Canada were more than double those of 1986. Calcium hypochlorite was exported in small quantities to 76 countries worldwide for an export value of $28 million, or an increase of $5 million compared with that of 1986. Exports of calcium phosphates, which is used as a feed additive for livestock, were valued at $53.5 million and went to over 50 countries, primarily in the Western Hemisphere. The combined customs value for exported calcium borate, calcium carbide, calcium chloride, and other calcium compounds totaled $19.3 million.

Imports for consumption of calcium metal were from four countries—Canada, China, France, and the U.S.S.R. China supplied more than one-half of the quantity imported; France, about 23%; Canada, 15%; and the U.S.S.R., about 9%. Imports of crude calcium chloride showed a marked increase compared with those of 1986. Imports from Canada were responsible for most of the increase; Canada supplied over three quarters of U.S. imports. Allied increased operating rates at its Amherstburg, Ontario, Canada, facility after the shutdown of its synthetic, Solvay soda ash plant near Syracuse, NY, in 1986. Imports of a variety of calcium compounds are listed in tabular form in this report for the first time.

Table 2.—U.S. exports of calcium chloride, by country

Country	1986		1987	
	Short tons	Value[1]	Short tons	Value[1]
Canada	13,341	$2,308,561	28,718	$4,007,252
Mexico	448	132,904	704	231,133
Netherlands	595	132,530	471	686,332
Sweden	907	412,852	524	216,624
Switzerland	277	141,178	857	179,986
United Arab Emirates	840	230,666	330	50,226
Venezuela	249	118,386	1,159	400,180
Other	[r]1,511	[r]485,170	1,955	885,566
Total	18,168	3,962,247	34,718	6,657,299

[r]Revised.
[1]U.S. Customs declared value.

Source: Bureau of the Census.

Table 3.—U.S. imports for consumption of calcium and calcium chloride

Year	Calcium		Crude calcium chloride		Other calcium chloride	
	Pounds	Value[1]	Short tons	Value[1]	Short tons	Value[1]
1983	332,834	$866,409	13,580	$654,490	204	$662,526
1984	248,973	669,586	21,803	1,341,166	275	475,749
1985	492,244	1,395,198	75,381	9,059,352	2,355	1,907,976
1986	566,170	1,310,084	143,328	14,403,393	2,098	1,263,552
1987	776,225	1,918,099	229,964	20,916,867	1,282	706,370

[1]U.S. Customs, insurance, freight.

Source: Bureau of the Census.

Table 4.—U.S. imports for consumption of calcium chloride, by country

Country	1986		1987	
	Short tons	Value[1]	Short tons	Value[1]
Crude:				
Canada	111,991	$9,317,161	180,786	$13,533,501
Germany, Federal Republic of	5,175	861,372	18,957	2,234,665
Mexico	516	12,614	5,422	952,860
Sweden	4,734	806,112	11,219	1,479,925
Other	20,912	3,406,134	13,580	2,715,916
Total	143,328	14,403,393	229,964	20,916,867
Other:				
Canada	363	418,256	489	433,831
Germany, Federal Republic of	1,286	460,180	54	83,699
Sweden	22	22,006	2	2,927
Other	427	363,110	737	185,913
Total	2,098	1,263,552	1,282	706,370

[1]U.S. Customs, insurance, freight.

Source: Bureau of the Census.

Table 5.—U.S. imports of other calcium chloride

	1986		1987	
	Short tons	Value[1]	Short tons	Value[1]
Calcium borate (crude)	39,158	$8,783,616	19,149	$3,326,187
Calcium bromide	3,109	965,988	4,038	1,016,511
Calcium carbide	17,616	5,645,762	15,881	5,502,804
Calcium carbonate, precipitated	18,706	7,832,341	16,001	7,883,693
Calcium carbonate, chalk whiting	5,457	1,160,048	5,319	1,174,752
Calcium carbonate (crude), natural chalk	154	2,085,850	114	1,596,521
Calcium cyanamide	3,397	922,703	2,422	1,172,710
Calcium hypochlorite	7,034	10,167,859	8,192	11,811,590
Calcium nitrate	73	16,959,888	76	16,505,195
Dicalcium phosphate	1,566	1,347,409	2,161	2,301,958
Limestone for fertilizer manufacture	165	2,891,835	211	3,605,978
Total	XX	58,763,299	XX	55,897,899

XX Not applicable.
[1]U.S. Customs declared value.

Source: Bureau of the Census.

WORLD REVIEW

Calcium metal was produced in Canada, France, Japan, and the U.S.S.R., in addition to the United States. Market economy country production was estimated to be about 1,500 tons. Total world production was an estimated 2,000 tons. Calcium chloride is a byproduct of synthetic soda ash production, especially in Eastern and Western Europe, and in many cases it is treated as a waste product. The calcium chloride brine from many facilities is dumped into rivers and estuaries. This practice, because of increased pressure from government agencies and environmental interest groups, may be severely curtailed in the future, which could result in a significant increase in the quantity of calcium chloride available in the world marketplace.

[1]Physical scientist, Branch of Industrial Minerals.

Cement

By Wilton Johnson[1]

U.S. demand for cement increased slightly, reaching a record high for the fifth consecutive year. The value of new construction followed a similar upward trend, driven by small increases in residential and public works activity. All regions of the country experienced gains in cement consumption except the South and West, which remained essentially unchanged.

Domestic production declined for the second year in a row as producers continued to shut down less efficient plants, thereby increasing their dependence on lower cost imports to fill the supply-demand gap. The average reported per-ton value of portland cement sold declined to its lowest level since 1979, while the value of masonry cement sold increased for the sixth consecutive year.

Acquisition of U.S. cement plants continued. By yearend, approximately 55% of U.S. cement production capacity had been acquired by foreign owners, and the sales of other plants were being negotiated.

Domestic Data Coverage.—Domestic production and consumption data for cement are developed by means of the portland and masonry cement voluntary survey. Of the 135 cement manufacturing plants to which an annual survey collection request was made, all responded, representing 100% of the cement production and consumption data shown in table 1.

Table 1.—Salient cement statistics

(Thousand short tons unless otherwise specified)

	1983	1984	1985	1986	1987
United States:[1]					
Production[2]	70,420	77,700	77,895	78,786	78,198
Shipments from mills[2 3]	70,933	80,166	83,032	87,592	89,131
Value[2 3 4] thousands	$3,534,324	$4,152,258	$4,286,399	$4,407,722	$4,393,684
Average value per ton[2 3 4]	$49.95	$51.80	$51.61	$50.32	$49.29
Stocks at mills,[2] Dec. 31	6,711	6,866	7,232	6,725	6,159
Exports	118	80	98	59	52
Imports for consumption	4,221	8,689	14,120	16,128	17,536
Consumption, apparent[5 6]	73,435	84,313	87,456	91,501	93,886
World: Production	[r]1,010,051	[r]1,036,392	[r]1,056,660	[p]1,100,814	[e]1,138,673

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Excludes Puerto Rico and the Virgin Islands.
[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

One State agency and 48 companies operated 135 plants in 40 States. In addition, two hydraulic cement manufacturing companies operated two plants in Puerto Rico.

Some of the data are arranged by State or by groups of States that form cement districts. A cement district may represent a group of States or a portion of a State. The States of California, Illinois, New York, Pennsylvania, and Texas are divided to provide more definitive marketing information within those States. Divisions for these States are as follows:

California, Northern.—Points north and west of the northern borders of Kern and San Luis Obispo Counties and the western borders of Inyo and Mono Counties.

California, Southern.—All other counties in California.

Chicago, Metropolitan.—The seven Illinois counties of Cook, Du Page, Kane, Kendall, Lake, McHenry, and Will.

Illinois.—All other counties in Illinois.

New York, Western.—All counties west of a dividing line following the eastern boundaries of Broome, Chenango, Lewis, Madison, Oneida, and St. Lawrence Counties.

New York, Eastern.—All counties east of the above dividing line, except Metropolitan New York.

New York, Metropolitan.—The five counties of New York City (Bronx, Kings, New York, Richmond, and Queens) plus Nassau, Rockland, Suffolk, and Westchester Counties.

Pennsylvania, Eastern.—All counties east of the eastern boundaries of Centre, Clinton, Franklin, Huntingdon, and Potter Counties.

Pennsylvania, Western.—All other counties in Pennsylvania.

Texas, Northern.—All counties north of a dividing line following the northern borders of Burnet, Crockett, Jasper, Jeff Davis, Llano, Madison, Mason, Menard, Milam, Newton, Pecos, Polk, Robertson, San Jacinto, Schleicher, Tyler, Walker, and Williamson Counties.

Texas, Southern.—All counties south of the above dividing line.

PORTLAND CEMENT

Clinker production in the United States, including Puerto Rico, remained essentially unchanged. Clinker imported for grinding into finished cement declined slightly as producers focused more on importation of finished cement to meet customers' needs. Additions to capacity resulting from plant construction in Florida and Texas were more than offset by plant closings in Nebraska, Pennsylvania, Texas, Washington, and Wisconsin.

Production Capacity.—By yearend, multiplant operations were being run by 25 companies. The size of individual companies, as a percentage of total U.S. clinker production capacity, ranged from 0.3% to 9%. The 5 largest producers provided 29% of total clinker production; the 10 largest producers provided a combined 50%. The 10 largest companies, in decreasing order of size of clinker production, were Lone Star Industries Inc., Lehigh Portland Cement Co., Lafarge Corp., Gifford Hill & Co. Inc., Dundee Cement Co., Blue Circle Inc., Southwestern Portland Cement Co., Ideal Basic Industries Inc., Moore McCormack Resources Inc., and CalMat Co.

At yearend, 247 kilns at 121 plants were being operated by 44 companies and 1 State agency in the United States, excluding Puerto Rico. Annual yearend production capacity and capacity utilization remained largely unchanged. The average annual maintenance downtime declined by 18% to 45 days. The average annual capacity of U.S. kilns and plants increased slightly to 350,000 tons and 718,000 tons, respectively, whereas company capacity declined 10% to 1.8 million tons as ownership patterns continued to change. Three plants produced white cement. In addition, 11 plants operated grinding mills using only imported, purchased, or interplant transfers of clinker.

Capacity Added.—Box-Crow Cement Co. began operating its 1-million-ton-per-year, state-of-the-art, dry-process, preheater-precalciner plant at Midlothian, TX. The plant also features a 1,200-ton-per-hour mobile crushing system.

Florida Crushed Stone Co. brought its 600,000-ton-per-year plant on-line in Brooksville, FL. For raw materials, the plant uses waste fines generated from production of limestone aggregate. The plant also features a 125-megawatt power generation facility and has the capacity to produce 350,000 tons of lime annually.

Plant Closings.—Ash Grove Cement West Inc. closed its Seattle, WA, plant in December and began using it as a distribution terminal. Coplay Cement Co., a subsidiary of the French firm Société des Ciments Français, closed its Nazareth, PA, No. 2 plant and turned it into a distribution facility. Ideal Basic Industries, a subsidiary of Holderbank Financiere Glaris S.A. of Holdererbank, Switzerland, discontinued production at its Superior, NE, plant and used it as a distribution terminal. River Cement Co., owned by RC Cement Co. Inc. of St. Louis, MO, ceased operation at its Orange, TX, plant and began using it as a distribution facility. Southwestern Portland Cement Co., a subsidiary of Southdown Inc. of Houston, TX, closed its Amarillo, TX, plant, and St. Marys Wisconsin Cement Inc. closed its Milwaukee, WI, cement plant and began using it as a distribution terminal.

Corporate Changes.—Ash Grove Cement West, Portland, OR, purchased Kaiser Cement Corp.'s plant at Montana City, MN. The 300,000-ton-per-year plant serves markets in Idaho, Montana, North Dakota, and Oregon, and Washington. Hanson Trust PLC, a large British construction firm, purchased Kaiser Cement Corp. of Oakland, CA. The sale included plants in northern and southern California and San Antonio, TX. National Cement Co., a subsidiary of Société Anonyme des Ciments Vicat of France, purchased the Lebec, CA, plant of General Portland Inc., a subsidiary of Lafarge Corp., also of France. The Pima Maricopa Indian Community bought Phoenix Cement Co. of Clarkdale, AZ, from Gifford-Hill and Co., a subsidiary of C. H. Beazer Holdings PLC of the United Kingdom. In addition to the 600,000-ton-per-year plant, the purchase also included a distribution terminal in Phoenix, AZ, and a nearby limestone deposit.

Presa S.p.A. Cementeria di Robilante, an Italian cement producer, purchased Kaiser Cement Corp.'s San Antonio, TX, plant and continued to operate it as a distribution terminal under the new name of Longhorn Cement Co. Lafarge Corp. relocated its corporate offices from Dallas, TX, to Reston, VA, and exercised its option to acquire National Gypsum Cement Co.'s Alpena, MI, cement plant.

Lone Star Industries Inc. and Centex Cement Corp. formed a joint venture called Mountain Cement Co. to manufacture and market cement in the Rocky Mountain area. Scancem Ans, a Norwegian-based partnership between Norcem Cement A/S of Norway and Industri AB Euroc of Sweden, purchased Allentown Portland Cement Co.'s 830,000-ton-per-year-capacity plant at Evansville, PA.

Table 2.—Portland cement production, capacity, and stocks in the United States, by district[1]

District	1986					1987				
	Plants active during year	Production[2] (thousand short tons)	Capacity[3]		Stocks[4] at mills, Dec. 31 (thousand short tons)	Plants active during year	Production[2] (thousand short tons)	Capacity[3]		Stocks[4] at mills, Dec. 31 (thousand short tons)
			Finish grinding (thousand short tons)	Percent utilized				Finish grinding (thousand short tons)	Percent utilized	
New York and Maine	6	4,018	4,028	99.8	276	5	3,720	4,068	91.4	254
Pennsylvania, eastern	9	4,790	5,903	81.1	344	8	4,759	5,734	82.9	293
Pennsylvania, western	4	1,435	2,310	62.1	175	4	1,538	2,417	63.6	162
Maryland	3	1,771	1,902	93.0	158	3	1,863	2,035	91.5	139
Ohio	6	1,657	2,603	63.6	163	5	1,717	2,460	69.8	164
Michigan	5	4,830	6,740	71.6	468	5	4,925	6,442	76.5	341
Indiana	4	2,347	2,981	78.7	221	4	2,692	2,732	98.5	178
Illinois	4	2,139	2,950	72.5	146	4	1,731	2,548	67.9	308
Georgia and Tennessee	4	2,115	2,565	82.4	226	4	2,194	2,565	85.5	186
South Carolina	3	2,252	3,447	65.3	114	3	2,459	3,447	71.3	101
Kentucky, Virginia, West Virginia	3	2,623	2,812	93.2	177	3	2,480	2,852	86.9	164
Florida	5	3,109	4,186	74.2	227	6	3,383	4,761	71.0	238
Nebraska and Wisconsin	4	W	W	W	W	1	W	W	W	W
Alabama	6	3,494	5,584	62.6	361	6	3,762	5,291	71.1	332
Arkansas, Louisiana, Mississippi	4	1,679	2,790	60.2	153	4	1,508	2,790	54.0	146
Utah	3	1,015	1,365	74.3	102	3	897	1,365	65.7	71
South Dakota	1	632	1,806	35.0	58	1	621	1,800	34.5	65
Iowa	4	2,006	3,072	65.2	292	4	2,172	2,732	79.4	254
Missouri	5	4,636	4,900	94.6	397	5	4,795	4,950	96.8	308
Kansas	5	1,747	2,485	70.2	226	5	1,743	2,435	71.5	203
Oklahoma	3	1,653	2,080	79.4	277	3	1,603	2,099	76.3	240
Texas, northern	9	3,677	5,474	67.1	294	8	3,252	5,665	57.4	213
Texas, southern	9	4,654	6,545	71.1	222	7	4,163	6,448	64.5	160
Idaho and Montana	3	630	975	64.5	124	3	679	960	70.7	107
Colorado and Wyoming	4	1,428	2,720	52.4	134	4	1,286	2,720	47.2	158
Alaska and Oregon	2	W	W	W	W	2	W	W	W	W
Arizona, Nevada, New Mexico	4	2,290	3,015	75.9	141	4	2,013	3,015	66.7	147
California, northern	3	2,727	3,025	90.1	130	3	2,830	3,025	93.5	160
California, southern	8	7,230	9,056	79.8	310	8	7,106	9,196	77.2	316
Hawaii	2	301	520	57.9	42	1	327	350	93.5	31
Washington	4	1,143	2,029	56.3	159	4	1,201	2,029	59.2	153
Total or average	139	75,217	102,288	73.7	6,276	130	74,557	101,351	73.6	5,708
Puerto Rico	2	1,130	2,209	51.1	34	2	1,303	2,176	59.8	34

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

[1]Includes Puerto Rico. Includes data for three white cement facilities as follows: California (1), Pennsylvania (1), and Texas (1). Includes data for grinding plants (13 in 1986 and 11 in 1987) as follows: Alaska (1), Florida (3) in 1986 and (2) in 1987, Iowa (1) in 1987, Michigan (1), New York (1) in 1986, Pennsylvania (2) in 1986 and (1) in 1987, Texas (3) in 1986 and (1) in 1987, Washington (2) in 1987, and Wisconsin (2).

[2]Includes cement produced from imported clinker (1986—1,727,000 tons and 1987—3,242,000 tons).

[3]Grinding capacity based on fineness necessary to grind Types I and II cement, making allowance for downtime required for maintenance.

[4]Includes imported cement. Source of imports withheld to avoid disclosing company proprietary data.

Table 3.—Clinker capacity and production in the United States,[1] by district, as of December 31, 1987

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[2] (thousand short tons)	Production[3] (thousand short tons)	Percent utilized
New York and Maine	4	1	--	5	6	13.0	64	3,995	3,351	83.8
Pennsylvania, eastern	2	5	--	7	16	16.0	36	5,091	4,303	84.5
Pennsylvania, western	3	1	--	4	8	7.0	43	2,088	1,730	82.8
Maryland	1	2	--	3	7	6.0	53	1,870	1,793	95.8
Ohio	2	2	1	5	8	7.0	47	2,306	1,663	72.1
Michigan	2	2	--	4	13	17.0	40	5,605	4,016	71.6
Indiana	2	2	--	4	9	10.0	58	2,997	2,520	84.0
Illinois	--	4	--	4	8	8.0	35	2,785	1,616	58.0
Georgia and Tennessee	1	2	1	4	7	7.0	40	2,335	2,174	93.1
South Carolina	2	1	--	3	7	8.0	60	2,465	2,340	94.9
Kentucky, Virginia, West Virginia	1	2	--	3	9	8.0	28	2,765	2,356	85.2
Florida	2	2	--	4	8	10.0	29	3,453	2,587	74.9
Nebraska and Wisconsin	--	1	--	1	2	W	99	W	W	W
Alabama	1	5	--	6	8	14.0	29	4,669	3,023	64.7
Arkansas, Louisiana, Mississippi	4	--	--	4	8	8.0	36	2,562	1,386	54.0
Utah	2	1	--	3	6	4.0	58	1,303	930	71.4
South Dakota	--	--	1	1	4	3.0	32	973	569	58.5
Iowa	--	3	--	3	6	8.0	45	2,340	1,958	83.6
Missouri	2	3	--	5	7	14.0	76	4,336	4,310	99.3
Kansas	3	2	--	5	15	7.0	66	2,076	1,733	83.4
Oklahoma	1	2	--	3	7	5.0	52	1,713	1,474	86.0
Texas, northern	5	3	--	8	17	13.0	33	4,365	3,125	71.6
Texas, southern	1	4	1	6	7	16.0	27	5,514	3,670	66.5
Idaho and Montana	3	--	--	3	4	2.0	50	742	631	85.0
Colorado and Wyoming	2	2	--	4	5	5.0	33	1,744	1,177	67.4
Alaska and Oregon	--	1	--	1	1	W	36	W	W	97.3
Arizona, Nevada, New Mexico	--	4	--	4	11	8.0	46	2,443	1,992	81.5
California, northern	--	3	--	3	3	10.0	56	3,023	2,788	92.2
California, southern	1	7	--	8	24	28.0	35	8,950	7,580	84.6
Hawaii	--	1	--	1	1	1.0	42	262	240	91.7
Washington	1	1	--	2	5	3.0	25	914	572	62.6
Total or average[4]	48	69	4	121	247	272.0	45	[4]86,963	68,719	79.0
Puerto Rico	--	2	--	2	9	7.0	53	2,198	1,143	52.0

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1]Includes Puerto Rico and white cement producing facilities.
[2]Calculated on individual company data; 365 days, minus average number of days for maintenance, times the reported 24-hour capacity.
[3]Includes production reported for plants that added or shut down kilns during the year.
[4]Data may not add to totals shown because of independent rounding.

Table 4.—Daily clinker capacity in the United States,[1] December 31

Short tons per 24-hour period	Number: Plants	Number: Kilns[2]	Total capacity (short tons)	Percent of total capacity
1986:				
Less than 1,150	20	35	16,926	6.5
1,151 to 1,700	32	58	46,585	17.9
1,701 to 2,300	28	52	54,376	20.9
2,301 to 2,800	17	37	42,628	16.3
2,801 and over	27	66	100,205	38.4
Total	124	248	260,720	100.0
1987:				
Less than 1,150	17	27	13,460	4.8
1,151 to 1,700	31	57	45,978	16.5
1,701 to 2,300	21	36	40,622	14.5
2,301 to 2,800	20	40	49,598	17.8
2,801 and over	34	96	129,723	46.4
Total	123	256	279,381	100.0

[1]Includes Puerto Rico and white cement producing facilities.
[2]Total number in operation at plants.

Table 5.—Raw materials used in producing portland cement in the United States[1]

(Thousand short tons)

Raw materials	1985	1986	1987
Calcareous:			
Limestone (includes aragonite, marble, chalk)	77,627	78,995	81,143
Cement rock (includes marl)	24,255	23,495	17,959
Coral	1,277	1,040	935
Other	243	428	--
Argillaceous:			
Clay	5,635	5,734	4,766
Shale	3,182	3,282	4,906
Other (includes staurolite, bauxite, aluminum dross, alumina, volcanic material, other)	123	261	263
Siliceous:			
Sand and calcium silicate	1,930	1,934	1,873
Sandstone, quartzite, other	608	709	758
Ferrous: Iron ore, pyrites, millscale, other iron-bearing material	1,307	1,081	1,079
Other:			
Gypsum and anhydrite	3,959	4,103	4,939
Blast furnace slag	97	74	109
Fly ash	796	689	803
Other, n.e.c	311	346	386
Total[2]	121,350	122,169	119,920

[1]Includes Puerto Rico.
[2]Data may not add to totals shown because of independent rounding.

MASONRY CEMENT

Production of masonry cement remained essentially unchanged. At yearend, 94 plants were manufacturing masonry cement in the United States. Two plants producing masonry exclusively were Chaney Lime & Cement Co., Allgood, AL, and Riverton Corp., Riverton, VA.

Table 6.—Masonry cement production and stocks in the United States, by district

District	1986 Plants active during year	1986 Production (thousand short tons)	1986 Stocks[1] at mills, Dec. 31 (thousand short tons)	1987 Plants active during year	1987 Production (thousand short tons)	1987 Stocks[1] at mills, Dec. 31 (thousand short tons)
New York and Maine	4	97	13	4	114	12
Pennsylvania, eastern	7	281	29	6	288	32
Pennsylvania, western	4	93	15	4	86	13
Maryland	2	W	W	2	W	W
Ohio	4	130	18	4	142	22
Michigan	4	271	62	5	259	50
Indiana	4	392	64	4	416	54
Illinois	1	W	W	2	W	W
Georgia and Tennessee	4	214	28	4	230	29
South Carolina	2	W	W	2	W	W
Kentucky, Virginia, West Virginia	4	294	15	4	335	21
Florida	4	415	7	4	435	18
Nebraska and Wisconsin	3	12	7	1	W	W
Alabama	7	249	24	7	278	30
Arkansas, Louisiana, Mississippi	2	69	6	2	W	W
Utah	1	W	W	1	W	W
South Dakota	1	2	1	1	6	3
Iowa	3	47	15	2	W	W
Missouri	4	160	18	4	186	19
Kansas	5	50	20	5	46	15
Oklahoma	3	52	13	3	40	13
Texas, northern	7	164	20	6	89	14
Texas, southern	5	52	8	4	68	8
Idaho and Montana	3	W	W	3	W	W
Colorado and Wyoming	2	W	W	2	W	W
Arizona, Nevada, New Mexico	3	90	6	3	82	7
California, northern	1	W	W	1	W	W
California, southern	1	W	W	1	W	W
Hawaii	1	7	([2])	1	10	1
Washington	3	5	5	2	W	W
Total or average[3]	99	3,569	449	94	3,641	451

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1]Includes imported cement.
[2]Less than 1/2 unit.
[3]Data may not add to totals shown because of independent rounding.

ALUMINOUS CEMENT

Aluminous cement, also known as calcium aluminate cement, high-alumina cement, and Cement Fondu, is a nonportland hydraulic cement. It continued to be produced at the following three plants in the United States: Lehigh, Buffington, IN; Lone Star Lafarge Inc., Chesapeake, VA; and Aluminum Co. of America, Bauxite, AR.

ENERGY

Approximately 76% of the energy consumed in cement production was in the form of fuel for kiln firing to produce clinker. Average energy consumption per ton of clinker produced was 4.1 million British thermal units (Btu).

The average consumption of electrical energy decreased slightly to 135 kilowatt-hours per ton. Assuming a 40% energy efficiency in conversion of fuel to electrical energy, this represents a fuel equivalent of 1.2 million Btu per ton. Thus, average fuel consumption for kiln firing plus electrical energy, primarily for finish grinding, was approximately 5.4 million Btu per ton, essentially unchanged from that of 1986.

Average fuel consumption for kiln firing in wet-process plants, 4.8 million Btu per ton, was 26% higher than average fuel consumption in dry-process plants, 3.8 million Btu per ton. Approximately 63% of clinker was produced by the dry-process method.

The industry reported 63 suspension and 13 grate preheaters in use during the year. Kilns without preheaters averaged 5.2 million Btu per ton of clinker produced; those with suspension preheaters averaged 3.3 million Btu per ton and those with grate-type preheaters averaged 4.9 million Btu per ton.

Coal accounted for 93% of kiln fuel consumption, natural gas accounted for 4%, and oil and waste fuel accounted for the remainder.

Table 7.—Clinker produced in the United States,[1] by fuel

Fuel	Clinker produced			Fuel consumed		
	Plants active during year	Quantity (thousand short tons)	Percent of total	Coal[2] (thousand short tons)	Oil (thousand 42-gallon barrels)	Natural gas (thousand cubic feet)
1986:						
Coal	23	12,644	18.0	2,332	--	--
Coal and oil	30	17,571	26.0	3,086	385	--
Coal and natural gas	58	30,887	44.0	4,571		10,641,711
Oil and natural gas	--	--	--	--	--	--
Coal, oil, natural gas	13	8,501	12.0	1,237	313	1,456,573
Total	124	69,603	100.0	11,226	698	12,098,284
1987:						
Coal	21	9,533	14.0	1,771	--	--
Coal and oil	30	20,212	29.0	3,673	708	--
Coal and natural gas	56	29,549	42.0	4,026	--	10,244,178
Oil and natural gas	--	--	--	--	--	--
Coal, oil, natural gas	16	10,568	15.0	1,843	347	1,749,183
Total	123	69,862	100.0	11,313	1,055	11,993,361

[1]Includes Puerto Rico.
[2]Includes 1% anthracite, 94% bituminous, and 5% petroleum coke in 1986; 1% anthracite, 95% bituminous, and 4% petroleum coke in 1987.

Table 8.—Clinker produced and fuel consumed by the portland cement industry in the United States,[1] by process

Process	Clinker produced			Fuel consumed		
	Plants active during year	Quantity (thousand short tons)	Percent of total	Coal[2] (thousand short tons)	Oil (thousand 42-gallon barrels)	Natural gas (thousand cubic feet)
1986:						
Wet	52	25,105	36.1	4,833	313	4,074,804
Dry	69	40,951	58.8	5,856	350	7,660,645
Both	3	3,547	5.1	537	35	362,835
Total	124	69,603	100.0	11,226	698	12,098,284
1987:						
Wet	48	23,919	34.2	4,525	545	4,084,751
Dry	71	43,702	62.6	6,459	507	7,783,432
Both	4	2,241	3.2	329	3	125,178
Total	123	69,862	100.0	11,313	1,055	11,993,361

[1]Includes Puerto Rico.
[2]Includes 1% anthracite, 94% bituminous, and 5% petroleum coke in 1986; 1% anthracite, 95% bituminous, and 4% petroleum coke in 1987.

Table 9.—Electric energy used at portland cement plants in the United States,[1] by process

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)
1986:								
Wet	--	--	53	3,905	3,905	37.4	27,968	139.6
Dry[2]	6	795	73	5,223	6,018	57.7	44,551	135.1
Both	--	--	5	514	514	4.9	3,828	134.3
Total or average	6	795	131	9,642	10,437	100.0	76,347	136.7
Percent of total electric energy used	--	7.1	--	92.4	--	--		
1987:								
Wet	--	--	46	3,028	3,028	29.7	25,851	117.1
Dry[2]	5	582	76	6,248	6,830	66.9	47,652	143.3
Both	--	--	4	344	344	3.4	2,357	145.9
Total or average	5	582	--	9,620	10,202	100.0	75,860	134.5
Percent of total electric energy used	--	5.7	126	94.2	--	--		

[1]Includes Puerto Rico. Includes grinding plants and white cement facilities.
[2]Includes data for grinding plants.

TRANSPORTATION

The pattern of cement transport did not differ significantly from that of recent years. U.S. shipments of portland cement to consumers were primarily in bulk, 94%; by truck, 93%; and made directly from cement manufacturing plants, 67%, rather than distribution terminals.

With respect to shipments of cement from plants to terminals, the preferred modes of transportation were railroads and waterways, 41% each. Transportation by truck accounted for 15%. Cement used at producing plants accounted for the remaining 3%.

Table 10.—Shipments of portland cement from mills in the United States,[1] in bulk and in containers, by type of carrier

(Thousand short tons)

Type of carrier	Shipments from plant to terminal		Shipments to ultimate consumer: From terminal to consumer		Shipments to ultimate consumer: From plant to consumer		Total shipments
	In bulk	In containers	In bulk	In containers	In bulk	In containers	
1986:							
Railroad	9,308	84	1,254	12	3,639	343	5,248
Truck	2,808	176	24,819	524	49,304	3,614	78,261
Barge and boat	9,121	97	717	--	385	7	1,109
Unspecified[2]	742	--	279	17	202	11	509
Total	21,979	357	27,069	553	53,530	3,975	[3]85,127
1987:							
Railroad	9,050	86	768	202	3,755	207	4,932
Truck	3,231	195	25,536	682	47,381	3,656	77,255
Barge and boat	8,917	12	75	--	229	--	304
Unspecified[2]	539	--	879	68	296	19	1,262
Total[4]	21,738	294	27,257	953	51,661	3,882	[5]83,753

[1]Includes Puerto Rico.
[2]Includes cement used at plant.
[3]Bulk shipments were 94.5%, and container (bag) shipments were 5.5%.
[4]Data may not add to totals shown because of independent rounding.
[5]Bulk shipments were 94.2% and container (bag) shipments were 5.8%.

CONSUMPTION AND USES

Consumer demand for cement in the United States, excluding Puerto Rico, reached a record high 93.9 million tons, the fifth consecutive year of growth following a 20-year low experienced at the depth of the recession in 1982. The amount of construction followed a similar upward pattern. According to the U.S. Department of Commerce, the current dollar value of new construction reached a record $399 billion, slightly higher than that recorded in 1986. Although housing starts declined in all but the north-central region of the country, according to Commerce data the value of residential construction was enhanced because of marked gains in the average house size and increased spending on home improvement.[2]

Shipments of domestically produced cement declined slightly. The gap between production and consumption was filled with imports shipped by producers and independent importers. The level of imports required to meet consumer demands continued to increase, reaching a record high 19% of apparent consumption, with about 70% of imports shipped by domestic producers.

All regions of the country, except the South and the West, registered slight gains in cement consumption. The South, because of its oil-based economy, continued to experience slow economic recovery. A decline of construction activity in the Mountain States resulted in a 9% decrease in cement consumption. However, States in the Pacific region, particularly southern California, continued to enjoy unprecedented growth in cement consumption. The north-central and northeast regions of the country registered the largest increases. The growth in these areas was caused by sharp increases in construction activity during the past few years.

The end-use distribution pattern for portland cement was essentially the same as that of recent years. Ready-mixed concrete producers were the primary consumers, accounting for about 74% of the total, followed by concrete product manufacturers. Smaller amounts were consumed by highway and other contractors; building material dealers; Federal, State, and other government agencies; and a variety of other miscellaneous users.

Table 11.—Portland cement shipped by producers in the United States, by district[1]

District	1986 Quantity (thousand short tons)	1986 Value (thousands)	1986 Average per ton	1987 Quantity (thousand short tons)	1987 Value (thousands)	1987 Average per ton
New York and Maine	3,812	$207,905	$54.55	3,511	$180,281	$51.35
Pennsylvania, eastern	4,862	265,800	54.66	4,852	266,963	55.02
Pennsylvania, western	1,428	58,387	40.88	1,473	67,746	45.99
Maryland	1,785	89,799	50.30	1,829	90,020	49.22
Ohio	1,706	79,383	46.53	1,748	83,661	47.86
Michigan	4,713	216,120	45.86	4,755	207,332	43.60
Indiana	2,136	92,327	43.22	2,320	103,177	44.47
Illinois	2,118	83,783	39.55	2,119	86,210	40.68
Georgia and Tennessee	2,254	108,194	48.00	2,262	108,729	48.07
South Carolina	2,306	109,529	47.49	2,567	117,878	45.92
Kentucky, Virginia, West Virginia	2,427	117,980	48.61	2,357	109,101	46.29
Florida	3,189	147,643	46.29	3,565	165,944	46.55
Nebraska and Wisconsin	W	W	W	W	W	W
Alabama	3,477	153,629	44.18	3,600	160,878	44.69
Arkansas, Louisiana, Mississippi	1,668	83,130	49.83	1,759	74,667	42.45
Utah	1,014	58,431	57.62	935	50,565	54.08
South Dakota	635	W	W	W	W	W
Iowa	1,819	86,984	47.81	2,139	104,457	48.83
Missouri	4,642	179,184	38.60	5,110	185,317	36.27
Kansas	1,763	91,110	51.67	1,697	81,045	47.76
Oklahoma	1,579	69,075	43.74	1,415	54,870	38.78
Texas, northern	3,707	198,397	53.51	3,206	158,944	49.58
Texas, southern	5,176	214,300	41.40	4,112	161,052	39.17
Idaho and Montana	707	35,599	50.35	607	34,121	56.21
Colorado and Wyoming	1,458	90,391	61.99	1,265	70,194	55.49
Alaska and Oregon	W	W	W	W	W	W
Arizona, Nevada, New Mexico	2,289	149,312	65.23	2,136	132,623	62.09
California, northern	2,406	142,018	59.02	2,838	167,658	59.08
California, southern	7,083	436,484	61.62	7,099	426,201	60.04
Hawaii	287	24,253	84.50	324	26,550	81.94
Washington	1,212	59,091	48.75	1,282	63,600	49.61
Total[2] [3] or average	75,181	3,759,942	50.01	74,868	3,646,561	48.71
Foreign imports[4]	8,814	411,614	46.70	10,480	480,212	45.82
Puerto Rico	1,132	93,288	82.40	1,296	106,185	81.93
Grand total[3] or average	85,127	4,264,844	50.10	[5]86,644	[5]4,232,959	48.85

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

[1]Includes Puerto Rico. Includes data for three white cement facilities as follows: California (1), Pennsylvania (1), and Texas (1). Includes data for grinding plants (13 in 1986 and 11 in 1987) as follows: Alaska (1), Florida (3) in 1986 and (2) in 1987, Iowa (1) in 1987, Michigan (1), New York (1) in 1986, Pennsylvania (2) in 1986 and (1) in 1987, Texas (3) in 1986 and (1) in 1987, Washington (2) in 1987, and Wisconsin (2).

[2]Includes cement produced from imported clinker.

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

[4]Cement imported and distributed by domestic producers only.

[5]Does not include cement consumed at plant.

Table 12.—Masonry cement shipped by producers in the United States,[1] by district

District	1986 Quantity (thousand short tons)	1986 Value (thousands)	1986 Average per ton	1987 Quantity (thousand short tons)	1987 Value (thousands)	1987 Average per ton
New York and Maine	102	$6,996	$68.59	131	$8,155	$62.25
Pennsylvania, eastern	297	19,337	65.10	306	22,973	75.08
Pennsylvania, western	94	7,345	78.13	92	7,491	81.42
Maryland	W	W	W	W	W	W
Ohio	138	11,540	83.62	139	11,964	86.07
Michigan	257	17,026	66.24	263	23,004	87.45
Indiana	395	22,936	58.06	422	32,299	76.53
Illinois	W	W	W	W	W	W
Georgia and Tennessee	209	15,031	71.91	230	16,809	73.08
South Carolina	W	W	W	W	W	W
Kentucky, Virginia, West Virginia	292	17,126	58.65	328	21,886	66.73
Florida	352	21,269	60.42	390	24,069	61.72
Nebraska and Wisconsin	W	W	W	W	W	W
Alabama	267	18,165	68.03	291	17,626	60.55
Arkansas, Louisiana, Mississippi	70	4,599	65.70	80	4,651	58.14
Utah	W	W	W	W	W	W
South Dakota	4	W	W	4	W	W
Iowa	48	3,199	66.64	W	W	W
Missouri	167	7,816	46.80	167	10,027	60.04
Kansas	51	3,264	64.00	52	3,150	60.58
Oklahoma	50	3,198	63.96	41	2,436	59.41
Texas, northern	146	11,155	76.40	103	7,589	73.68
Texas, southern	64	4,636	72.43	69	3,694	53.54
Idaho and Montana	3	187	62.33	W	W	W
Colorado and Wyoming	W	W	W	W	W	W
Alaska and Oregon	W	W	W	W	W	W
Arizona, Nevada, New Mexico	89	6,739	75.71	82	6,365	77.62
California, northern	W	W	W	W	W	W
California, southern	W	W	W	W	W	W
Hawaii	7	1,078	154.00	10	1,559	155.90
Washington	6	530	88.33	W	W	W
Total[2] or average	3,525	231,551	65.69	3,680	259,926	70.63
Foreign imports[3]	72	4,616	64.11	103	6,985	67.82
Grand total[2] or average	3,596	236,167	65.68	3,783	266,911	70.55

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1]Does not include quantities produced on the job by masons.
[2]Data may not add to totals shown because of independent rounding.
[3]Cement imported and distributed by domestic producers only. Source of imports withheld to avoid disclosing company proprietary data.

Table 13.—Cement shipments, by destination and origin[1]

(Thousand short tons)

Destination and origin	Portland cement[2] 1985	Portland cement[2] 1986	Portland cement[2] 1987	Masonry cement 1985	Masonry cement 1986	Masonry cement 1987
Destination:						
Alabama	1,306	1,302	1,405	100	112	137
Alaska[3]	156	121	94	W	W	--
Arizona	2,318	2,400	2,299	W	W	W
Arkansas	773	803	766	45	48	43
California, northern	3,439	3,438	3,598	W	W	W
California, southern	6,691	7,844	8,121	W	W	W
Colorado	1,574	1,450	1,110	23	22	16
Connecticut[3]	870	1,037	1,029	17	21	24
Delaware[3]	194	224	254	10	12	15
District of Columbia[3]	116	142	146	1	1	1
Florida	6,140	6,360	6,819	468	499	531
Georgia	2,875	3,224	3,321	228	242	248
Hawaii	214	287	329	7	7	10
Idaho	236	291	251	1	1	(4)
Illinois	1,391	1,511	1,498	28	30	30
Chicago, metropolitan[3]	1,333	1,803	2,037	45	59	66
Indiana	1,353	1,580	1,704	76	97	103
Iowa	1,078	1,046	1,199	11	13	12
Kansas	1,293	1,218	1,351	20	21	25

See footnotes at end of table.

Table 13.—Cement shipments, by destination and origin[1] —Continued

(Thousand short tons)

Destination and origin	Portland cement[2] 1985	Portland cement[2] 1986	Portland cement[2] 1987	Masonry cement 1985	Masonry cement 1986	Masonry cement 1987
Destination —Continued						
Kentucky	1,014	1,115	1,201	78	85	92
Louisiana	2,420	1,964	1,761	65	48	43
Maine	283	336	361	10	12	12
Maryland	1,503	1,666	1,645	139	144	156
Massachusetts[3]	1,395	1,686	1,589	45	53	51
Michigan	2,103	2,478	2,740	104	127	146
Minnesota[3]	1,419	1,464	1,582	40	47	51
Mississippi	758	827	787	57	55	53
Missouri	1,735	2,221	2,091	39	47	53
Montana	190	241	175	1	1	1
Nebraska	783	764	720	11	11	10
Nevada	637	670	754	(4)	(4)	(4)
New Hampshire[3]	374	387	345	15	16	15
New Jersey[3]	1,743	1,972	1,932	78	87	88
New Mexico	620	572	517	10	9	8
New York, eastern	621	670	746	36	42	46
New York, western	812	986	989	43	53	57
New York, metropolitan[3]	1,722	1,932	1,851	50	54	55
North Carolina[3]	1,796	1,980	2,145	238	264	283
North Dakota[3]	286	277	278	5	4	4
Ohio	2,646	3,028	3,314	135	174	189
Oklahoma	1,329	1,107	1,076	40	34	34
Oregon	709	626	728	(4)	(4)	(4)
Pennsylvania, eastern	1,774	1,994	2,132	63	74	87
Pennsylvania, western	1,118	1,222	1,350	70	77	82
Rhode Island[3]	165	199	244	4	6	6
South Carolina	1,019	1,052	1,138	119	136	152
South Dakota	292	332	272	4	4	5
Tennessee	1,480	1,655	1,863	154	184	203
Texas, northern	5,474	4,705	3,799	171	140	96
Texas, southern	5,433	4,531	4,267	101	74	69
Utah	1,059	940	804	2	2	1
Vermont[3]	212	172	173	4	5	6
Virginia	2,116	2,410	2,557	177	219	225
Washington	1,208	1,251	1,361	6	7	8
West Virginia	387	426	455	29	28	31
Wisconsin	1,240	1,475	1,587	39	47	46
Wyoming	413	342	317	2	1	1
U.S. total[5]	83,638	87,756	88,977	3,264	3,556	3,727
Foreign countries[6]	177	145	185	108	105	114
Puerto Rico	962	1,132	1,296	--	--	--
Total shipments[5]	84,778	89,033	90,458	3,373	3,659	3,841
Origin:						
United States[7]	74,250	75,181	74,868	3,187	3,525	3,715
Puerto Rico	962	1,132	1,296	--	--	--
Foreign:[8]						
Domestic producers	5,532	8,814	10,480	62	72	60
Others	4,034	3,909	3,814	124	62	67
Total shipments[5]	84,778	89,033	90,458	3,373	3,659	3,841

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 (1986—327,000 tons and 1987—305,000 tons) used in the manufacture of prepared masonry cement.
[3]Has no cement-producing plants.
[4]Less than 1/2 unit.
[5]Data may not add to totals shown because of independent rounding.
[6]Direct shipments by producers to foreign countries and U.S. possessions and territories; includes States indicated by symbol W.
[7]Includes cement produced from imported clinker by domestic producers.
[8]Imported cement distributed by domestic producers, Canadian cement manufacturers, and other importers. Origin of imports withheld to avoid disclosing company proprietary data.

Table 14.—Cement shipments,[1] by region and subregion

Region and subregion[2]	Portland cement				Masonry cement			
	Thousand short tons		Percent of grand total		Thousand short tons		Percent of grand total	
	1986	1987	1986	1987	1986	1987	1986	1987
Northeast:								
New England	3,817	3,742	4.3	4.2	112	114	3.2	3.1
Middle Atlantic	8,774	9,001	10.0	10.1	387	416	10.8	11.2
Total[3]	12,591	12,742	14.3	14.3	499	530	14.0	14.3
South:								
Atlantic	17,508	18,480	20.0	20.8	1,546	1,641	43.5	44.0
East Central	4,900	5,255	5.6	5.9	435	485	12.2	13.0
West Central	13,110	11,674	14.9	13.1	344	285	9.7	7.6
Total[3]	35,518	35,409	40.5	39.8	2,325	2,412	65.4	64.6
North Central:								
East	11,851	12,881	13.5	14.5	528	580	14.9	15.6
West	7,321	7,494	8.3	8.4	147	160	4.1	4.3
Total[3]	19,172	20,374	21.8	22.9	675	740	19.0	19.9
West:								
Mountain	6,906	6,228	7.9	7.0	36	28	1.0	.7
Pacific	13,567	14,231	15.5	16.0	21	18	.6	.5
Total[4]	20,473	20,459	23.4	23.0	57	46	1.6	1.2
Grand total[3]	87,756	88,985	100.0	100.0	3,556	3,727	100.0	100.0

[1]Includes imported cement shipped by domestic and Canadian cement manufacturers and other importers.
[2]Geographic regions as designated by the U.S. Department of Commerce, Bureau of the Census.
[3]Data may not add to totals shown because of independent rounding.
[4]Does not include proprietary data from table 13.

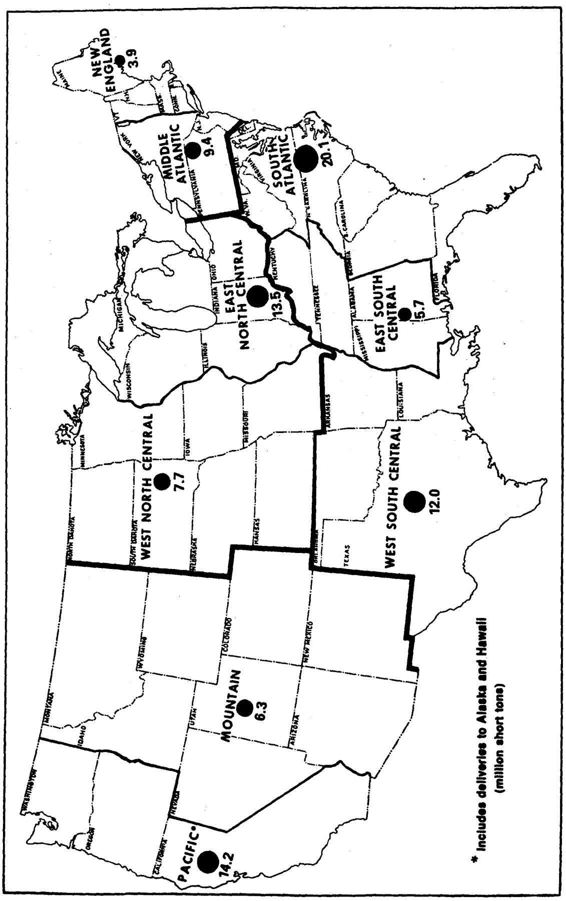

Figure 1.—Shipments of cement by geographic region of destination in 1987.

Table 15.—Portland cement shipments in 1987, by district of origin and type of customer[1]

District of 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] (thousand short tons)
	Quantity (thousand short tons)	Percent	Quantity (thousand short tons)	Percent	Quantity (thousand short tons)	Percent	Quantity (thousand short tons)	Percent	Quantity (thousand short tons)	Percent	Quantity (thousand short tons)	Percent	Quantity (thousand short tons)	Percent	
New York and Maine	157	4.5	601	17.1	2,496	71.0	104	2.9	149	4.2	1	--	10	.3	3,517
Pennsylvania, eastern	453	9.3	1,126	23.2	2,983	61.5	103	2.1	34	.7	81	1.7	70	1.5	4,852
Pennsylvania, western	174	11.8	246	16.7	873	59.2	119	8.1	61	4.1	--	--	(3)	.1	1,473
Maryland	98	5.4	365	19.9	1,251	68.4	27	1.5	36	1.9	--	--	53	2.9	1,831
Ohio	141	8.1	295	16.9	1,247	71.3	62	3.6	1	--	(3)	--	3	.1	1,750
Michigan	165	3.4	578	11.8	3,704	75.7	351	7.2	76	1.5	6	.1	15	.3	4,895
Indiana	115	5.0	282	12.2	1,686	72.7	224	9.6	1	--	--	--	12	.5	2,320
Illinois	16	.7	126	6.0	1,749	82.6	191	9.0	37	1.7	--	--	(3)	--	2,119
Georgia and Tennessee	132	5.8	407	18.0	1,516	67.0	68	3.0	101	4.5	30	1.3	9	.4	2,263
South Carolina	57	2.2	429	16.7	1,845	71.8	108	4.2	66	2.6	3	.1	61	2.4	2,568
Kentucky, Virginia, West Virginia	131	5.6	278	11.8	1,683	71.4	169	7.2	74	3.1	--	--	22	.9	2,357
Florida	411	11.5	478	13.4	2,504	70.0	30	.8	70	1.9	9	.3	76	2.1	3,578
Nebraska and Wisconsin	W	W	W	W	W	W	W	W	W	W	--	--	--	--	W
Alabama	251	7.0	532	14.8	2,359	65.4	235	6.5	129	3.6	15	.4	84	2.3	3,604
Arkansas, Louisiana, Mississippi	80	4.6	154	8.8	1,179	67.0	151	8.6	154	8.7	9	.5	32	1.8	1,759
Utah	24	2.6	49	5.3	632	67.6	133	14.3	90	9.6	5	.6	(3)	--	935
South Dakota	5	1.1	26	4.9	310	59.6	75	14.5	45	8.6	W	W	W	W	W
Iowa	73	3.4	371	17.3	1,451	67.8	82	3.8	142	6.7	--	--	21	1.0	2,140
Missouri	203	4.0	346	6.8	3,794	74.2	533	10.4	227	4.4	2	.1	4	.1	5,110
Kansas	71	4.2	82	4.8	1,306	76.9	122	7.2	72	4.3	--	--	44	2.6	1,697

Oklahoma	35	2.5	79	5.6	936	66.1	139	9.8	110	7.7	4	.2	114	8.1	1,417
Texas, northern	144	4.5	333	10.4	1,850	57.7	169	5.3	379	11.8	85	2.6	246	7.7	3,207
Texas, southern	90	2.2	440	10.7	3,032	73.7	187	4.5	271	6.6	39	1.0	53	1.3	4,112
Idaho and Montana	20	3.4	41	6.8	380	62.6	67	11.1	69	11.3	(3)	--	29	4.8	607
Colorado and Wyoming	39	3.1	120	9.5	921	72.6	166	13.1	15	1.2	1	.1	5	.4	1,267
Alaska and Oregon	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W
Arizona, Nevada, New Mexico	80	3.8	411	19.2	1,301	60.9	59	2.7	277	13.0	(3)	--	8	.4	2,136
California, northern	260	9.2	363	12.8	2,058	72.5	9	.3	126	4.4	(3)	--	22	.8	2,838
California, southern	230	3.2	824	11.6	5,481	77.2	24	.3	372	5.2	35	.5	132	2.0	7,099
Hawaii	22	6.9	39	12.1	236	73.0	6	1.9	12	3.7	3	1.1	4	1.3	323
Washington	44	3.4	115	9.0	993	77.3	23	1.8	56	4.3	(3)	--	54	4.2	1,285
Foreign imports[4]	107	1.0	166	1.6	10,193	97.3	--	--	--	--	--	--	16	.1	10,480
Total[3] or average	3,863	4.5	9,820	11.5	62,938	73.7	3,902	4.6	3,268	3.8	332	.4	1,263	1.5	85,384
Puerto Rico	574	44.3	61	4.7	627	48.4	--	--	32	2.5	1	.1	(3)	--	1,296

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1]Includes Puerto Rico.
[2]Data may not add to totals shown because of independent rounding.
[3]Less than 1/2 unit.
[4]Cement imported and distributed by domestic producers only. Source of imports withheld to avoid disclosing company proprietary data.

Table 16.—Portland cement shipped from plants in the United States,[1] by type

Type	1986 Quantity (thousand short tons)	1986 Value[2] (thousands)	1986 Average per ton	1987 Quantity (thousand short tons)	1987 Value[2] (thousands)	1987 Average per ton
General use and moderate heat (Types I and II)	78,440	$3,862,869	$49.25	79,499	$3,808,456	$47.91
High-early-strength (Type III)	3,031	159,592	52.65	3,318	175,160	52.80
Sulfate-resisting (Type V)	433	26,295	60.72	716	39,389	55.01
Oil well	1,021	54,667	53.54	899	45,054	50.12
White	317	55,111	173.85	345	59,873	173.54
Portland slag and portland pozzolan	757	39,903	52.71	773	39,827	51.51
Expansive	42	3,743	89.11	50	4,641	92.82
Miscellaneous[3]	1,085	62,663	57.75	1,045	60,558	57.95
Total[4] or average	85,127	4,264,844	50.10	[5]86,644	[5]4,232,959	48.85

[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, low-heat (Type IV), and regulated fast-setting cement.
[4]Data may not add to totals shown because of independent rounding.
[5]Does not includes cement consumed at plant.

PRICES

The average mill value of portland cement declined slightly for the third consecutive year reaching its lowest point since 1979, despite record-high shipments to meet consumer demand. The decline can be attributed in part to consumption of record-high levels of imports, which show a corresponding decrease in value, and to extreme competition among producers for a greater share of the domestic market. The average mill value of masonry cement, which was not influenced to any great extent by imports, increased for the sixth consecutive year.

The average price of cement, as reported by Engineering News-Record (ENR), declined slightly to about $63.70 per ton. The ENR prices were based on an average per ton value of cement delivered to 20 cities. The prices range from a low of $46 per ton in Dallas, TX, to a high of $79 in New York City.[3]

Table 17.—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
1983	$49.89	$63.74	$50.45
1984	51.62	67.02	52.24
1985	51.30	66.64	51.87
1986	50.10	65.68	50.73
1987	48.85	70.55	49.76

[1]Includes Puerto Rico. Mill value is the actual value of sales to customers, f.o.b. plant, less all discounts and allowances, 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.
[2]Masonry cement made at cement plants only.

FOREIGN TRADE

According to trade data reported by the U.S. Department of Commerce, Bureau of the Census, the United States and its and territories experienced the third consecutive year of record-high imports. Combined imports of hydraulic cement and clinker increased 9% to 17.7 million tons, accounting for approximately 19% of apparent consumption. In decreasing order, Mexico, Canada, and Spain were the principal import sources, providing for more than 69% of the total. The increases were due primarily to gray cement imports. Clinker imports declined slightly, while white cement experienced a moderate increase.

In other foreign trade developments, Allied Cement Co. opened a 600,000-ton-annual-throughput-capacity terminal in the Port of Los Angeles, CA. Allied imports cement from Japan and Taiwan. CalMat Co. was expected to purchase 50% interest in the operation.

Coastal Cement Corp. opened a 400,000-ton-capacity import terminal in Boston, MA, to import cement from Spain.

Exports of hydraulic cement and clinker as reported by the Bureau of the Census declined slightly to 53,000 tons. Cement was shipped to more than 40 countries with Canada receiving 87% of the total.

Table 18.—U.S. exports of hydraulic cement and cement clinker, by country

Country	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)	1987 Quantity (short tons)	1987 Value (thousands)
Bahamas	479	$46	1,780	$152	706	$58
Canada	88,626	18,735	54,390	7,688	45,301	7,025
Mexico	3,903	1,477	1,121	445	3,307	1,355
Venezuela	114	128	56	20	631	331
Other[1]	r4,775	r1,092	r1,209	r719	2,064	794
Total[2]	97,897	21,478	58,556	9,024	52,009	9,563

rRevised.
[1]Includes 40 countries in 1985, 42 in 1986, and 39 in 1987.
[2]Data may not add to totals shown because of independent rounding.

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

Table 19.—U.S. imports for consumption of hydraulic cement and clinker, by country

(Thousand short tons and thousand dollars)

Country	1985 Quantity	1985 Value Customs	1985 Value C.i.f.[1]	1986 Quantity	1986 Value Customs	1986 Value C.i.f.[1]	1987 Quantity	1987 Value Customs	1987 Value C.i.f.[1]
Canada	3,393	131,117	145,005	3,272	123,220	133,907	4,154	146,693	157,606
Colombia	662	16,430	20,244	913	22,566	28,070	612	14,914	22,090
France	552	13,866	18,319	669	18,355	24,016	772	15,152	24,373
Greece	511	9,760	12,202	1,275	26,710	33,507	1,641	36,559	49,141
Japan	1,134	28,786	37,105	750	20,325	24,833	723	18,351	25,108
Korea, Republic of	484	26,194	29,738	456	11,814	15,202	616	14,241	18,095
Mexico	2,502	75,755	87,339	4,242	110,390	133,403	4,960	125,666	156,585
Spain	3,383	80,448	103,353	3,176	90,479	110,230	3,044	80,745	106,996
Venezuela	1,569	38,282	50,320	1,290	31,739	41,673	766	17,534	24,498
Other	298	16,791	20,148	276	13,395	17,586	438	18,677	22,096
Total[2]	14,487	437,429	523,773	16,319	468,993	562,427	17,726	488,532	606,588

[1]Cost, insurance, and freight.
[2]Data may not add to totals shown because of independent rounding.

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

Table 20.—U.S. imports for consumption of clinker, by country

(Thousand short tons and thousand dollars)

Country	1985 Quantity	1985 Value Customs	1985 Value C.i.f.[1]	1986 Quantity	1986 Value Customs	1986 Value C.i.f.[1]	1987 Quantity	1987 Value Customs	1987 Value C.i.f.[1]
Canada	746	22,156	25,763	358	10,534	12,768	846	25,056	28,150
Colombia	193	3,938	5,012	280	5,814	7,031	58	1,265	1,515
France	414	9,434	11,789	529	11,328	14,324	342	7,839	9,818
Greece	407	7,900	9,390	507	9,598	13,159	343	6,330	8,272
Japan	291	6,397	7,840	234	4,897	4,839	37	883	1,222
Mexico	581	14,671	16,387	1,095	19,199	23,823	1,215	21,114	26,241
Spain	1,656	31,877	39,917	711	13,726	17,653	734	14,121	17,543
Other	r345	r6,694	r8,315	r258	r4,603	r6,970	93	2,765	2,941
Total[2]	4,633	103,067	124,413	3,972	79,699	100,567	3,668	79,373	95,702

rRevised.
[1]Cost, insurance, and freight.
[2]Data may not add to totals shown because of independent rounding.

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

Table 21.—U.S. imports for consumption of hydraulic cement and clinker, by customs district and country

(Thousand short tons and thousand dollars)

Customs district and country	1986			1987		
	Quantity	Value		Quantity	Value	
		Customs	C.i.f.[1]		Customs	C.i.f.[1]
Anchorage:						
Canada	16	1,566	1,978	8	431	766
Japan	29	1,079	1,176	30	1,263	1,514
Korea, Republic of	(2)	7	8	10	322	516
Total	45	2,652	3,162	48	2,016	2,796
Baltimore:						
Bahamas	--	--	--	13	327	414
Belgium	(2)	64	79	--	--	--
Brazil	(2)	1	2	--	--	--
Colombia	13	368	451	19	492	693
Germany, Federal Republic of	(2)	13	15	(2)	8	9
Greece	50	1,133	1,256	189	4,431	4,808
Japan	(2)	50	69	--	--	--
Mexico	14	313	495	13	373	501
Netherlands	67	1,760	1,879	(2)	28	29
Spain	(2)	35	40	--	--	--
Venezuela	62	1,709	2,196	84	2,144	2,587
Yugoslavia	(2)	52	98	--	--	--
Total[3]	208	5,498	6,580	318	7,803	9,041
Boston:						
Canada	138	4,878	5,165	147	4,048	4,224
Greece	92	2,277	2,358	123	2,885	3,090
Mexico	28	768	799	7	158	173
Spain	10	213	223	26	1,891	1,988
Venezuela	23	540	655	--	--	--
Total[3]	292	8,676	9,201	303	8,982	9,474
Buffalo:						
Canada	950	30,809	36,431	964	37,582	37,868
Japan	--	--	--	(2)	12	12
Total	950	30,809	36,431	964	37,594	37,880
Charleston:						
Canada	--	--	--	(2)	5	5
Germany, Federal Republic of	--	--	--	(2)	6	8
Greece	60	1,204	1,500	--	--	--
Netherlands	(2)	17	21	--	--	--
Panama	--	--	--	31	681	853
Spain	--	--	--	30	780	980
Total[3]	60	1,221	1,521	61	1,472	1,845
Chicago:						
Germany, Federal Republic of	(2)	118	152	(2)	225	252
Japan	--	--	--	(2)	7	10
Total	(2)	118	152	(2)	232	262
Cleveland:						
Canada	37	1,450	1,721	176	5,781	7,558
Netherlands	1	398	781	--	--	--
Spain	--	--	--	(2)	2	2
United Kingdom	1	27	27	(2)	24	24
Total[3]	39	1,875	2,529	176	5,807	7,585
Detroit:						
Belgium-Luxembourg	(2)	28	28	--	--	--
Canada	349	17,728	18,365	938	33,120	35,354
Spain	--	--	--	93	1,943	1,976
Total[3]	349	17,755	18,393	1,031	35,063	37,331
Duluth:						
Canada	208	6,526	8,293	77	2,294	2,849
Germany, Federal Republic of	(2)	5	5	--	--	--
Greece	--	--	--	36	887	1,432
Total[3]	208	6,531	8,298	113	3,181	4,282

See footnotes at end of table.

Table 21.—U.S. imports for consumption of hydraulic cement and clinker, by customs district and country —Continued

(Thousand short tons and thousand dollars)

Customs district and country	1986			1987		
	Quantity	Value		Quantity	Value	
		Customs	C.i.f.[1]		Customs	C.i.f.[1]
El Paso:						
Malaysia	(2)	3	5	--	--	--
Mexico	504	18,960	18,960	595	20,950	20,950
Total	504	18,963	18,965	595	20,950	20,950
Great Falls:						
Canada	(2)	65	65	(2)	13	13
Germany, Federal Republic of	(2)	21	23	--	--	--
Yugoslavia	--	--	--	(2)	10	10
Total	1	86	88	(2)	23	23
Honolulu:						
Australia	--	--	--	2	155	155
Japan	85	1,882	2,552	25	540	708
Korea, Republic of	10	368	495	21	1,063	1,138
Total	95	2,250	3,047	48	1,758	2,001
Houston:						
Colombia	152	3,345	3,822	33	789	891
Germany, Federal Republic of	(2)	207	256	(2)	54	64
Korea, Republic of	(2)	50	50	--	--	--
Mexico	105	1,888	2,683	74	1,453	2,182
Spain	577	15,586	17,896	642	12,644	17,502
Venezuela	(2)	7	12	--	--	--
Total[3]	835	21,083	24,719	749	14,940	20,639
Laredo:						
Mexico	182	5,804	5,804	301	8,978	8,978
Los Angeles:						
Bahamas	--	--	--	91	3,006	3,497
Canada	20	347	464	--	--	--
Denmark	11	764	1,130	13	451	1,115
France	(2)	59	66	202	4,569	6,107
Germany, Federal Republic of	(2)	93	109	(2)	40	48
Japan	375	10,622	12,619	435	10,347	15,503
Korea, Republic of	343	8,700	11,069	454	10,283	13,138
Spain	182	4,980	6,598	(2)	72	130
Taiwan	(2)	15	19	23	525	714
United Kingdom	(2)	1	1	--	--	--
Yugoslavia	(2)	235	424	(2)	47	88
Total[3]	933	25,816	32,499	1,218	29,340	40,340
Miami:						
Bahamas	58	1,652	1,880	50	1,434	1,618
Belgium-Luxembourg	3	179	332	2	128	242
Costa Rica	(2)	10	11	--	--	--
Denmark	--	--	--	4	349	400
France	--	--	--	10	320	407
Germany, Federal Republic of	--	--	--	2	6	8
Greece	--	--	--	53	1,161	1,677
Japan	(2)	39	51	--	--	--
Mexico	319	9,170	11,481	323	6,561	15,242
Spain	464	14,108	17,024	447	12,664	17,357
Venezuela	445	10,194	13,905	428	9,949	13,255
Total[3]	1,289	35,352	44,684	1,318	32,572	50,203
Milwaukee:						
Germany, Federal Republic of	--	--	--	(2)	14	16
Mobile:						
France	23	809	914	31	1,213	1,228
Greece	283	5,234	7,137	166	2,820	3,631
Mexico	245	3,881	4,695	339	5,001	6,835

See footnotes at end of table.

Table 21.—U.S. imports for consumption of hydraulic cement and clinker, by customs district and country —Continued

(Thousand short tons and thousand dollars)

Customs district and country	1986			1987		
	Quantity	Value		Quantity	Value	
		Customs	C.i.f.[1]		Customs	C.i.f.[1]
Mobile —Continued						
Spain	232	4,127	5,414	40	682	915
United Kingdom	--	--	--	29	496	659
Total	783	14,051	18,160	605	10,212	13,268
New Orleans:						
Belgium-Luxembourg	--	--	--	31	650	905
Canada	101	6,553	8,088	61	3,860	4,665
Colombia	46	900	1,134	--	--	--
France	434	12,834	15,709	179	1,217	6,719
Greece	58	1,460	1,498	222	5,135	6,528
Mexico	444	9,520	13,559	657	15,176	20,723
Netherlands	(2)	181	197	--	--	--
Spain	382	11,497	12,940	463	12,385	15,806
Venezuela	7	146	212	--	--	--
Total	1,472	43,091	53,337	1,613	38,423	55,346
New York City:						
Bahamas	7	222	294	--	--	--
Belgium	(2)	4	5	--	--	--
Canada	65	1,311	1,965	32	716	868
Colombia	29	833	1,118	2	49	77
France	--	--	--	58	1,590	1,594
Germany, Federal Republic of	(2)	10	13	(2)	43	45
Greece	648	13,562	17,485	638	15,432	21,969
Japan	1	779	784	--	--	--
Mexico	26	425	588	162	3,645	5,464
Spain	405	13,809	17,385	434	15,382	22,273
Venezuela	72	1,683	2,061	22	503	613
Total[3]	1,253	32,638	41,698	1,346	37,360	52,902
Nogales: Mexico	404	14,518	14,520	381	13,039	13,039
Norfolk:						
Bahamas	25	650	1,019	10	248	385
Canada	(2)	7	7	--	--	--
Colombia	17	474	582	--	--	--
France	25	2,357	2,591	70	2,468	3,118
Germany, Federal Republic of	(2)	3	3	(2)	11	13
Greece	--	--	--	16	386	621
Spain	211	2,558	5,379	323	8,560	11,812
United Kingdom	(2)	2	3	--	--	--
Venezuela	90	2,251	3,099	31	820	1,276
Total[3]	368	8,302	12,683	451	12,493	17,225
Ogdensburg:						
Canada	405	13,839	13,839	514	15,801	15,817
Netherlands	--	--	--	(2)	244	294
Total	405	13,839	13,839	514	16,045	16,111
Pembina: Canada	48	2,025	2,025	103	4,645	4,645
Philadelphia:						
Germany, Federal Republic of	(2)	5	6	(2)	187	204
Greece	23	503	568	62	1,209	1,424
Mexico	1	25	25	--	--	--
Netherlands	(2)	182	221	(2)	82	104
Spain	94	5,839	8,039	135	4,545	4,890
Turkey	(2)	2	5	--	--	--
Venezuela	--	--	--	17	404	629
Total[3]	119	6,053	8,864	214	6,427	7,251
Port Arthur:						
Mexico	26	662	782	--	--	--
Venezuela	159	2,911	3,636	--	--	--
Total[3]	185	3,573	4,418	--	--	--

See footnotes at end of table.

Table 21.—U.S. imports for consumption of hydraulic cement and clinker, by customs district and country —Continued

(Thousand short tons and thousand dollars)

Customs district and country	1986			1987		
	Quantity	Value		Quantity	Value	
		Customs	C.i.f.[1]		Customs	C.i.f.[1]
Portland, ME:						
Canada	11	599	599	12	584	584
Spain	13	269	333	--	17	20
Total[3]	24	868	932	12	601	604
Portland, OR:						
Japan	47	1,095	1,618	104	1,029	1,192
Korea, Republic of	37	1,382	1,749	31	1,939	2,470
Total[3]	84	2,477	3,367	135	2,968	3,661
Providence:						
Canada	39	1,651	1,970	40	1,278	1,613
Colombia	74	2,191	3,028	105	2,585	5,128
Greece	5	135	203	--	--	--
Mexico	78	1,839	2,947	45	1,046	1,674
Spain	67	2,364	2,971	--	--	--
Venezuela	13	370	552	6	162	258
Total[3]	276	8,550	11,671	196	5,071	8,673
St. Albans: Canada	399	13,018	13,018	406	12,650	12,650
San Diego:						
Canada	8	258	304	--	--	--
Japan	--	--	--	52	1,533	1,870
Mexico	694	22,373	25,015	631	21,507	22,347
Mozambique	--	--	--	10	259	273
Total[3]	702	22,631	25,319	693	23,299	24,489
San Francisco:						
Canada	138	4,556	6,188	121	3,196	6,485
China	(2)	6	12	--	--	--
Japan	57	1,022	1,283	--	--	--
Korea, Republic of	65	935	1,830	25	634	835
Mexico	108	3,086	3,480	233	6,027	6,371
Total[3]	368	9,605	12,793	380	9,857	13,691
San Juan, PR:						
Barbados	42	1,472	2,015	--	--	--
Belgium-Luxembourg	8	585	1,009	7	495	862
Brazil	1	92	138	1	51	70
Colombia	66	1,220	1,618	25	528	694
Denmark	4	326	542	9	786	1,004
Dominican Republic	1	16	21	--	--	--
Germany, Federal Republic of	1	55	63	--	--	--
Honduras	24	717	1,053	--	--	--
Japan	--	--	--	56	1,577	2,312
Mexico	5	134	241	(2)	13	14
Netherlands	1	49	71	34	773	919
Spain	3	238	598	--	--	--
Venezuela	34	1,329	1,847	16	711	746
Total[3]	191	6,233	9,216	149	4,934	6,621
Savannah:						
Germany, Federal Republic of	(2)	15	19	(2)	19	23
Japan	(2)	2	2	--	--	--
Spain	111	2,608	2,802	72	2,181	2,284
Venezuela	11	250	276	10	239	329
Total[3]	123	2,875	3,099	82	2,439	2,636
Seattle:						
Canada	335	12,392	13,423	556	20,592	21,641
Japan	156	3,757	4,679	151	3,619	4,285
Yugoslavia	(2)	10	43	--	--	--
Total[3]	491	16,159	18,145	707	24,211	25,926

See footnotes at end of table.

Table 21.—U.S. imports for consumption of hydraulic cement and clinker, by customs district and country —Continued

(Thousand short tons and thousand dollars)

Customs district and country	1986 Quantity	1986 Value Customs	1986 Value C.i.f.[1]	1987 Quantity	1987 Value Customs	1987 Value C.i.f.[1]
Tampa:						
Bahamas	4	102	117	--	--	--
Colombia	363	8,277	10,505	286	6,819	9,329
Denmark	41	W	W	51	W	W
France	187	W	W	220	W	W
Greece	42	932	1,169	137	3,100	3,960
Mexico	1,066	18,879	27,083	1,167	20,979	31,637
Panama	15	344	345	--	--	--
Spain	369	8,307	10,858	321	6,346	8,441
Venezuela	366	10,025	12,982	136	3,313	4,714
Total[3]	2,453	58,151	72,262	2,318	48,671	68,494
Virgin Islands of the United States:						
Colombia	25	1,272	1,345	7	225	238
Dominican Republic	1	21	23	(2)	14	15
Leeward and Windward Islands	4	109	173	1	15	29
Venezuela	7	325	364	33	794	838
Total[3]	37	1,727	1,905	41	1,048	1,119
Wilmington, NC:						
Colombia	127	3,687	4,468	139	3,414	5,041
Mexico	10	250	389	--	--	--
Spain	6	186	226	--	--	--
Total	143	4,123	5,083	139	3,414	5,041
Grand total[3]	16,319	468,993	562,427	17,726	488,532	606,588

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1]Cost, insurance, and freight.
[2]Less than 1/2 unit.
[3]Data may not add to totals shown because of independent rounding.

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

Table 22.—U.S. imports for consumption of cement and clinker

(Thousand short tons and thousand dollars)

Year	Roman, portland, other hydraulic cement		Hydraulic cement clinker		White nonstaining portland cement		Total[1]	
	Quantity	Value (customs)	Quantity	Value (customs)	Quantity	Value (customs)	Quantity	Value (customs)
1983	3,104	109,791	1,005	33,633	160	18,014	4,268	161,439
1984	6,379	204,899	2,215	59,801	252	29,507	8,846	294,207
1985	9,581	306,472	4,633	103,067	274	27,890	14,487	437,429
1986	12,086	361,149	3,972	79,699	261	28,145	16,319	468,993
1987	13,782	384,989	3,668	79,373	276	24,170	17,726	488,532

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

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

WORLD REVIEW

World cement production increased only slightly. China continued to lead all nations in cement production, followed by the U.S.S.R., the United States, and Japan. Worldwide, the industry operated at an estimated 80% of capacity. Countries with excess capacity continued to seek new markets for their product. Although the United States continued to be a principal recipient of imports, the number of countries that exported cement to the United States continued to decline. Twenty-four countries exported cement to the United States in 1987, six fewer than in 1986; however, the volume of cement imported in 1987 was 1 million tons more than in 1986.

Foreign buyers continued to show interest in the U.S. cement industry. By yearend, approximately 55% of U.S. cement production capacity had been acquired by foreign firms from eight countries. Seven of the top ten producing companies in the United States were owned by Western European parent companies, and several Japanese firms were negotiating the purchase of U.S. capacity.

The international issue of Rock Products magazine described individual plant construction, modernization, or expansion activities of the cement-producing nations.[4] Although there were no major additions to capacity reported, there continued to be considerable activity aimed at expanding existing capacity either through new construction or by upgrading existing facilities. The industry reported the introduction of new technology, primarily the installation of high-pressure grinding rollers and high-efficiency separators.

Egypt.—Consumer demand for cement continued to grow. Egyptian cement producers had several construction and modernization projects planned or in various stages of development. The addition of new capacity was aimed at reducing the country's dependence on imports. Alexandria Portland Cement Co. completed work on the No. 1 kiln at its Ameriyah plant. The No. 2 kiln was expected to go on line in early 1988. Both kilns have a capacity of 3,600 tons per day. Hewland Portland Cement Co. put its 220,000-ton-per-year, white cement plant on line at El-Minya.

Germany, Federal Republic of.—Demand for cement continued to decline and the industry continued to adjust capacity to meet long-term needs by closing older plants and outfitting others with state-of-the-art, high-efficiency separators.

Italy.—Italcementi-Fabriche Riunite Cemento S.p.A. installed a new 2,200-ton-per-day preheater kiln at its Sicily plant. Colacem S.p.A. installed a 2,000-ton-per-day preheater kiln at its Gubbio plant. Presa S.p.A.-Cementeriadi outfitted its 4,400-ton-per-day Robilante plant No. 3 kiln with a precalciner system.

Norway.—Norcem Cement A/S, Norway's only cement producer, was modernizing one of the two lines at its Dalen plant to increase the capacity to 3,600 tons per day. Norcem was also in the process of installing a high-pressure grinding mill at its Brevik plant.

Saudi Arabia.—Qassim Cement Co. commissioned the 2,400-ton-per-day-capacity addition to its Buraydah plant, and Yamama Saudi Cement Co. Ltd. completed a 3,300-ton-per-day production line at its Riyadh plant.

Spain.—Cementos Portland Morata De Jalon SA put its new 130-ton-per-hour mill on-line. Other producers sought to reduce operating costs and improve operating efficiency through application of automated centralized control systems and installation of grinding rollers and high-efficiency separators.

Turkey.—The Turkish cement industry continued its fourth consecutive year of production increases. To keep pace with rising demand, several new plants and modernization projects occurred during the year: Citosan (General Directorate) put its 660,000-ton-per-year plant on line; Bati Anadolu Cimento Sanayii AS was upgrading its No. 2 line at its Izmir plant from 1,400 to 1,900 tons per day; and Eskisehilr Cemento Fabrikasi TAS was converting its kiln to a preheater system to increase production from 770 tons per day to 1,500 tons per day. Other plants were in various stages of modernization including the installation of high-efficiency separators and raw material conveyance, grinding, and storage systems.

Table 23.—Hydraulic cement: World production, by country[1]

(Thousand short tons)

Country	1983	1984	1985	1986[p]	1987[e]
Afghanistan[2]	14	123	85	[r] [e]95	110
Albania[e]	925	[3]948	940	940	945
Algeria[e]	5,300	6,100	6,720	[r]7,120	7,170
Angola[e]	240	390	390	390	390
Argentina	6,198	[r]5,644	5,121	[r] [e]6,100	7,000
Australia	5,331	6,022	6,489	6,471	6,600
Austria	5,409	5,400	5,027	5,036	5,000
Bahamas	[r]28	--	--	(4)	--
Bangladesh[5]	338	301	265	322	[3]342
Barbados	--	[e]165	[e]240	219	220
Belgium	6,304	6,300	6,103	5,928	6,400
Benin[e]	331	331	331	331	331
Bolivia	361	315	418	326	330
Brazil	23,005	21,761	22,721	27,885	[3]28,076

See footnotes at end of table.

Table 23.—Hydraulic cement: World production, by country[1] —Continued

(Thousand short tons)

Country	1983	1984	1985	1986[p]	1987[e]
Bulgaria	6,221	6,302	5,838	6,285	6,280
Burma	369	343	526	478	[3]429
Cameroon	672	NA	NA	NA	NA
Canada	8,676	9,489	11,235	11,687	13,900
Chile	1,383	1,532	1,571	1,583	1,650
China	119,325	133,468	[e]157,100	[e]178,000	198,000
Colombia	5,204	5,816	6,294	7,121	[3]6,575
Congo	17	NA	64	[e]64	64
Costa Rica	425	[r]517	524	573	573
Cuba	3,562	3,689	3,508	[r] [e]3,640	3,900
Cyprus	1,039	940	727	952	955
Czechoslovakia	11,572	11,607	[e]11,300	[e]11,200	11,200
Denmark	1,827	1,839	1,917	2,237	2,200
Dominican Republic	1,217	1,260	1,110	1,175	1,200
Ecuador	[r]1,565	[r]1,910	2,167	[r] [e]2,300	2,200
Egypt	6,063	7,165	6,337	8,391	11,000
El Salvador	[r]479	[r]440	496	488	[3]669
Ethiopia[e]	190	265	275	275	275
Fiji	121	108	103	102	105
Finland	2,102	1,814	[e]1,760	[e]1,760	1,760
France	27,011	25,049	25,955	[e]25,900	[3]25,970
Gabon	132	229	270	232	[3]151
German Democratic Republic	12,987	12,737	12,795	13,126	12,700
Germany, Federal Republic of	33,583	31,867	28,393	29,299	27,900
Ghana	[e]320	252	400	241	[3]302
Greece	15,648	14,904	15,067	14,706	14,800
Guadeloupe	[e]176	188	190	199	210
Guatemala	498	[r]462	580	710	[3]1,459
Haiti[e]	[3]238	240	240	200	220
Honduras	535	589	383	386	440
Hong Kong	1,892	2,037	2,023	2,465	2,400
Hungary	4,677	4,569	4,054	4,239	[3]4,578
Iceland	127	130	126	122	120
India	27,950	32,000	36,409	40,124	[3]40,763
Indonesia	9,025	9,765	11,112	12,060	13,000
Iran[e]	11,000	[r]13,000	[r]13,700	[r]13,530	13,600
Iraq[e]	6,170	8,800	8,800	8,800	11,000
Ireland	1,638	1,518	1,606	1,541	1,545
Israel	2,269	2,275	2,227	2,270	2,270
Italy	43,229	41,648	40,429	38,956	39,900
Ivory Coast	702	591	748	855	[3]719
Jamaica	305	288	264	266	275
Japan	89,167	86,928	80,311	78,535	77,000
Jordan	1,401	2,192	2,230	1,978	2,500
Kenya	1,411	1,283	934	1,446	[3]1,456
Korea, North[e]	8,800	8,800	8,800	8,800	8,800
Korea, Republic of	23,459	22,501	22,514	25,797	[3]28,287
Kuwait	1,239	1,305	1,315	1,118	1,120
Lebanon	1,653	1,378	[e]1,100	[e]1,000	1,000
Liberia	94	93	105	107	100
Libya[e]	5,500	6,600	7,200	[3]2,289	[3]2,976
Luxembourg	389	375	325	[e]330	340
Madagascar	39	39	39	39	39
Malawi	78	77	[e]70	76	77
Malaysia	3,562	3,824	3,448	3,501	3,130
Mali	[e]22	28	21	[e]22	28
Martinique[e]	[r]228	[r]210	220	220	220
Mexico	18,814	[r]20,322	22,796	21,772	22,000
Mongolia	[r]182	[r]155	166	[r] [e]220	220
Morocco	4,242	3,955	4,072	4,125	4,200
Mozambique[e]	[3]463	496	496	496	496
Nepal	50	43	35	102	110
Netherlands	3,425	3,501	3,209	3,417	3,440
New Caledonia[e]	66	66	66	66	55
New Zealand	838	907	951	[e]960	[3]994
Nicaragua[e]	110	110	110	110	110
Niger[e]	42	42	42	42	44
Nigeria[e]	3,970	3,300	3,680	3,860	3,860
Norway	1,837	1,705	1,764	1,929	1,870
Pakistan	5,443	5,178	[e]5,765	[e]5,760	7,530
Panama	360	335	336	370	385
Paraguay	169	120	51	197	165
Peru	[r]2,166	2,060	1,937	2,346	2,200
Philippines[6]	4,831	4,025	3,395	3,811	3,860
Poland	17,857	18,409	16,535	17,416	[3]17,747
Portugal	6,683	6,106	5,913	6,001	6,400
Qatar	413	527	350	340	330
Romania	15,397	15,450	13,490	15,670	15,760
Saudi Arabia	8,957	7,882	9,149	10,130	10,140

See footnotes at end of table.

Table 23.—Hydraulic cement: World production, by country[1] —Continued

(Thousand short tons)

Country	1983	1984	1985	1986[p]	1987[e]
Senegal	435	424	449	397	[3]410
Singapore	3,476	3,110	2,195	1,989	[3]1,684
South Africa, Republic of	8,705	9,025	7,754	6,885	6,830
Spain (including Canary Islands)[7]	33,771	28,038	26,673	[e]26,500	25,800
Sri Lanka[e]	[3]558	551	660	660	660
Sudan	[e]220	194	213	[e]220	220
Suriname[e]	[3]82	55	55	55	55
Sweden	2,469	2,638	2,425	2,336	2,425
Switzerland	4,516	4,609	4,689	4,842	4,400
Syria	3,996	4,720	4,736	4,630	4,630
Taiwan	16,325	15,690	15,893	16,321	[3]17,266
Tanzania[e]	460	[3]408	330	330	330
Thailand	8,006	9,083	8,726	8,723	9,400
Togo	256	268	313	384	[3]407
Trinidad and Tobago	[r]433	447	362	372	350
Tunisia	3,142	3,061	3,372	3,289	3,750
Turkey	14,986	17,348	19,380	22,050	[3]24,228
Uganda[e]	22	22	22	22	22
U.S.S.R	141,268	143,453	144,096	148,943	150,000
United Arab Emirates	2,280	4,415	[e]4,400	2,745	2,745
United Kingdom	14,767	14,860	14,704	[e]14,770	14,770
United States (including Puerto Rico)	71,347	78,699	78,859	79,916	[3]79,501
Uruguay	442	368	346	375	[3]442
Venezuela	4,899	5,272	5,836	6,113	5,950
Vietnam[e]	[3]1,023	1,210	1,430	1,700	[3]1,667
Yemen (Sanaa)	[r]937	[r]1,532	1,543	1,279	[3]838
Yugoslavia	10,573	10,268	9,952	10,061	[3]9,880
Zaire	565	[r]589	485	[r e]440	440
Zambia	171	266	349	368	[3]413
Zimbabwe	639	NA	NA	NA	NA
Total	[r]1,010,051	[r]1,036,392	1,056,660	1,100,814	1,138,673

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.
[1]Table includes data available through July 8, 1988.
[2]Data are for the year beginning Mar. 21 of that stated.
[3]Reported figure.
[4]Less than 1/2 unit.
[5]Data are for the year ending June 30 of that stated.
[6]Converted from officially reported data provided in terms of 94-pound cement bags.
[7]Excludes natural cement.

TECHNOLOGY

The industry continued to introduce and experiment with various types of technology aimed at conserving energy and improving plant operating efficiency. Among the more notable developments were industry efforts to expand the use of waste materials in cement kilns as an alternative to fuel oils, natural gas, and/or coal. In a paper presented at the 23d International Cement Seminar in December 1987, industry representatives described progress, challenges, and opportunities in using solvent-derived fuels (SDF) in cement kilns.[5] The paper concluded that while the use of SDF can lead to significant fuel cost savings, there are public acceptance, regulatory, and other institutional barriers that must be overcome.

Results of a 2-year operational test also showed that increases in both operating capacities and energy savings can be obtained using different grinding procedures. Heidelberger Zement AG tested new grinding procedures at its plant in Leimen, Federal Republic of Germany. The pilot test was designed to determine the energy savings and capacity increases of a ball mill when combined with a high-pressure grinding roller. Tests concluded that by combining the grinding roller with the ball mill, capacity increases of up to 40% and energy savings of 20% were achieved. In the case of finish grinding, energy savings of up to 40% were achieved.[6]

The Bureau of Mines published the results of a 1-year study to test and evaluate the resistance of sulfur concrete to corrosion and to examine its permeation characteristics and performance in various industrial environments. The study is part of a Bureau program to find new uses for the Nation's plentiful supply of sulfur in construction materials. Results indicate that sulfur concrete is a corrosion-resistant material that demonstrates superior performance in environments where conventional materials fail. It has improved resistance to chloride and sulfate permeability when compared with portland cement concrete.[7]

[1]Mineral industry specialist, Branch of Industrial Minerals.

[2]U.S. Department of Commerce, International Trade Administration. Construction Review. V. 33, No. 6, Nov.-Dec. 1987, pp. 2-24.

[3]Engineering News-Record. ENR Materials Prices. V. 220, No. 1, Jan. 1988, pp. 42-46.

[4]Rock Products. Cement International. V. 91, No. 4, Apr. 1988, pp. 63-88.

[5]Rock Products Magazine Proceedings, Rock Products 23d International Cement Seminar. 1987, pp. 45-77.

[6]Work cited in footnote 4.

[7]Wrzesinski, W. R., and W. C. McBee. Permeability and Corrosion Resistance of Reinforced Sulfur Concrete. BuMines RI 9157, 1988, pp. 1-13.

Chromium

By John F. Papp[1]

In 1987, reported chromium consumption was 409,964 tons.[2] The reported consumption of chromite by the chemical and metallurgical industry and by the refractory industry increased. Metallurgical industry production includes ferrochromium produced as part of the National Defense Stockpile (NDS) conversion program. Imports of chromite increased and imports of chromium ferroalloys decreased compared with those of 1986.

Domestic Data Coverage.—Domestic data coverage by the primary consuming industries—metallurgical, refractory, and chemical—are developed by the Bureau of Mines by means of the voluntary monthly "Chromite Ores and Chromium Products" survey. The companies listed in table 3 by industry accounted for 100% of the chromite consumption data by industry in table 5. Of those companies that consumed chromite in 1987, 67% of the metallurgical companies, 83% of the refractory companies, and 100% of the chemical companies reported chromite consumption. Consumption was estimated for the remaining 33% of the metallurgical industry.

Table 1.—Salient chromium statistics

(Thousand short tons, gross weight)

	1983	1984	1985	1986	1987
CHROMITE					
United States:					
Exports	11	55	101	92	1
Reexports	5	4	4	1	5
Imports for consumption	190	305	414	488	540
Consumption	320	512	560	427	556
Stocks, Dec. 31: Consumer	456	327	300	314	364
World: Production	r9,050	r10,777	11,590	p12,227	e12,115
CHROMIUM FERROALLOYS[1]					
United States:					
Production[2]	36	95	110	105	118
Exports	4	15	10	6	5
Reexports	2	1	1	1	2
Imports for consumption	282	434	335	398	334
Consumption	388	395	369	365	437
Stocks, Dec. 31: Consumer	26	25	31	30	24
World: Production	r2,697	r3,220	3,325	p3,251	e3,113

eEstimated. pPreliminary. rRevised.
[1]High- and low-carbon ferrochromium plus ferrochromium-silicon.
[2]Includes chromium metal, exothermic chromium additives, and other miscellaneous chromium alloys.

Domestic production data for chromium ferroalloys and metal are developed by the Bureau of Mines by means of two separate voluntary surveys. These two surveys are the monthly "Chromium Ores and Chromium Products" and the annual "Ferroalloys." Production by the metallurgical companies listed in table 3 represented 100% of domestic production shown in table 4. Sixty-seven percent of those companies responded to both surveys. Production for the remaining 33% was estimated.

Legislation and Government Programs.—The U.S. Air Force continued to study critical materials, one of which was chromium, for the purpose of identifying Air Force material needs. The Office of Industrial Base, U.S. Department of Defense, studied the possibility of funding a chromium recycling project under title III of the Defense Production Act. The project would recover superalloy-grade chromium metal from superalloy scrap, thereby reducing dependence on foreign sources for materials critical to the national defense.

The U.S. Department of State, pursuant to section 303(a)(2) of the Comprehensive Anti-Apartheid Act of 1986, as amended (Public Law 99-440), certified to Congress that chromium (including ferrochromium) is a strategic mineral essential for the economy or defense of the United States that is unavailable from reliable and secure suppliers.

The U.S. Department of Transportation made final rule corrections for the transportation of hazardous chromium materials. The materials identified as hazardous and their reportable quantities include ammonium bichromate, 1,000 pounds; calcium chromate, 1,000 pounds; chromic acid, 1,000 pounds; chromic sulfate, 1,000 pounds; chromium metal (of diameter less than 1,000 micrometers or 0.004 inch), 1 pound; chromous chloride, 1,000 pounds; potassium bichromate, 1,000 pounds; potassium chromate, 1,000 pounds; sodium bichromate, 1,000 pounds; sodium chromate, 1,000 pounds.

The Office of the U.S. Trade Representative (USTR) negotiated a new tariff nomenclature for the United States with U.S. trading partners that are part of the General Agreement on Tariffs and Trade (GATT). The new nomenclature harmonizes U.S. nomenclature with that of its GATT trading partners, so it is called the Harmonized System. In addition to changing nomenclature, the Harmonized System uses metric units. Implementation of the Harmonized System was expected upon congressional passage of implementing legislation.

The United States negotiated a trade agreement with Canada. The agreement was to become effective in 1989, if Congress and Canada ratify it. Under the agreement the 1.9% import duty on ferrochromium containing more than 4% carbon is to be lifted on January 1, 1989.

In accordance with the President's November 1982 directive, the General Services Administration (GSA) continued to upgrade NDS chromium ore to high-carbon ferrochromium. The GSA reported conversion of ferrochromium on a calendar year contract basis as follows:

Year	Ore converted (short tons)	High-carbon ferrochromium (short tons)		Value (millions)
		Gross	Content	
1984	125,628	50,254	33,268	$22.3
1985	137,015	49,463	32,662	22.5
1986	94,028	35,212	23,036	17.6
1987	138,604	57,776	44,157	33.6

The Minerals Marketing Corp. of Zimbabwe petitioned the USTR to designate low-carbon ferrochromium and ferrochromium-silicon eligible for duty-free status under the Generalized System of Preferences. The petition was made under sections 503(a) and 131(b) of the Trade Act of 1974 (19 U.S.C. 2463(a)). USTR anticipated deciding on the request in April 1988.

Table 2.—U.S. Government stockpile goals and yearend inventories for chromium in 1987

(Thousand short tons, gross weight)

Material	Stockpile goals	Physical inventory		
		Stockpile-grade	Nonstockpile-grade	Total
Chromite, metallurgical	3,200	1,729	253	1,982
Chromite, chemical	675	242	--	242
Chromite, refractory	850	391	--	391
High-carbon ferrochromium	185	537	1	538
Low-carbon ferrochromium	75	300	19	319
Ferrochromium-silicon	90	57	1	58
Chromium metal	20	4	--	4

Source: Federal Emergency Management Agency.

The U.S. Public Health Service, Agency for Toxic Substances and Disease Registry, issued a draft toxicological profile.[3] The draft profile was published for public comment.

DOMESTIC PRODUCTION

The major marketplace chromium materials are chromite ore and chromium metal, ferroalloys, and chemicals. In 1987, the United States produced chromium metal, ferroalloys, and chemicals. No chromite ore was mined domestically.

The potential for building a ferrochromium smelter at Coos Bay, OR, was studied. Oregon Power and Light Co., the potential power supplier, P.S.M. Technologies Inc., the potential chromite ore supplier, and the Governor of Oregon supported development of the project. Furnace technology was to have been supplied by Wooding Inc. of New Jersey. A closed nickel smelter at Riddle, OR, was studied for its potential to be converted into a ferrochromium smelter.

Table 3.—Principal producers of chromium products in 1987, by industry

Industry and company	Plant
Metallurgical:	
Elkem AS, Elkem Metals Co	Marietta, OH, and Alloy, WV.
Macalloy Inc	Charleston, SC.
Metallurg Inc., Shieldalloy Corp.[1]	Newfield, NJ.
Moore McCormack Resources Inc., Globe Metallurgical Inc	Beverly, OH.
Satra Concentrates Inc	Steubenville, OH.
SKW Alloys Inc	Calvert City, KY, and Niagara Falls, NY.
Refractory:	
Basic Inc	Maple Grove, OH.
Corhart Refractories Co. Inc	Pascagoula, MS.[2]
General Refractories Co	Lehi, UT.
Harbison-Walker Refractories, a division of Dresser Industries Inc	Hammond, IN.
National Refractories & Minerals Corp	Moss Landing, CA, and Columbiana, OH.
North American Refractories Co. Ltd	Womelsdorf, PA.
Chemical:	
American Chrome & Chemicals Inc	Corpus Christi, TX.
Occidental Chemicals Corp	Castle Hayne, NC.

[1]Name changed to Shieldalloy Metallurgical Corp. effective 1988.
[2]Plant closed in 1987.

Table 4.—Production, shipments, and stocks of chromium ferroalloys and chromium metal in the United States

(Short tons)

Material	Net production: Gross weight	Net production: Chromium content	Net shipments	Producer stocks, Dec. 31
1986:				
Low-carbon ferrochromium High-carbon ferrochromium Chromium concentrate	95,813	59,479	105,972	8,956
Ferrochromium-silicon Chromium metal Other[1]	9,594	5,461	9,687	5,149
Total	105,407	64,940	115,659	14,105
1987:				
Low-carbon ferrochromium High-carbon ferrochromium Chromium concentrate	115,541	73,558	120,324	4,271
Ferrochromium-silicon Chromium metal Other[1]	2,093	2,076	6,149	1,366
Total	117,634	75,634	126,473	5,637

[1]Includes exothermic chromium additives and other miscellaneous chromium alloys.

Elkem Metals Co. signed an agreement in principal to sell 70% of its Marietta, OH, power-generating plant to American Municipal Power—Ohio. The plant capacity was 250 megawatts of electricity and process steam. Elkem used power from its coal-fired plant to produce chromium metal and low-carbon ferrochromium at its Marietta plant. At yearend the terms of sale were being negotiated. Elkem signed an agreement to market specialty chromium products in Japan through Showa Denko K.K. The Elkem products to be sold by Showa Denko included regular- and vacuum-grade electrolytic chromium metal, 9% carbon chromium metal, and chromium carbide. Elkem planned to install a furnace for the production of higher quality chromium metal than it currently produces, and to restart a high-carbon ferrochromium furnace.

Corhart Refractories Co. Inc. closed its Pascagoula, MS, plant where it manufactured chromium-containing refractories for the glass and steel industries. Corhart attributed the closing to poor market conditions for steelmaking refractories, resulting from changing steelmaking technology and declining domestic steel production. As a result of this rationalization, about 160 jobs were lost, 92 at Pascagoula and 68 at other locations. Corhart continued refractory material production at Louisville, KY, and Buckhannon, WV. Corhart was owned by the company's management and two investment companies, Thomas H. Lee Co. and Prudential Insurance Co. The investment companies sold their share in Corhart to Société Europeene Des Produits Refractaires (SEPR). SEPR, part of the Saint Gobain Group, is a French-based company that is a large producer of fusion-cast refractory blocks and shapes for the glass industry.

Metallurg Inc. planned to merge its U.S. trading subsidiary with its U.S. production company, Shieldalloy Corp., to form Shieldalloy Metallurgical Corp. The merger is to occur in 1988.

CONSUMPTION AND USES

Domestic consumption of chromite ore and concentrate was 555,865 tons in 1987. Of the total chromite consumed, the chemical and metallurgical industry used 505,449 tons; and the refractory industry, 50,416. Much of the chromite consumed and ferrochromium produced by the metallurgical industry were part of the NDS conversion program. (See "Legislation and Government Programs" section of this chapter.)

Chromium has a wide range of uses in the three primary consumer groups. In the metallurgical industry, its principal use in 1987 was in stainless steel. Of the 443,779 tons of chromium ferroalloys, metal, and other chromium-containing materials reported consumed, stainless steel accounted for 82%; full-alloy steel, 7%; superalloys, 3%; and other end uses, 8%.

The primary use of chromium in the refractory industry was in the form of chromite to make refractory bricks to line metallurgical furnaces. Chromite consumption by the refractory industry increased to 50,416 tons.

The chemical industry consumed chromite for manufacturing sodium bichromate, chromic acid, and pigments. Sodium and potassium chromate and bichromate are the materials from which a wide range of chromium chemicals are made.

Table 5.—Consumption of chromite and tenor of ore used by primary consumer groups in the United States

Year	Chemical and metallurgical industry		Refractory industry		Total	
	Gross weight (short tons)	Average Cr_2O_3 (percent)	Gross weight (short tons)	Average Cr_2O_3 (percent)	Gross weight (short tons)	Average Cr_2O_3 (percent)
1983	247,921	43.3	72,050	36.9	319,971	42.0
1984	414,687	44.0	97,469	37.4	512,156	42.8
1985	495,176	41.5	65,245	38.1	560,421	41.2
1986	377,300	40.3	49,938	37.1	427,238	40.2
1987	505,449	41.0	50,416	39.0	555,865	41.0

Table 6.—U.S. consumption of chromium ferroalloys and metal in 1987, by end use

(Short tons, gross weight)

End use	Ferrochromium		Ferrochromium-silicon	Other	Total
	Low-carbon	High-carbon			
Steel:					
Carbon	2,936	3,665	182	W	6,783
Stainless and heat-resisting	11,845	341,839	9,390	579	363,653
Full-alloy	4,266	27,562	1,184	W	33,012
High-strength, low-alloy, and electric	1,786	2,087	W	W	3,873
Tool	1,023	3,077	W	--	4,100
Cast irons	868	5,934	27	W	6,829
Superalloys	4,349	5,459	W	2,900	12,708
Welding materials[1]	491	W	--	161	652
Other alloys[2]	590	345	W	2,120	3,055
Miscellaneous and unspecified	343	850	7,181	740	9,114
Total[3]	28,497	390,818	17,964	[4]6,500	443,779
Chromium content	19,210	223,895	6,575	4,942	254,622
Stocks, Dec. 31	3,490	19,877	557	[5]976	24,900

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."
[1]Includes structural and hard-facing welding material.
[2]Includes magnetic and nonferrous alloys.
[3]Includes estimates.
[4]Includes 4,179 tons of chromium metal.
[5]Includes 775 tons of chromium metal.

STOCKS

Reported consumer stocks of chromite increased from 313,795 tons in 1986 to 363,938 tons in 1987. Chemical and metallurgical industry stocks increased, whereas refractory industry stocks declined. Producer stocks of chromium ferroalloys, metal, and other materials declined from 14,105 tons in 1986 to 5,637 tons in 1987. Consumer stocks decreased from 31,790 tons in 1986 to 24,900 tons in 1987. At the 1987 annual rate of chromium ferroalloy and metal consumption, producer plus consumer stocks represented about a 3-week supply.

Table 7.—U.S. consumer stocks of chromite, December 31, by industry

(Short tons, gross weight)

Industry	1983	1984	1985	1986	1987
Chemical and metallurgical	379,744	257,702	251,552	274,796	340,471
Refractory	75,832	69,619	48,635	38,999	23,467
Total	455,576	327,321	300,187	313,795	363,938

Table 8.—U.S. consumer stocks of chromium ferroalloys and metal, December 31, by product

(Short tons, gross weight)

Product	1983	1984	1985	1986[r]	1987
Low-carbon ferrochromium	3,474	3,375	5,482	5,495	3,493
High-carbon ferrochromium	20,948	19,946	24,115	22,972	19,867
Ferrochromium-silicon	1,294	1,422	1,289	1,460	557
Other[1]	954	1,559	1,280	1,771	911
Total	26,670	26,302	32,166	31,698	24,828

[r]Revised.
[1]Includes chromium briquets, chromium metal, exothermic chromium additives, and other miscellaneous chromium alloys.

PRICES

The price of South African chromite ore increased, while that of Turkish chromite ore decreased. The published price of South African Transvaal chromite, 44% Cr_2O_3 (no specific chromium-to-iron ratio), increased from a range of $40 to $42 per metric ton, f.o.b. South African ports, to a range of $40 to $46 in April, where it remained through December. The published price of Turkish chromite ore declined from $125 per metric ton, f.o.b. Turkish ports, to $100 in April, where it remained until December, when it increased to $115.

Table 9.—Price quotations for chromium materials at beginning and end of 1987

Material	January	December
	Cents per pound of chromium	
High-carbon ferrochromium:		
Domestic:		
50% to 55% chromium	(1)	50.25
66% to 70% chromium	54	52
Imported:		
50% to 55% chromium	38.25 - 38.75	58 - 60
60% to 65% chromium	41.5 - 42.5	60 - 65
Low-carbon ferrochromium:		
Domestic:		
0.025% carbon	100	100
0.05% carbon	95	95
Simplex	100	110
Imported: 0.05% carbon	83 - 84	100 -105
	Cents per pound of product	
Electrolytic chromium metal	315 -375	315 -375
Ferrochromium-silicon	38.6	38.6

[1]Price listing suspended in 1984 until Sept. 1987, when it was reinstated at 50.25 cents per pound of chromium.

Source: Metals Week.

The price of domestic high-carbon ferrochromium containing 50% to 55% chromium, suspended since August 1984, was reinstated in September at 50.25 cents per pound of contained chromium, where it remained through December. The published price of domestic high-carbon ferrochromium containing 60% to 70% chromium declined from 54 cents per pound of contained chromium in October to 52 cents, where it remained through December. The prices of domestic low-carbon ferrochromium containing 0.025% carbon and of that containing 0.05% carbon remained unchanged. The published price of Simplex low-carbon ferrochromium increased from $1.00 per pound of contained chromium in September to $1.10, where it remained through December. The price of ferrochromium-silicon remained unchanged. The price of chromium metal remained unchanged.

The price of imported ferrochromium increased. The published price of imported high-carbon ferrochromium containing 50% to 55% chromium increased in March from a range of 38.25 to 38.75 cents per pound of contained chromium to a range of 40 to 42 cents, in May to a range of 41.5 to 43 cents, in June to a range of 42.5 to 43.25 cents, in August to a range of 43.5 to 44.5 cents, in October to a range of 50 to 52 cents, and in December to a range of 58 to 60 cents.

FOREIGN TRADE

Exports of chromium materials from the United States included chromite ore and chromium metal, ferroalloys, chemicals, and pigments.

Imports for consumption of chromium materials included chromite ore and concentrate made from ore; chromium ferroalloys, including low-carbon ferrochromium, high-carbon ferrochromium, and ferrochromium-silicon; metal; and chromium chemicals and pigments.

Table 10.—U.S. exports and reexports of chromite ores and concentrates

Year	Exports		Reexports	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1983	11,032	$1,874	4,561	$1,350
1984	54,928	2,957	3,855	864
1985	100,810	4,600	3,676	670
1986	92,108	4,143	1,457	511
1987	1,262	707	5,332	352

Source: Bureau of the Census.

Table 11.—U.S. exports of chromium materials, by type

Type	1985	1986	1987		Principal destinations, 1987
	Quantity (short tons)	Quantity (short tons)	Quantity (short tons)	Value (thousands)	
Chromite ore and concentrate	100,810	92,108	1,262	$707	Canada (62%); Mexico (13%); Chile (12%); Italy (6%).
Metal and alloys:					
Chromium metal[1]	222	321	415	4,670	Japan (44%); United Kingdom (35%); Ghana (20%).
Chromium ferroalloys	[2]10,262	[3]6,035	[4]4,568	5,730	Canada (61%); Mexico (18%); Venezuela (8%).
Chemicals:					
Chromic acid	3,881	5,596	4,504	8,361	Republic of Korea (20%); Japan (16%); Canada (14%); China (14%).
Potassium chromate and dichromate	71	21	10	9	Philippines (40%); Republic of Korea (30%); Panama (30%).
Sodium chromate and dichromate	9,726	15,837	16,556	12,063	China (33%); Italy (18%); Colombia (13%); Thailand (13%).
Pigments	1,928	2,491	3,545	9,530	Canada (14%); Federal Republic of Germany (14%); Mexico (13%); Philippines (13%).

[1]Wrought and unwrought and waste and scrap.
[2]Contained 6,277 tons of chromium.
[3]Contained 3,496 tons of chromium.
[4]Contained 2,743 tons of chromium.

Source: Bureau of the Census.

Table 12.—U.S. imports for consumption of chromite, by country

Country	Not more than 40% Cr_2O_3: Gross weight (short tons)	Not more than 40% Cr_2O_3: Cr_2O_3 content (short tons)	Not more than 40% Cr_2O_3: Value (thousands)	More than 40% but less than 46% Cr_2O_3: Gross weight (short tons)	More than 40% but less than 46% Cr_2O_3: Cr_2O_3 content (short tons)	More than 40% but less than 46% Cr_2O_3: Value (thousands)	46% or more Cr_2O_3: Gross weight (short tons)	46% or more Cr_2O_3: Cr_2O_3 content (short tons)	46% or more Cr_2O_3: Value (thousands)	Total[1]: Gross weight (short tons)	Total[1]: Cr_2O_3 content (short tons)	Total[1]: Value (thousands)
1986:												
Canada	12,833	4,748	$745	--	--	--	--	--	--	12,833	4,748	$745
Philippines	18,375	6,446	1,625	--	--	--	426	228	$55	18,801	6,674	1,680
South Africa, Republic of	498	187	38	122,618	55,073	$4,968	217,776	104,427	9,439	340,892	159,687	14,445
Turkey	91,474	33,111	3,827	2,295	1,007	62	--	--	--	93,769	34,118	3,889
U.S.S.R	21,908	8,325	897	--	--	--	--	--	--	21,908	8,325	897
Total[1]	145,088	52,817	7,132	124,912	56,080	5,030	218,203	104,655	9,495	488,203	213,552	21,657
1987:												
Canada	131	47	23	--	--	--	--	--	--	131	47	23
New Caledonia	--	--	--	--	--	--	5,245	2,680	749	5,245	2,680	749
Philippines	13,729	4,807	1,172	2,668	1,201	264	12	7	3	16,409	6,015	1,439
South Africa, Republic of	--	--	--	162,333	73,076	6,532	114,088	57,150	4,913	276,421	130,226	11,445
Turkey	189,814	68,593	7,278	26,715	11,141	1,686	3,920	1,809	275	220,449	81,543	9,239
U.S.S.R	21,367	8,120	879	--	--	--	--	--	--	21,367	8,120	879
Total[1]	225,042	81,567	9,352	191,716	85,417	8,483	123,265	61,646	5,940	540,023	228,630	23,775

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

Source: Bureau of the Census.

Table 13.—U.S. imports for consumption of ferrochromium, by country

Country	Low-carbon ferrochromium (less than 3% carbon): Gross weight (short tons)	Low-carbon: Chromium content (short tons)	Low-carbon: Value (thousands)	High-carbon ferrochromium (3% or more carbon): Gross weight (short tons)	High-carbon: Chromium content (short tons)	High-carbon: Value (thousands)
1986:						
Brazil	--	--	--	8,047	4,380	$2,975
China	--	--	--	1,102	750	458
Finland	--	--	--	14,387	7,757	6,535
Germany, Federal Republic of	7,157	5,062	$8,029	--	--	--
Greece	--	--	--	4,409	2,676	1,796
Italy	454	331	580	--	--	--
Japan	38	24	47	296	201	316
Norway	57	43	27	--	--	--
South Africa, Republic of	16,471	9,243	8,234	214,084	114,070	75,140
Sweden	4,799	3,420	5,433	--	--	--
Turkey	4,960	3,369	5,036	44,134	28,225	21,714
Yugoslavia	--	--	--	24,645	15,744	11,833
Zimbabwe	6,033	4,092	5,320	37,340	24,365	19,220
Total[1]	39,969	25,582	32,707	348,443	198,168	139,987
1987:						
Brazil	--	--	--	5,022	2,693	1,914
Canada	1	([2])	2	14	8	6
China	--	--	--	6	4	4
Finland	--	--	--	3,309	1,714	1,141
Germany, Federal Republic of	7,846	5,550	11,432	2,795	1,983	1,303
Greece	--	--	--	7,385	4,536	3,050
Italy	464	338	690	--	--	--
Japan	356	238	477	394	262	461
South Africa, Republic of	20,719	12,091	12,945	195,655	102,778	71,651
Sweden	1,911	1,321	2,419	853	581	611
Turkey	3,891	2,621	3,769	11,905	7,657	5,445
United Kingdom	20	13	33	--	--	--
Yugoslavia	--	--	--	17,151	11,067	7,558
Zimbabwe	7,039	4,768	5,956	38,794	25,222	19,404
Total[1]	42,246	26,940	37,723	283,282	158,505	112,546

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

Source: Bureau of the Census.

Table 14.—U.S. imports of selected chromium materials, by type

Type	1985 Quantity (short tons)	1986 Quantity (short tons)	1987 Quantity (short tons)	1987 Value (thousands)	Principal sources, 1987
Metal and alloys:					
Chromium metal[1]	3,954	4,485	4,356	$24,096	United Kingdom (38%); China (20%); Japan (18%); France (16%).
Ferrochromium-silicon	[2]3,940	[3]9,221	[4]8,356	4,920	Zimbabwe (66%); Republic of South Africa (34%).
Chemicals:					
Chromic acid	4,905	4,626	2,820	4,039	Netherlands (28%); Mexico (19%); United Kingdom (16%); China (13%).
Chromium carbide	123	101	173	1,524	Federal Republic of Germany (61%); Japan (25%); United Kingdom (14%).
Potassium chromate and dichromate	639	827	1,109	1,387	United Kingdom (52%); U.S.S.R. (22%); Federal Republic of Germany (13%); Canada (11%).
Sodium chromate and dichromate	10,836	7,657	5,241	3,173	United Kingdom (25%); Turkey (24%); Republic of South Africa (18%); Argentina (16%).

See footnotes at end of table.

Table 14.—U.S. imports of selected chromium materials, by type —Continued

Type	1985 Quantity (short tons)	1986 Quantity (short tons)	1987 Quantity (short tons)	1987 Value (thousands)	Principal sources, 1987
Pigments:					
Chrome green	202	26	104	97	Canada (66%); United Kingdom (33%).
Chrome yellow	3,181	2,131	3,698	5,573	Canada (77%); Federal Republic of Germany (7%); Hungary (6%); Netherlands (4%).
Chrome oxide green	1,511	2,828	2,658	5,540	Federal Republic of Germany (35%); United Kingdom (34%); Romania (17%); Japan (12%).
Hydrated chromium oxide green	13	--	17	41	All to France.
Molybdenum orange	1,077	826	1,219	2,461	Canada (78%); Federal Republic of Germany (16%); Japan (6%).
Strontium chromate	431	131	131	308	France (61%); Federal Republic of Germany (15%); Canada (11%).
Zinc yellow	1,731	1,420	1,331	1,787	Norway (40%); Hungary (39%); Canada (11%).

[1]Wrought and unwrought and waste and scrap.
[2]Contained 1,493 tons of chromium.
[3]Contained 3,532 tons of chromium.
[4]Contained 3,116 tons of chromium.

Source: Bureau of the Census.

Table 15.—U.S. import duties for chromium-containing materials in 1987

Item	TSUS No.	Most favored nation (MFN)	Non-MFN
Ore: Chrome ore and concentrate	601.15	Free	Free.
Metal and alloys:			
Low-carbon ferrochromium	606.22	3.1% ad valorem	30% ad valorem.
High-carbon ferrochromium	606.24	1.9% ad valorem	7.5% ad valorem.
Ferrosilicon chromium	606.42	10% ad valorem	25% ad valorem.
Chromium metal[1]	632.18	3.7% ad valorem	30% ad valorem.
Chemicals:			
Potassium chromate and dichromate	420.08	1.5% ad valorem	3.5% ad valorem.
Sodium chromate and dichromate	420.98	2.4% ad valorem	8.5% ad valorem.
Chromium carbide	422.92	4.2% ad valorem	25% ad valorem.
Chromic acid	423.0092	3.7% ad valorem	Do.
Pigments:			
Chrome green	473.10	do	Do.
Chrome yellow	473.12	do	Do.
Chromium oxide green	473.14	do	Do.
Hydrated chromium oxide green	473.16	do	Do.
Molybdenum orange	473.18	do	Do.
Strontium chromate	473.19	do	Do.
Zinc yellow	473.20	do	Do.

[1]Includes wrought and unwrought and waste and scrap chromium metal.

NOTE.—The special tariff treatment programs—Generalized System of Preferences, Caribbean Basin Economic Recovery Act, and United States-Israel Free Trade Area Implementation Act of 1985—apply to many of these items. Eligible for full tariff reductions are the least developed developing countries in accordance with section 503(a)(2)(A) of the Trade Agreements Act of 1979 (93 STAT. 251).

WORLD REVIEW

Albania.—Albania planned to increase chromite production by 36% and ferrochromium production by 100% as part of its 1986-90 5-year plan. A third 9-megavolt-ampere furnace was constructed and commissioned. The new furnace was expected to reach full production capacity in 1989.

Australia.—Callina NL began a bulk sampling program at its Wilson River lease in Tasmania. Callina estimated that it could produce about 112,000 tons per year of chromite concentrate from three alluvial deposits estimated to contain about 45 million tons of ore.

Australmin Holdings Ltd. was formed as a result of Australia Oil and Gas Minerals Ltd.'s acquisition of Australmin Pacific NL. Australmin Holdings has a 100% interest in an alluvial chromite deposit off the southwestern shore of New Caledonia that it was developing. Exploration indicated a resource of 80 million cubic meters containing about 3.5% chromic oxide (Cr_2O_3). Australmin Holdings planned to conduct drilling and beneficiation studies.

The Broken Hill Pty. Co. Ltd. (BHP), Australia's only stainless steel producer, decided to cease stainless steel production. BHP operated a 39,000-ton-per-year stainless steel-producing plant at Port Kembla. BHP planned to continue rolling stainless steel from imported stainless steel coils and slabs.

Brazil.—Electrical power cost and availability were problems to Brazilian ferroalloy producers. Cia. de Ferro-Ligas Bahia S.A. (FERBASA), Brazil's ferrochromium producer, experienced power rationing for part of the year because of a prolonged drought. FERBASA also sought a price increase for domestically sold ferrochromium from the Interministerial Prices Council because prices had been frozen since March 1986. The Ministry of Finance authorized a 10% increase in ferrochromium prices. About 70% of FERBASA's production was consumed in Brazil.

Brazilian ferroalloy producers obtained Government approval to build private hydropower plants. The plants were planned to be financed privately, and electricity was to be transported by the national power grid. It was anticipated that private hydropower for the ferroalloy producers would result in lower ferroalloy production cost.

Associação Brasileira dos Produtores de Ferroligas reported 1987 production of 102,940 tons of high-carbon ferrochromium, 13,237 tons of low-carbon ferrochromium, 8,906 tons of ferrochromium-silicon, and 136 tons of chromium metal. Internal sales were reported to have been 81,930 tons of high-carbon ferrochromium, 12,817 tons of low-carbon ferrochromium, 662 tons of ferrochromium-silicon, and 123 tons of chromium metal. Export sales were reported to have been 18,721 tons of high-carbon ferrochromium and 28 tons of low-carbon ferrochromium.

Cuba.—A chromite ore processing plant was under construction in the Moa region. The plant was expected to have a production capacity of about 55,000 tons per year. Its cost was estimated to be about $11 million. Cuban refractory chromite production for 1986 was reported to have been about 118,500 tons, of which about 50,000 tons was exported. Production for 1987 was expected to surpass that of 1986 as Minera Holguin's processing plant, constructed in 1986, came into full production.

European Economic Community.—The European Economic Community (EEC) raised its 1986 duty-free import quota for 6% to 8% carbon ferrochromium from 132,000 to 243,000 tons in March and from 243,000 to 441,000 tons in November. EEC set 1988 quotas at 2,927 tons of not more than 0.10% carbon ferrochromium and 231,000 tons of more than 6% carbon ferrochromium. The quota for more than 4% carbon ferrochromium was not set at yearend.

EEC high-carbon ferrochromium producers filed a complaint with the EEC Commission alleging that Finland was dumping high-carbon ferrochromium in the EEC. EEC low-carbon ferrochromium producers requested the EEC Commission to reopen its antidumping complaint of 1983 against the Republic of South Africa, Turkey, and Zimbabwe. Although the EEC consumption of low-carbon ferrochromium fell from 58,000 tons in 1984 to 43,000 tons in 1987, EEC production fell from 46,000 tons in 1984 to 39,000 tons in 1987, and imports from the Republic of South Africa, Turkey, and Zimbabwe increased from 34,000 tons in 1983 to 37,000 tons in 1987.

France.—Construction of a ferrochromium plant at Dunkirk was begun with completion expected in 1988. The new plant was to produce 4% to 6% carbon ferrochromium initially, with a capacity of 16,000 tons per year. The new plant was being constructed by Ferroaleaciones Españolas S.A. (Fesa) of Spain and other investors known as Chromeurope S.A.

Germany, Federal Republic of.—Part of the Metallurg Group, Gesellschaft für Electrometallurgie mbH (GfE), resumed low-carbon ferrochromium production at GfE's Weisweiller plant. GfE closed its plant for furnace repairs and because of low market demand. GfE sought West German Government protection from lower priced imports. The West German specialty steel industry argued that 85% of ferrochromium currently consumed in the Federal Republic of Germany is high-carbon ferrochromium, a product GfE produced until 1986, when it put its high-carbon ferrochromium furnaces on care and maintenance, and that an increase in low-carbon ferrochromium prices would make those steels that use it increase in price to above market prices.

Greece.—Hellenic Ferroalloys S.A. started construction of an ore-dressing plant to increase chromite concentrate production capacity from 60,000 to 120,000 tons per year. Hellenic also planned to increase its mine production to feed the new plant. The new production facilities were expected to become operational in 1988.

India.—Metals and Minerals Trade Corp. reported chromite ore exports for 1985-86 to have been 246,000 tons; 1986-87, 86,000 tons; and 1987-88 (estimated), 276,000 tons. Ferrochromium production was reported for fiscal year 1986-87 to have been 92,490 tons. The Geological Survey of India continued systematic drilling to identify chromite resources in the Sukinda Valley area. An additional 16 million tons of chromite may be added to reserves in the Damsal Nala area as a result of resource identification drilling.

OMC Alloys Ltd., a subsidiary of Orissa Mining Corp. Ltd., put its pellet roasting kilns into operation in April. OMC planned the construction of India's third chromite beneficiation plant and the second such plant in Orissa. OMC planned the construction of a briquetting plant along with the beneficiation plant. The beneficiation plant was to take low-grade ore (less than 50% Cr_2O_3), and the briquetting plant was to take high-grade ore (greater than 50% Cr_2O_3). The beneficiation plant was to produce at an annual rate of 93,000 tons. The briquetting plant was to produce 55,000 tons per year and was to feed local ferrochromium producers, including Indian Charge Chrome Ltd. (a subsidiary of Indian Metals & Ferro Alloys Corp. Ltd. (IMFA)), Indian Development Corp., and Ferro Alloys Corp. Ltd. (FACOR). The beneficiation plant and briquetting plant were expected to be completed in 1989. The development was part of an Indian trend toward production of the higher valued ferrochromium material, rather than lower valued ore, for export.

Tata Iron and Steel Co. Ltd. started expansion of its Sukinda chromite mine with installation of an ore beneficiation plant to treat low-grade ore, old lumps, and some overburden. Feed grade was expected to average about 20% Cr_2O_3; the product was to be about 50% Cr_2O_3. Plant equipment was to be supplied by Sala International AB of Sweden and Mineral Deposits Ltd. of Australia.

IMFA continued construction of Indian Charge Chrome Ltd. (ICC). ICC includes a 50,000-metric-ton-per-year ferrochromium plant and a 108-megawatt coal-fired electric powerplant. IMFA has ferrochromium production facilities at Therubali and Choudhar. ICC expected construction to be completed in 1988. The Therubali plant produced for domestic consumption; the Choudhar plant was closed pending completion of its power supply.

FACOR operated ferrochromium plants at Randia, Orissa State, and Shreeramnagar, Andra Pradesh State. The Shreeramnagar smelter produced for domestic consumption. FACOR's Shreeramnagar smelter experienced a 40% cutback in electrical power owing to drought in that region. FACOR temporarily reduced exports while it repaired an electric furnace at the Randia smelter. FACOR had been producing about 45,000 tons of ferrochromium per year.

Indonesia.—A chromite mine was being developed by Acorn Diamond Indonesia. The mine, on the east coast of Central Sulawesi, had reserves containing about 1 million tons of ore. About 0.6 million cubic yards per year was to be processed to recover about 40,000 tons per year of 43% Cr_2O_3 concentrate containing less than 1% silica. The mine was owned and to be operated by two Indonesian companies, PT Palmabin and PT Bituminusa.

Iran.—Iran concluded a trade agreement with the German Democratic Republic in which Iran was to supply chromite in exchange for chemicals, metals, plastics, and other materials.

Japan.—The Ministry of International Trade and Industry budgeted about $15.7 million for fiscal year 1987 (April 1, 1987, through March 31, 1988) to purchase stockpile materials. The Japanese Government planned to buy the equivalent of 42 days of domestic consumption for the Government stockpile and 18 days of consumption for the private stockpile by 1991. By the end of fiscal year 1987, Japan planned to have stockpiled about 32 days' supply of ferrochromium, of which 22 days' supply would be in the Government stockpile and about 10 days in the private stockpile. The amount of ferrochromium in the stockpile at the end of fiscal year 1987 was estimated to be about 48,980 tons.

Awamura Metal Industry Co. Ltd. closed its ferrochromium smelter in Uji, Kyoto

Prefecture. The plant had a production capacity of 40,000 tons per year from a 25-megavolt-ampere furnace.

Japan Metals & Chemicals Co. Ltd. (JMC) stopped ordering chromium ore for its Sakata ferrochromium smelter in Yamagata Prefecture. The Sakata plant was one of three operated by JMC. The plant had a production capacity of 47,000 tons, but produced only 21,000 tons in 1986. JMC proposed to close the Sakata plant and increase production at its Oguni, Yamagata Prefecture, and Kita Kyushu, Fukuoka Prefecture, plants. Oguni had an annual capacity of 20,000 tons of low-carbon ferrochromium and 18,000 tons of high-carbon ferrochromium; capacity at Kyushu was 75,000 tons of high-carbon ferrochromium. Sumitomo Metal Co. negotiated sale of the Sakata plant to China.

Kurimoto Iron Works Ltd., a member of the Kawasaki Steel Corp. group, ended ferrochromium production in April.

Japan reported 1987 calendar year imports of 743,776 tons of chromite ore from which it produced 305,511 tons of high-carbon ferrochromium, 36,264 tons of low-carbon ferrochromium, and 13,946 tons of ferrochromium-silicon. Japan imported an additional 471,470 tons of ferrochromium and 7,899 tons of ferrochromium-silicon. Japan exported 1,024 tons of greater than 0.1% carbon ferrochromium and 4,359 tons of other ferrochromium. Stainless steel production in Japan was 2,613,585 tons, exceeding that of each of the preceding 5 years.

Korea, Republic of.—Pohang Iron and Steel Co. Ltd. (Posco) planned to start hot-strip coil stainless steel production in 1988. Annual hot-rolled startup production capacity of 260,000 tons was planned, with a plant design that permits expansion to 420,000 tons. Posco has been working with West German companies to construct an electric melting furnace and an argon-oxygen decarburization refining furnace for the production of stainless steel since March 1987. Sammi Steel Co. Ltd. and Samyang Metal Co. produced cold-rolled stainless steel strip from Japanese produced hot-rolled strip.

New Caledonia.—The Mining and Energy Bureau of Statistics of New Caledonia reported 1986 chromite concentrate production to have been 79,594 tons. Production in 1987 was estimated at 72,000 tons. The decreased production resulted from decreased demand from China.

Oman.—Oman Mining Co. was reportedly producing about 7,000 tons of chromite per year for export from a capacity of about 20,000 tons per year. French companies were expected to start mining chromite deposits.

Pakistan.—Pakistan Chrome Mines had been producing about 3,000 to 4,000 tons of metallurgical-grade chromite per year from an underground mine at Muslim Bagh in Zhob District of Baluchistan Province. The mine had a capacity of about 30,000 tons per year. Mineral Grinding Mills mined chromite near Baranlak in Khuzday District with a capacity of about 10,000 to 20,000 tons per year. Paracha Brothers (Pty.) Ltd. was operating on a trial basis beneficiating chromite in Karachi that came from a mine in North-West Frontier Province near Peshawar and four mines in Baluchistan near Dalbandin, Nokkundi, Kharan, and Khuzdar. Paracha anticipated developing a 20,000-ton-per-year production capacity.

The Sudan Development Authority located 0.410 million ton of chromite reserves in the North-West Frontier Province. Mining International Ltd. sought a joint venture with the Sudan Development Authority to develop a deposit near Kohistan.

South Africa, Republic of.—The Minerals Bureau reported South African production of chromite in 1986 to have been 3,805,770 tons, and that of chromium ferroalloys, 964,722 tons. Chromite production in 1987 was estimated at 3,680,000 tons.

Chromore Ltd., 51% owned by S. A. Manganese Amcor Ltd. (Samancor), operated five mines: Groothoek, Montrose, Mooinooi, Tweefontein, and Waterkloof. Shallow mining was started at Grasvally and Ruighoek, which had been closed down. Chromore reactivated the Jagdlust Mine. Rand Mines operated the Winterveld and Henry Gould Mines.

Chromecorp Technology (Pty.) Ltd., a newly organized chromium producer, purchased Chroombronne Mine from Erts Handel (Pty.) Ltd. Chromecorp Technology was producing with a capacity range of 130,000 to 170,000 tons per year at its Chroombroone Mine near Kroondal, Transvaal. Mine expansion to a production capacity of 250,000 tons per year was planned to meet anticipated chromium ore demand by Chromecorp Technology's planned ferrochromium smelter.

Western Platinum Ltd. (Wesplat), a primary platinum-group metals (PGM) producer, announced plans to double production over a 5-year period from the UG2 chromitite seam. The chromite byproduct of UG2 chromitite seam PGM mining has been stockpiled, and increased production from the seam was expected to increase the quantity of stockpiled material. The technologic feasibility of ferrochromium production from Wesplat's byproduct chromite was demonstrated by the Council for Mineral Technology.

Batlhako Ferrochrome (Pty.) Ltd., a new ferrochromium producer in Bophuthatswana, started production. The plant's production capacity was 25,000 metric tons per year, and the plant was being supplied chromite by Batlhako Mining Ltd. from the Ruighoek Mine. The smelter was at the minesite. Marketing for Batlhako was being handled by Samancor.

Tubatse Ferrochrome (Pty.) Ltd. planned to increase its ferrochromium production capacity by increasing furnace size to permit greater power consumption and by beneficiating slag. The capacity increases would be about 20,000 tons per year by increasing furnace production and about 8,000 tons per year by slag processing. Tubatse was operating with a capacity of about 150,000 tons per year before furnace modifications. One furnace was relined and modified, and other plant modifications to increase production capacity were expected to be completed in 1988.

Ferrometals Ltd. operated five ferrochromium-producing furnaces with total production capacity of about 332,000 tons per year and two refining furnaces with a total capacity of about 50,000 tons per year of intermediate carbon (carbon between 0.1% and 4%). Ferrometals was studying a direct-reduction process to increase production capacity.

Middelburg Steel & Alloys Holdings (Pty.) Ltd. (MSA) modernized its low-carbon ferrochromium production facilities at Middelburg, Transvaal. These renovations permitted MSA to produce special grades of low-carbon ferrochromium. MSA worked with Showa Denko (Japan) to develop low-nitrogen (0.02% maximum) and ultralow-carbon (0.015% maximum) grades. Modernization included the installation of air pollution control equipment; a ferrochromium-silicon holding furnace for decarburization; and crushing, sizing, computer process control, and electronic weighing equipment. MSA developed a smelt processing that permits production of low-carbon ferrochromium containing 57% to 67% chromium from chromite mined in Transvaal. Low-carbon ferrochromium was produced in low-chromium (less than 60% chromium), medium-chromium (60% to 65% chromium), and high-chromium (greater than 65% chromium) grades. As a result of modernization, MSA has increased its low-carbon ferrochromium production capacity at Middelburg from about 40,000 to about 50,000 tons per year. MSA decided to increase its charge-grade high-carbon ferrochromium production capacity by increasing production capacity of its direct-current plasma arc furnace at Krugersdrop, Transvaal. Furnace modification from a 16-megavolt-ampere to a 40-megavolt-ampere electrical power capacity was started. Modification was expected to be completed in 1988. Production capacity as a result of the furnace modification was to increase from 20,000 to 40,000 tons per year of charge-grade high-carbon ferrochromium. MSA considered adding a prereduction step to its charge-grade high-carbon ferrochromium production process at Middelburg to increase production capacity. A decision on whether to add prereduction and in what way to add it was expected in 1988.

A new charge-grade high-carbon ferrochromium plant with a 130,000-ton-per-year capacity was planned by Chromecorp Technology. The plant was to be near Rustenburg, Transvaal. The plant was expected to cost about $26 million and be composed of two 30-megavolt-ampere electric arc furnaces. The plant was to be constructed about 18 kilometers from its ore supplier, Chroombronne Mine.

Spain.—Fesa was constructing a ferrochromium plant at Dunkirk, France. Fesa's plant at Medina Del Campo, Valladolid Province, had a production capacity of 37,000 tons per year of 65% chromium high-carbon ferrochromium. Production was only about 20,000 tons per year owing to electrical power limitations. Fesa was negotiating an interruptible electrical power supply contract with Spanish power authorities. (See "France" in this section.)

Swaziland.—A new 60,000-ton-per-year high-carbon ferrochromium plant was planned by Swazi Chrome. The company negotiated with the Swaziland Government for installation of power lines and for power rates. Plant construction was expected to start upon favorable outcome of power rate negotiations.

Sweden.—SwedeChrome AB at Malmö started high-carbon ferrochromium production. SwedeChrome expected to reach full production capacity of 86,000 tons per year in 1988. At capacity production, Swede-Chrome also would produce 380 gigawatt-hours of recovered thermal energy converted to electrical energy annually that was to be sold to the local power authority, and 94,000 tons of slag that was to be used for landfill upon receipt of an environmental permit to do so. At full-capacity production, the plant was expected to consume annually about 190,000 tons of chromite, 39,000 tons of coal, 20,000 tons of sand, 17,000 tons of limestone, 12,000 tons of coke, and 345 gigawatt-hours of electrical energy.

Vargon Alloys AB, Sweden's only established ferrochromium producer, was purchased by Vargon management and Mellanfonden, a Swedish wage earner fund, from Fides Treuhand GmbH (a Swiss holding company). Four management officials purchased 65%; Mellanfonden, 35%. Vargon operated two ferrochromium-producing furnaces: a 24-megavolt-ampere furnace that could produce 27,000 to 33,000 tons of high-carbon ferrochromium per year (operated at about 16 megawatts), and a 105-megavolt-ampere furnace that could produce about 83,000 to 88,000 tons of charge-grade high-carbon ferrochromium per year (operated at about 51 megawatts). Vargon obtained chromium ore primarily from Finland and sold its ferrochromium in Sweden, the Federal Republic of Germany, and the United Kingdom.

Turkey.—Etibank's Antalya low-carbon ferrochromium smelter had a production capacity of about 10,000 tons per year, but production has never exceeded about 8,000 tons per year. Etibank continued construction of additional high-carbon ferrochromium production capacity at its Elâzig plant, located about 380 miles by rail from the Port of Iskenderun at Elâzig, Guleman. The original plant contained two 17-megavolt-ampere furnaces that, together, gave the plant about 50,000 tons per year of high-carbon ferrochromium production capacity. The two new furnaces, together, representing an additional 100,000 tons per year of capacity, were built by Elkem (Norway). Plant process equipment was supplied by Outokumpu Oy (Finland), and construction was by Voest-Alpine AG (Austria). The new furnaces were to be fed sintered and rotary-kiln-prereduced ore. Production from the new furnaces was expected to start in 1988. Production from the new furnaces at Elâzig was expected to consume most of Turkey's currently excess metallurgical chromite production.

Yugoslavia.—Hek Jugohrom converted a 24-megavolt-ampere furnace from high-carbon ferrochromium to ferrosilicon production and planned also to convert a 14-megavolt-ampere furnace. Jugohrom continued production of low-carbon ferrochromium from three 8-megavolt-ampere furnaces that had an annual production capacity of about 13,000 tons. Dalmacija Carbide and Ferro Alloy Works converted a ferrosilicon furnace to high-carbon ferrochromium, adding 30,000 to 39,000 tons per year of production capacity.

Zimbabwe.—Zimbabwe reported 1986 chromite production of 609,694 tons, up from 1985 production of 580,350 tons. Twenty-three chromite mining cooperatives have been developed in Zimbabwe, aided by Zimbabwe Mining Development Corp. and the Department of Mining Engineering in the Ministry of Mines. The cooperative mines accounted for about 35,000 tons of production in 1986, supplying Zimbabwe Alloys Ltd. (Zimalloys) with about 27% of its needs and Zimbabwe Mining and Smelting Co. (ZIMASCO) with about 12% of its needs. The Ministry of Mines, Zimalloys, and Union Carbide Zimbabwe (Pvt.) Ltd. entered a joint venture to test specialized mining equipment designed for the narrow north section of the Great Dyke seam.

ZIMASCO started construction of an induction remelting furnace that was to add about 17,000 tons of production capacity to its current 180,000 tons per year of high-carbon ferrochromium production capacity. The new induction remelting furnace was expected to be completed and in operation in 1989. ZIMASCO planned to restart a 12.5-megavolt-ampere furnace in 1988. That furnace has a 17,000-ton-per-year high-carbon ferrochromium production capacity and was typically held in reserve for use when other furnaces were under repair.

Zimalloys converted its S1 furnace from ferrochromium-silicon to high-carbon ferromanganese production.

Table 16.—Chromite: World production, by country[1]

(Thousand short tons, gross weight)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Albania[e]	755	794	909	940	915
Brazil[3]	[r]178	[r]287	209	[r e]220	250
Cuba[4]	37	41	[e]40	[r e]120	135
Finland[4]	271	492	558	747	785
Greece[5]	30	68	65	[e]68	70
India	397	466	617	679	575
Iran	53	65	62	[r e]62	62
Japan	9	8	13	12	13
Madagascar	50	66	140	91	110
New Caledonia	101	93	87	80	68
Oman	[e]26	8	--	7	7
Pakistan	7	3	6	9	9
Philippines	294	288	300	[e]202	190
South Africa, Republic of[4 6]	[r]2,718	3,756	4,077	4,307	4,175
Sudan[e]	22	22	[7]10	9	9
Turkey	381	537	649	599	660
U.S.S.R.[e 8]	3,240	3,240	3,240	[r]3,470	3,470
Vietnam[e]	18	18	17	17	17
Zimbabwe	463	525	591	588	595
Total	[r]9,050	[r]10,777	11,590	12,227	12,115

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through May 6, 1988.
[2]In addition to the countries listed, Bulgaria, China, and North Korea may also produce chromite, but output is not reported quantitatively and available general information is inadequate for formulation of reliable estimates of output levels. Figures for all countries represent marketable output unless otherwise noted.
[3]Figures are sum of (1) crude ore sold directly for use and (2) concentrate output, both as reported in Brazilian sources. Total run-of-mine crude ore production (not comparable to data for other countries) was as follows, in thousand short tons: 1983—517; 1984—782; 1985—802; 1986—810 (revised, estimated); and 1987—830 (estimated).
[4]Direct-shipping lump ore plus concentrates and foundry sand.
[5]Exports of direct-shipping ore plus production of concentrates.
[6]Includes production by Bophuthatswana, which was as follows, in thousand short tons: 1983—258 (revised); 1984—442; 1985—395; 1986—500; and 1987—496 (estimated).
[7]Reported figure.
[8]Estimates for 1985 and 1987 are based in part on crude chromium ore output reported in Soviet sources as 3,704 and 3,968 thousand short tons, respectively.

TECHNOLOGY

The Bureau of Mines reviewed, evaluated, and compiled thermodynamic data on chromium monosulfide and dichromium trisulfide.[4] The Bureau investigated the carbonyl process in techniques for the recovery of chromium from domestic primary and secondary sources. Chromium metal was subjected to a carbonylization test, and carbonylization metal extraction was applied to stainless steel, stainless steel slag, and superalloy scrap and grinding waste.[5]

The LG-6 chromitite layer of the Bushveld Complex was studied. It was found that spiral separation of chromite from host rock concentrated the PGM content of the tailings. For those operations that mine the LG-6 seam and spiral-concentrate the ore, there may be sufficient concentration of PGM in chromite mine tailings to support PGM recovery.[6] Chromite mining technology developed at the Kokkinorotsos deposit of the Hellenic Mining Co. in Cyprus was reported. Cemented hydraulic fill was adopted at the Kokkinorotsos Mine to compensate for unstable and potentially dangerous host rock. The technique provided greater flexibility in mine design and greater ore recovery.[7]

The thermodynamics of chromite ore smelting were studied. Reaction mechanism and rates were proposed, and carbon contents of up to 60% chromium were calculated.[8] A smelting reduction process was being developed. Chromite smelting was achieved in an experimental blast furnace, and a pilot plant was built.[9] Development of the ferrochromium industry was studied. High-carbon ferrochromium producers were found to have been driven by quality and cost requirements to operate at high efficiency and to develop new processess that are energy efficient and use inexpensive raw materials.[10] Steel industry trends were studied as they affected ferrochromium production. Process control resulted in the use of high-carbon ferrochromium as charge material and low-carbon ferrochromium as a trimming material. That trend, with the associated decline in use of medium-carbon ferrochromium, was expected to continue.[11]

Plasma smelting technology applied to chromium ferroalloy production was reviewed, and the MSA and PlasmaChrome processess were discussed. Advantages claimed for the plasma smelting process included decreased electrode consumption, less critical selection of feed, wide selection of carbon reductants, wide range of slag composition, improved process control, continuous-feeding operation, and less noise.[12] Ferrochromium production started at SwedeChrome using a plasma-torch-heated shaft furnace. Successful operation of the MSA direct current electric arc plasma furnace at 16 megavolt-amperes resulted in Middelburg's decision to increase furnace capacity to about 40 megavolt-amperes.

The Bureau of Mines studied the use of chromium-free steel to substitute for high-tonnage heat-treatable alloy steels used to manufacture gears, shafts, and other machine parts. Manganese and molybdenum were used in place of chromium to achieve hardenability and transformation characteristics comparable to those of chromium steels used for the same purpose. The chromium-free steel could be produced without changing manufacturing procedures or equipment.[13] The Bureau studied crack propagation and spalling of white cast iron balls. The mechanism of spalling in 3 high-chromium white cast irons subject to 10 different heat treatments was determined.[14] The substitution of manganese for chromium in high-speed tool steels was studied; only 1% manganese could be tolerated before performance was compromised.[15]

The National Aeronautics and Space Administration studied the importance of chromium to superalloys. Chromium content was increased from about 20% to about 25% to achieve greater grain oxidation resistance. However, the higher chromium content was perceived to have a deleterious effect on strength. As a result chromium was reduced to about 10% in favor of aluminum for oxidation resistance. The reduced chromium content led to the onset of hot corrosion-enhanced oxidation from sodium and sulfur.[16]

The position of the Western European ferrochromium industry was studied. The character of chromium ore supply and the transportation cost advantage of chromite-producing countries were identified. To ensure long-term supply competitiveness, ferrochromium producers in nonchromite-producing countries had to offset their transportation cost disadvantage through lower cost electrical energy supply, greater energy recovery, greater chromium yield, and/or transportation advantage to the end user market.[17]

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[2]All tonnages are in short tons unless otherwise specified.

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Clays

By Sarkis G. Ampian[1]

Total quantity of clays sold or used by domestic producers increased 7% in tonnage and 10% in value to a new record high $1.20 billion. This increase in production continues the upward trend in clay output for 5 of the last 6 years. Clays in one or more of six classification categories—ball clay, bentonite, common clay and shale, fire clay, fuller's earth, or kaolin—were produced in 44 States and Puerto Rico. Clay production was not reported in Alaska, Delaware, the District of Columbia, Hawaii, Rhode Island, Vermont, or Wisconsin. The leading producing States, in descending order, were Georgia, Texas, North Carolina, Ohio, Alabama, California, and Wyoming. Unpredictable differences in the costs of fuels such as coal, gas, and oil, were still a major concern to clay producers and manufacturers trying to reduce operating costs. Industrywide efforts to economize and obtain alternative competitive fuels, as well as to modernize, were commonplace during 1987. Environmental restrictions and accompanying costs, combined with rising capital costs at yearend, began to slow production.

Production of common clay and shale increased because of an upturn in construction. This upturn was due to low prevailing interest rates and to an improving business climate for most of the year, both of which increased demand for clay building materials. Construction activity, traditionally slow during the last quarter, was further slowed by increases in the prime lending rate. An exception to the Nation's overall buoyant construction industry was noted in the oil-producing States of the Southwest. There, declining revenues depressed overall residential, business, and Government activity. However, steady oil prices and an increased number of operating oil and gas rigs increased optimism in the area during the last quarter, apparently ending the area's malaise.

Increases in production of specialty clays resulted from an improvement in the overall economy and a strong export demand attributed to the weakening U.S. dollar. The declining steel, oil and gas exploration, and foundry industries, all major consumers of specialty clays, had adjusted to their lowest levels of production and prepared to take advantage of both the strong export demand and improved domestic economy.

Table 1.—Salient U.S. clays and clay products statistics[1]

(Thousand short tons and thousand dollars)

	1983	1984	1985	1986	1987
Domestic clays sold or used by producers:					
Quantity	40,858	43,702	44,974	44,620	47,657
Value	$931,092	$1,032,127	$1,011,377	$1,095,179	$1,202,284
Exports:					
Quantity	2,484	2,699	2,780	2,913	3,332
Value	$254,237	$295,733	$309,871	$351,161	$512,964
Imports for consumption:					
Quantity	21	32	41	38	38
Value	$3,488	$4,868	$5,981	$7,501	$9,392
Clay refractories shipments: Value	$595,299	$782,308	$629,738	$529,268	$617,493
Clay construction products shipments: Value	$1,160,543	$1,342,196	$1,427,851	$1,601,640	$1,782,023

[1]Excludes Puerto Rico.

Kaolin accounted for 18% of clay production but 64% of clay value. Kaolin production of 8.8 million short tons and exports of 2.0 million tons were record highs. Ball clay and fuller's earth production matched past record-high years.

Domestic Data Coverage.—Domestic production data for clays are developed by the Bureau of Mines from one voluntary survey of U.S. operations. Of the 1,131 operations covered by the survey, 1,116 responded, representing 99% of the total clay and shale production sold or used and shown in table 1.

Table 2.—Clays sold or used by producers in the United States in 1987, by State[1]

(Short tons unless otherwise specified)

State	Ball clay	Bentonite	Common clay and shale	Fire clay	Fuller's earth	Kaolin	Total	Total value
Alabama	--	W	2,071,690	126,840	--	40,441	[2]2,238,971	[2]$16,216,547
Arizona	--	28,530	189,621	--	--	--	218,151	1,905,317
Arkansas	--	--	706,185	--	--	202,209	908,394	8,651,462
California	--	116,293	2,092,234	--	--	87,805	2,296,332	33,045,543
Colorado	--	100	289,002	--	--	2,948	292,050	1,763,455
Connecticut	--	--	W	--	--	--	W	W
Florida	--	--	127,518	--	431,147	38,522	597,187	39,496,244
Georgia	--	--	2,439,686	--	591,234	7,423,820	10,454,740	756,093,514
Idaho	--	W	W	--	--	8,944	21,781	229,835
Illinois	--	--	232,949	--	W	--	[3]232,949	[3]977,048
Indiana	--	--	1,036,669	W	--	--	[4]1,036,669	[4]4,055,534
Iowa	--	--	472,788	--	--	--	472,788	1,494,770
Kansas	--	W	603,680	--	--	--	[2]603,680	[2]2,575,572
Kentucky	W	--	883,267	W	--	--	[3 4]1,030,518	[3 4]8,820,874
Louisiana	--	--	356,904	--	--	--	356,904	9,191,774
Maine	--	--	W	--	--	--	W	W
Maryland	--	--	383,054	--	--	--	383,054	1,939,968
Massachusetts	--	--	W	--	--	--	W	W
Michigan	--	--	1,333,498	--	--	--	1,333,498	5,338,433
Minnesota	--	--	W	--	--	W	W	W
Mississippi	W	278,871	559,955	--	W	--	1,123,325	26,932,947
Missouri	--	--	1,139,749	336,088	W	--	[3]1,475,837	[3]10,414,581
Montana	--	--	28,879	W	--	--	[4]28,879	[4]98,270
Nebraska	--	--	223,728	--	--	--	223,728	721,059
Nevada	--	11,799	--	--	W	W	65,424	2,468,190
New Hampshire	--	--	W	--	--	--	W	W
New Jersey	--	--	W	5,985	--	--	[5]5,985	[5]139,768
New Mexico	--	--	50,350	898	--	--	51,248	141,110
New York	--	--	672,635	--	--	--	672,635	3,562,468
North Carolina	500	--	3,173,037	--	--	55,516	3,229,053	15,282,025
North Dakota	--	--	50,101	--	--	--	50,101	99,701
Ohio	--	--	2,895,970	291,300	--	--	3,187,270	12,713,992
Oklahoma	--	--	797,301	--	--	--	797,301	1,782,741
Oregon	--	18,147	249,677	--	--	--	267,824	985,880
Pennsylvania	--	--	1,182,748	23,373	--	W	[6]1,206,121	[6]4,750,713
Puerto Rico	--	--	148,029	--	--	--	148,029	317,751
South Carolina	--	--	1,244,886	--	139,194	809,460	2,193,540	[3]38,243,426
South Dakota	--	--	W	--	--	--	W	W
Tennessee	691,570	--	569,303	--	W	--	[3]1,260,873	[3]25,480,282
Texas	W	27,547	3,283,652	4,225	W	W	3,474,976	25,959,476
Utah	--	29,000	286,154	--	--	--	315,154	1,958,941
Virginia	--	--	1,171,442	--	W	--	[3]1,171,442	[3]6,291,100
Washington	--	--	412,031	3,562	--	--	415,593	2,355,954
West Virginia	--	--	266,037	--	--	--	266,037	564,574
Wyoming	--	2,127,645	W	--	--	--	[5]2,127,645	[5]62,031,122
Undistributed	291,735	168,301	703,316	11,280	895,216	157,545	[7]1,569,629	[7]67,509,912
Total	983,805	2,806,233	32,327,725	803,551	2,056,791	8,827,210	47,805,315	1,202,601,873

W Withheld to avoid disclosing company proprietary data; included with "Total" and/or "Undistributed."
[1]Includes Puerto Rico.
[2]Excludes bentonite.
[3]Excludes fuller's earth.
[4]Excludes fire clay.
[5]Excludes common clay.
[6]Excludes kaolin.
[7]Incomplete total; difference included with individual State totals.

Table 3.—Number of mines[1] from which producers sold or used clays in the United States in 1987, by State

State	Ball clay	Bentonite	Common clay and shale	Fire clay	Fuller's earth	Kaolin	Total
Alabama	--	1	22	5	--	9	37
Arizona	--	5	5	--	--	--	10
Arkansas	--	--	17	--	--	6	23
California	1	5	68	--	--	5	79
Colorado	--	1	32	8	--	--	41
Connecticut	--	--	2	--	--	--	2
Florida	--	--	3	--	4	1	8
Georgia	--	--	16	--	8	86	110
Idaho	--	1	2	1	--	2	5
Illinois	--	--	10	--	2	--	12
Indiana	--	--	16	--	--	2	18
Iowa	--	--	10	--	--	--	10
Kansas	--	1	18	--	--	--	19
Kentucky	6	--	11	2	--	--	19
Louisiana	--	1	8	--	--	--	9
Maine	--	--	3	--	--	--	3
Maryland	1	--	7	--	--	--	8
Massachusetts	--	--	3	--	--	--	3
Michigan	--	--	5	--	--	--	5
Minnesota	--	--	1	--	--	2	3
Mississippi	1	6	20	--	1	--	28
Missouri	--	--	12	42	2	1	57
Montana	--	9	5	1	--	--	15
Nebraska	--	--	5	--	--	--	5
Nevada	--	6	--	--	--	2	8
New Hampshire	--	--	1	--	--	--	1
New Jersey	--	--	1	1	--	--	2
New Mexico	--	--	4	2	--	--	6
New York	1	--	10	--	--	--	11
North Carolina	--	--	54	--	--	2	56
North Dakota	--	--	3	--	--	--	3
Ohio	--	--	58	15	--	--	73
Oklahoma	--	--	18	--	--	--	18
Oregon	--	12	8	--	--	--	20
Pennsylvania	--	--	36	11	--	1	48
South Carolina	--	--	30	--	3	18	51
South Dakota	--	1	1	--	--	--	2
Tennessee	17	--	7	--	3	--	27
Texas	1	11	64	2	1	1	80
Utah	--	3	18	--	1	--	22
Virginia	--	--	15	--	1	--	16
Washington	--	--	10	3	--	--	13
West Virginia	--	--	3	1	--	--	4
Wyoming	--	137	2	--	--	--	139
Total	28	200	646	93	26	138	1,131

[1]Includes both active and idle operations.

DOMESTIC PRODUCTION, PRICES, AND FOREIGN TRADE, BY TYPE OF CLAY

KAOLIN

Domestic production of kaolin increased 3% to 8.8 million tons, while its reported value increased more than 11% to $775.3 million. Both the reported output and value, for the second consecutive year, reached record highs. Kaolin, in general, and filler grades, in particular, have enjoyed steady increases in demand for the past 15 years, with output rising from 6.0 million tons in 1973 to this year's record-high tonnage of 8.8 million. The average unit value for all grades of kaolin rose about 8% to $87.83 per ton. Kaolin was produced in 13 States, with Georgia and South Carolina accounting for 93% of total production. Arkansas, California, and North Carolina were the other three major producing States. Both Arkansas and California produce refractory- and chemical-grade kaolins. Kaolin producers reported major domestic end uses for their clay as follows: paper coating, 35%; paper filling, 19%; refractories, 8%; fiberglass and insulation, 6%; face brick, 5%; rubber, 4%; and chemicals, 3%.

Kaolin is 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.

Kaolin production was spurred by the continuing growth of the overall economy, particularly increased paper production. Strong demands for paper-, catalyst-, plastic-, and paint-calcined grades, combined with a strong export demand due to the weakening U.S. dollar, led the way. Capacity increases in both washed and calcined grades of the early 1980's were insufficient, at times, to meet demand. Further capacity expansions were either under way or planned by many producers to meet the anticipated demands of the catalyst, paint, paper, and plastic manufacturers. Kaolin sales for refractories appeared to have rebounded slightly at yearend. Increased demand for high-alumina, kaolin-base refractory bricks and specialties by the cement, foundry, and steel industries was mostly responsible. The refractory industry had fully adjusted to new lower levels of production brought about by changes in steelmaking and refractories technology and imports. Production of the three paper-grade kaolins increased in 1987 nearly 11% from 5.3 to 5.9 million tons. Delaminated, water-washed, and low-temperature calcined production increased 16%, 11%, and 6%, respectively.

All Georgia and South Carolina kaolin filler-extender-pigment producers, both air-floated and water-washed, continued to modernize to reduce operating costs and to produce higher valued products. Emphasis continued to be on energy-related costs and on expanding the production capabilities for calcined pigment lines used chiefly by the growing catalyst, paint, paper, plastics, and rubber industries. In this regard, kaolin expansions in Georgia were announced by Engelhard Corp.'s Specialty Chemicals Div. and Anglo-American Clays Corp. (a subsidiary of English China Clays (ECC) America Inc.). At yearend, Thiele Kaolin Co. Inc., Engelhard, broke ground for an $80 million expansion of its calcined kaolin products manufacturing facilities in McIntyre and Gordon. Expected to be completed in late 1988, the enlargement will provide 300,000 tons per year (tpy) of additional calcined and ancillary support equipment. Anglo-American Clays completed its fourth calciner at its Sandersville complex, which will enable it to increase calcined kaolin output by more than 65%. Thiele Kaolin, also in Sandersville, started a $50 million expansion to begin production of calcined kaolin grades. Plans also called for extra mining and processing capabilities to support the new calcining operation. In noncalcined kaolin developments, a newly installed ozone bleaching facility owned by Nord Kaolin Co., a subsidiary of Nord Resources Corp., became fully operational during the year in Jeffersonville. Ozone bleaching is designed primarily to increase reserves by treating otherwise unusable crude gray kaolin clays. Georgia Kaolin Co., a subsidiary of Combustion Engineering Inc., requested permits to use gas-turbine exhausts from cogeneration projects in its spray-dryers at the American Industrial Clay Co. plant in Deepstep. If the permits are granted and the trials are successful on currently installed sprayer baghouses, it will signal a new approach to reducing a major industrywide operating cost. Katalistiks International, a subsidiary of Union Carbide Corp., acquired land in Savannah to set up a new operation for manufacturing a second-generation line of fluid cracking catalysts (FCC) to complement its existing mix of catalysts, supports, and molecular sieves. In a reorganization, Cyprus Minerals Co. Inc. merged four groups of its industrial minerals division into a single unit. Presently, Cyprus Industrial Minerals has three operating companies, one of which produces a full line of soft and hard kaolins in Sandersville and Aiken, SC, respectively.

In development work, Georgia Kaolin undertook a drilling-feasibility study to determine if the quality and quantity of the reserves warranted a kaolin processing facility in Redwood Falls, MN. Nova Natural Resources Inc., also in Minnesota, canceled its request for a permit to operate a kaolin mine in Honner Township. Nova, although still interested in the kaolin project, planned to work jointly with the Northwestern Portland Cement Co.'s kaolin pit. Northwestern presently uses about 50,000 tpy of kaolin in cement production.

Aided by a weakening U.S. dollar and despite strong foreign competition, exports of kaolin, reported as clays by the U.S. Department of Commerce, increased nearly 28% to 2.03 million tons valued at $340 million. The unit value of the exported clay increased to $168.05, or nearly 25% more than that of 1986, indicating that a higher percentage of premium-quality grades was shipped. Kaolin, including calcined material was exported to 56 countries, 17 less than in 1986. The 17 countries were mostly small importers. The major recipients, in descending order, were Japan, Canada, Italy, the Netherlands, and Mexico. Exports from Finland and Italy increased more than 300% and 50%, respectively. Imports to Finland in the past have been largely from the United Kingdom. Kaolin producers reported end uses for their exports as follows: paper coating, 71%; paper-filling, 18%; rubber, 5%; paint, 2%; and other, including ceramics, plastics, and refractories, the remainder.

Kaolin imports for consumption increased slightly to 10,524 tons valued at $1.4 million. The unit price of kaolin imported from the United Kingdom, the leading source country, rose more than 14% to $129.22 per ton, reflecting the strong worldwide demand for kaolins. China shipped kaolin to domestic consumers for the first time since these statistics were published. Neither the quality nor the grade of the clay was discernible.

Kaolin prices quoted in trade journals generally advanced during the year. Chemical Marketing Reporter, December 28, 1987, quoted prices as follows:

Water-washed, fully calcined, bags, carload lots, f.o.b. Georgia, per ton	[1]$260.00
Calcined, paper-grade, same basis, per ton	350,00
Paper-grade, uncalcined, bulk, carload lots, f.o.b. Georgia, per ton:	
No. 1 coating	98.00
No. 2 coating	76.00
No. 3 coating	73.00
No. 4 coating	[1]73.00
Filler, general purpose, same basis per ton	[1]59.00
Delaminated, water-washed, uncalcined, paint-grade, 1-micrometer average, same basis, per ton	[1]250.00
Dry-ground, air-floated, soft, same basis, per ton	38.00
National Formulary, powder, colloidal, bacteria controlled, 50-pound bags, 5,000-pound lots, per pound	.25

[1]Average of quoted prices.

Table 4.—Kaolin sold or used by producers in the United States, by State

State	1986		1987	
	Short tons	Value	Short tons	Value
Alabama	80,371	$2,396,169	40,441	$1,617,084
Arkansas	190,785	7,152,537	202,209	7,011,203
California	95,048	2,371,925	87,805	3,082,079
Colorado	--	--	2,948	149,586
Florida	35,414	2,771,146	38,522	3,089,946
Georgia	6,778,492	635,219,813	7,423,820	713,524,435
Idaho	1,644	W	8,944	W
Missouri	4,676	47,134	--	--
North Carolina	51,000	1,442,490	55,516	1,516,127
South Carolina	1,063,088	35,588,061	809,460	35,516,618
Other[1]	248,964	8,859,945	157,545	9,784,815
Total	8,549,482	695,849,220	8,827,210	775,291,893

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Includes Minnesota, Nevada, Pennsylvania, Texas, and data indicated by symbol W.

Table 5.—Kaolin sold or used by producers in the United States, by kind

Kind	1986		1987	
	Short tons	Value	Short tons	Value
Air-float	1,454,675	$78,092,960	1,571,742	$74,028,189
Calcined[1]	1,185,088	166,701,281	1,204,459	202,977,802
Delaminated	915,641	56,809,167	1,057,857	103,533,884
Unprocessed	1,121,499	14,712,850	713,415	14,695,875
Water-washed	3,872,579	379,532,962	4,279,737	380,056,143
Total	8,549,482	695,849,220	8,827,210	775,291,893

[1]Includes both low-temperature filler and high-temperature refractory grades.

Table 6.—Calcined kaolin sold or used by producers in the United States, by State

State	High-temperature		Low-temperature	
	Short tons	Value	Short tons	Value
1986				
Alabama and Georgia	478,144	$33,273,985	[1]470,149	[1]$119,288,257
Other	[2]184,244	[2]8,485,118	[3]52,551	[3]5,653,921
Total	662,388	41,759,103	522,700	124,942,178
1987				
Alabama and Georgia	468,809	33,765,315	[1]495,749	[1]154,237,336
Other	[2]180,669	[2]8,124,229	[3]59,232	[3]6,850,922
Total	649,478	41,889,544	554,981	161,088,258

[1]Excludes Alabama.
[2]Includes Arkansas, California (1987), Colorado (1987), Idaho, Missouri (1986).
[3]Includes Pennsylvania and Texas.

Table 7.—Georgia kaolin sold or used by producers, by kind

Kind	1986		1987	
	Short tons	Value	Short tons	Value
Air-float	913,849	$35,111,526	976,909	$38,330,548
Calcined[1]	915,581	159,331,295	924,117	186,385,567
Delaminated	915,641	56,809,167	1,057,857	103,533,884
Unprocessed	210,336	7,297,076	235,591	8,176,477
Water-washed	2,823,085	376,670,749	4,229,346	377,097,959
Total	6,778,492	635,219,813	7,423,820	713,524,435

[1]Includes both low-temperature filler and high-temperature refractory grades.

Table 8.—Georgia kaolin sold or used by producers, by use

(Short tons)

Use	1986 Air-float	1986 Unprocessed[1]	1986 Water-washed[2]	1986 Total	1987 Air-float	1987 Unprocessed[1]	1987 Water-washed[2]	1987 Total
Domestic:								
Adhesives	26,438	--	23,978	50,416	26,812	--	19,967	46,779
Aluminum sulfate and other chemicals	--	110,000	--	110,000	--	150,947	--	150,947
Animal feed	30,012	--	--	30,012	33,950	--	--	33,950
Asphalt tile and linoleum	13,512	--	43	13,555	15,558	--	--	15,558
Catalysts (oil refining)	46,016	--	17,153	63,169	20,492	--	45,393	65,885
Face brick	--	--	18,930	18,930	--	18,132	2	18,134
Fiberglass and mineral wool	168,994	--	61,045	230,039	214,444	--	59,253	273,697
Fine china and dinnerware; crockery and earthenware	20,510	1,377	--	21,887	22,732	--	--	22,732
Firebrick, blocks and shapes	62,565	2,723	95	65,383	59,277	8,368	--	67,645
Grogs and calcines, refractory	--	252,709	464	253,173	20,225	420,000	469	440,694
Medical, pharmaceutical, cosmetic	--	--	1,291	1,291	406	--	1,063	1,469
Paint	12,787	--	207,203	219,990	15,572	--	237,768	253,340
Paper coating	--	--	2,313,664	2,313,664	--	--	2,485,279	2,485,279
Paper filling	178,920	--	1,153,431	1,332,351	212,544	--	1,114,071	1,326,615
Plastics	3,600	--	37,397	40,997	425	--	47,742	48,167
Pottery	31,497	689	--	32,186	61,186	--	--	61,186
Refractories[3]	39,091	31,699	8,151	78,941	1,555	28,848	5,014	35,417
Roofing granules	26,249	--	--	26,249	7,313	--	22	7,335
Rubber	31,011	--	20,656	51,667	28,062	--	31,320	59,382
Sanitary ware	128,918	11,705	6,442	147,065	56,511	--	--	56,511
Miscellaneous, air-float:								
Common brick, fertilizers, gypsum products, pesticides and related products, roofing and structural tile, other uses not specified	48,212	--	--	48,212	112,176	--	--	112,176
Miscellaneous, unprocessed:								
Fertilizers, pesticides and related products, other uses not specified	--	54,866	--	54,866	--	37,664	--	37,664
Miscellaneous, water-washed:								
Gypsum products, ink, pesticides and related products, waterproofing and sealing, fertilizers, other uses not specified	--	--	170,388	170,388	--	--	197,958	197,958
Total	868,332	465,768	4,040,331	5,374,431	909,240	663,959	4,245,321	5,818,520

See footnotes at end of table.

Table 8.—Georgia kaolin sold or used by producers, by use —Continued

(Short tons)

Use	1986				1987			
	Air-float	Unprocessed[1]	Water-washed[2]	Total	Air-float	Unprocessed[1]	Water-washed[2]	Total
Exports:								
Paint	124	--	112,446	112,570	127	--	31,985	32,112
Paper coating	27,386	--	776,962	804,348	28,492	--	1,154,774	1,183,266
Paper filling	5,065	--	222,479	227,544	22,390	--	284,347	306,737
Plastics	40	--	--	40	41	--	--	41
Refractories	--	190,000	--	190,000	--	--	--	--
Rubber	--	--	--	--	511	--	23,663	24,174
Undistributed	12,902	--	56,657	69,559	16,108	--	42,862	58,970
Total	45,517	190,000	1,168,544	1,404,061	67,669	--	1,537,631	1,605,300
Grand total	913,849	655,768	5,208,875	6,778,492	976,909	663,959	5,782,952	7,423,820

[1]Includes high-temperature calcined.
[2]Includes low-temperature calcined and delaminated.
[3]Includes electrical porcelain; floor and wall tile (ceramic); flue linings; high-alumina brick and specialties; glazes, glass, enamels; kiln furniture; and refractory mortar and cement.

Table 9.—South Carolina kaolin sold or used by producers, by kind

Kind	1986		1987	
	Short tons	Value	Short tons	Value
Air-float	506,705	$31,298,499	537,116	$32,017,582
Unprocessed	556,383	4,289,562	272,344	3,499,036
Total	1,063,088	35,588,061	809,460	35,516,618

Table 10.—South Carolina kaolin sold or used by producers, by kind and use

(Short tons)

Kind and use	1986	1987
Air-float:		
Adhesives	17,483	18,208
Animal feed and pet waste absorbent	3,603	3,459
Ceramics[1]	3,637	2,896
Fertilizers and pesticides and related products	6,732	20,308
Fiberglass	99,393	143,498
Paint	580	332
Paper coating and filling	8,644	18,547
Plastics	9,581	9,142
Rubber	235,142	194,283
Refractories[2]	5,693	6,073
Other uses[3]	82,743	63,970
Exports[4]	33,474	56,400
Total	506,705	537,116
Unprocessed: Face brick and other uses	556,383	272,344
Grand total	1,063,088	809,460

[1]Includes floor and wall tile, pottery, and roofing granules.
[2]Includes refractory calcines and grogs; refractory mortar and cement; high-alumina refractories; and firebrick, blocks and shapes.
[3]Includes animal oil; catalysts (oil refining); chemical manufacturing; ink, medical; sewer pipe; and unknown uses.
[4]Includes ceramics, adhesives, paper filling, pesticides and related products, and rubber.

Table 11.—Kaolin sold or used by producers in the United States, by use

(Short tons)

Use	1986 Air-float	1986 Unprocessed[1]	1986 Water-washed[2]	1986 Total	1987 Air-float	1987 Unprocessed[1]	1987 Water-washed[2]	1987 Total
Domestic:								
Adhesives	43,921	--	25,978	69,899	45,020	--	22,967	67,987
Aluminum sulfate and other chemicals	--	155,352	--	155,352	--	210,609	--	210,609
Animal feed	33,615	--	3,259	36,874	37,409	--	4,000	41,409
Brick, common and face	6,655	645,289	236	652,180	--	353,239	2	353,241
Catalysts (oil and gas refining)	107,528	--	17,153	124,681	64,261	--	47,911	112,172
Cement, portland	--	204,339	--	204,339	--	81,288	--	81,288
China and dinnerware	20,209	1,377	3,000	24,586	21,827	--	--	21,827
Crockery and other earthenware	W	W	--	W	9,164	--	--	9,164
Electrical porcelain	16,773	--	4,043	20,816	6,460	--	2,393	8,853
Fertilizers[3]	--	--	4,846	4,846	23	--	2,863	2,886
Fiberglass, mineral wool and other insulation	268,387	--	98,990	367,377	358,276	--	100,253	458,529
Firebrick, blocks and shapes	66,031	2,723	95	68,849	84,743	33,846	--	118,589
Floor and wall tile; ceramic glazes, glass, enamels	20,331	5,194	5,719	31,244	12,597	2,723	3,646	18,966
Flue linings, high-alumina brick and specialties	661	87,903	400	88,964	694	68,800	--	69,494
Foundry sand	412	--	--	412	--	--	--	--
Grogs and calcines, refractory	2,794	388,562	464	391,820	22,786	574,956	469	598,211
Gypsum products and wallboard	14,983	3,257	806	19,046	7,746	2,026	4,000	13,772
Ink	--	--	W	W	85	--	2,243	2,328
Kiln furniture, refractory mortar and cement	20,903	35,936	1,389	58,228	2,619	--	1,368	3,987
Linoleum and asphalt tile	13,512	--	4,043	17,555	16,133	--	5,089	21,222
Medical, pharmaceutical, cosmetic	1,629	--	1,291	2,920	2,178	--	1,063	3,241
Paint	13,367	3,789	233,373	250,529	15,904	3,573	267,768	287,245
Paper coating	--	--	2,315,664	2,315,664	--	--	2,487,279	2,487,279
Paper filling	187,564	--	1,153,431	1,340,995	231,091	--	1,114,071	1,345,162
Pesticides and related products	7,004	11,509	2,265	20,778	20,622	17,882	2,300	40,804
Plastics	13,181	--	37,397	50,578	9,567	--	47,742	57,309
Pottery	35,041	689	465	36,195	65,238	--	--	65,238
Roofing granules	26,868	--	1,000	27,868	7,313	--	22	7,335
Roofing and structural tile	348	--	--	348	392	--	--	392
Rubber	266,153	--	21,794	287,947	222,345	--	32,320	254,665
Sanitary ware	130,689	11,705	6,601	148,995	58,437	--	1,000	59,437
Waterproofing and sealing	--	--	W	W	--	4,950	3,724	8,674
Miscellaneous	53,017	12,481	191,833	257,331	120,275	7,334	195,971	323,580
Total	1,371,576	1,570,105	4,135,535	7,077,216	1,443,205	1,361,226	4,350,464	7,154,895

Exports:								
Ceramics	13,337	--	5,804	19,141	9,760	--	--	9,760
Foundry sand, grogs and calcines; other refractories	1,700	212,000	--	213,700	1,849	--	--	1,849
Paint	124	--	118,087	118,211	127	--	35,985	36,112
Paper coating	27,386	--	776,962	804,348	28,492	--	1,154,774	1,183,266
Paper filling	5,120	--	222,479	227,599	22,441	--	284,347	306,788
Plastics	40	--	--	40	41	--	--	41
Rubber	31,403	--	19,863	51,266	55,359	--	23,663	79,022
Miscellaneous	3,989	1,782	32,190	37,961	10,468	1,667	43,342	55,477
Total	83,099	213,782	1,175,385	1,472,266	128,537	1,667	1,542,111	1,672,315
Grand total	1,454,675	1,783,887	5,310,920	8,549,482	1,571,742	1,362,893	5,892,575	8,827,210

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous."
[1]Includes high-temperature calcined.
[2]Includes low-temperature calcined and delaminated.
[3]Includes soil conditioners and mulches.

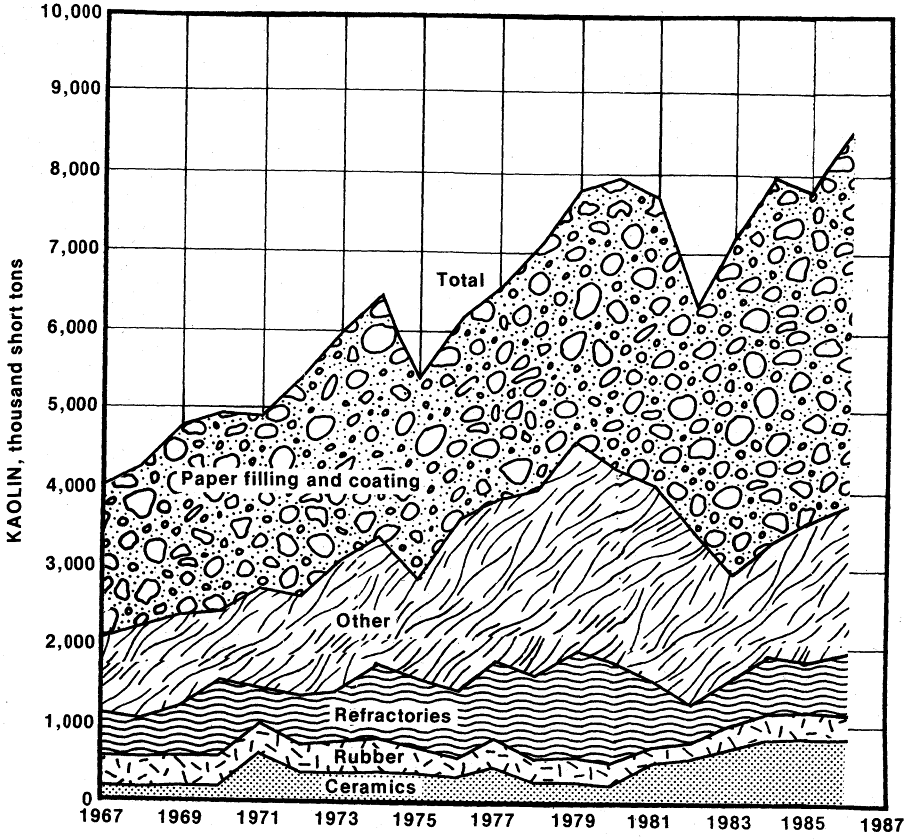

Figure 1.—Kaolin sold or used by domestic producers for specified uses.

BALL CLAY

Production of domestic ball clay increased nearly 11% to approximately 984,000 tons valued at about $36 million. The 1987 production figure is only 3,000 tons under the record-high output of 987,000 tons reported in 1979. Tennessee provided about 70% of the Nation's output, followed, in descending order of production, by Kentucky, Mississippi, Texas, and North Carolina. Production increased in all the major producing States. The growth of the water-slurried Tennessee ball clay demand, combined with the number of producers, now permits publication of selected production statistics. The principal ball clay markets were ceramics, mostly dinnerware, pottery, sanitary ware, and wall tile. Domestic producers continued to enjoy a strong export market usually about 20% of total production, spurred by a weakening U.S. dollar. Continued recovery of the domestic industry, encouraged by competitive interest rates, mortgages, and the improved overall economy during the first three-quarters of the year, increased the demand for ball clays.

Ball clay is a plastic, white-firing clay used principally for bonding in ceramic ware. The clay is of sedimentary origin and consists mainly of the clay mineral kaolinite and sericite mica.

Increased production capacities, modernizations, and/or new plant construction continued cautiously during the year. Ball clay producers either were slowly increasing their capabilities to produce, blend, store, and ship (mostly by slurry-tank rail car) water-slurried clay for ceramic markets or were switching to this capability. In this context, Kentucky-Tennessee Clay Co., Mayfield, KY, created a new slurry by blending and combining the properties of Kentucky clays with those of the existing Tennessee clay slurries. These clays were specifically designed to meet the demands of increasing automation in the ceramic tile industry. H. C. Spinks Clay Co. Inc., Gleason, TN, announced a one-third expansion of storage facilities for its ball clay slurry plant in Gleason to meet increasing demand. In addition, Spinks introduced a statistical process control (SPC) procedure designed to enhance the consistency and quality of its products. The SPC system involves the use of an extensive computer network to monitor key processes and mineral quality parameters.

The average unit value for ball clay reported by domestic producers decreased 7% to $36.09. Chemical Marketing Reporter, December 28, 1987, listed ball clay prices, unchanged from those of 1986, as follows:

Domestic, air-floated, bags, carload lots, Tennessee, per ton	$49.00
Domestic, crushed, moisture-repellent, bulk carload lots, Tennessee, per ton	24.00

Ball clay exports increased more than 11% to 179,000 tons valued at $6.3 million. Unit value decreased nearly 8% to $35.05 from $38.18 per ton, reflecting a larger percentage of lower valued clays. Shipments were made to 27 countries, 1 more than in 1986. The major recipients, in descending order, were Mexico, Canada, and the Philippines. The expanding Mexican ceramic markets continued to be supplied by domestic clay because of international financial difficulties. Mexican ceramic exports, predominantly to the United States, are fabricated largely with U.S. and domestic clays.

Ball clay imports for consumption, beneficiated and not beneficiated, almost entirely from the United Kingdom, decreased about 41% to 1,759 tons valued at $239,000. The unit value of these clays increased more than 30% to $135.87 per ton, indicating an increasing percentage of the higher valued beneficiated varieties than in previous years.

Table 12.—Ball clay sold or used by producers in the United States, by State

State	Air-float		Water-slurried		Unprocessed		Total	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
1986								
Tennessee	[1]426,150	[1]$18,896,723	W	W	189,499	$5,025,280	615,649	$23,922,003
Other	[2]266,380	[2]10,521,659	W	W	[3]5,143	[3]144,271	271,523	10,665,930
Total	692,530	29,418,382	W	W	194,642	5,169,551	887,172	34,587,933
1987								
Tennessee	374,405	15,230,434	108,473	$3,749,623	208,692	5,047,865	691,570	24,027,922
Other[4]	229,632	9,528,799	W	W	W	W	[5]292,235	[5]11,474,807
Total	604,037	24,759,233	108,473	3,749,623	208,692	5,047,865	[5]983,805	[5]35,502,729

W Withheld to avoid disclosing company proprietary data.
[1]Includes water-slurried.
[2]Includes Kentucky, Maryland, Mississippi, and Texas.
[3]Includes California, Kentucky, and Mississippi.
[4]Includes Kentucky, Mississippi, North Carolina, and Texas.
[5]Includes data indicated by symbol W.

Table 13.—Ball clay sold or used by producers in the United States, by use

(Short tons)

Use	1986			1987			
	Air-float[1]	Unprocessed	Total	Air-float[1]	Water-slurried	Unprocessed	Total
Ceramics[2]	43,943	--	43,943	38,790	--	--	38,790
Fillers, extenders, binders[3]	68,817	5,767	74,584	125,070	--	3,924	128,994
Floor and wall tile	98,605	29,700	128,305	77,950	10,590	55,893	144,433
Pottery[4]	17,508	65,841	244,349	148,354	234	76,612	225,200
Refractories[5]	21,340	13,703	35,043	40,493	--	18,350	58,843
Sanitary ware	94,933	54,543	149,476	16,082	95,451	66,918	178,451
Miscellaneous	85,856	11,680	97,536	26,021	--	41,159	67,180
Exports	100,528	13,408	113,936	131,277	2,432	8,205	141,914
Total	692,530	194,642	887,172	604,037	108,707	271,061	983,805

[1]Includes water-slurried.
[2]Includes catalyst (oil refining); fiberglass; glazes, glass, and enamels.
[3]Includes adhesives (1986); animal feed; asphalt emulsions (1987); asphalt tile; paper coating and filling (1986); pesticides and related products; rubber; wallboard (1987); and other uses not specified.
[4]Includes crockery and other earthenware; and fine china and dinnerware.
[5]Includes electrical porcelain; firebrick, blocks and shapes; grogs and calcines (1986); high alumina brick and specialties; and kiln furniture (1986).

FIRE CLAY

Fire clay sold or used by domestic producers increased about 35% in production and value over that of 1986 (which had the lowest reported figures in more than 10 years) to nearly 804,000 tons and $16.8 million, respectively. This increase marked the first major upturn in production in nearly 5 years and was attributed largely to the upswing in the overall economy, exports, and the recovering smokestack industries, which consumed the bulk of manufactured fire clay refractories and clays. Fire clay production declined from the record high of the early 1970's of approximately 4 million tons, to about 2 million tons in the early 1980's, and eventually to the low 1986 amount. Fire clay is detrital material, either plastic or rocklike, containing low percentages of alkalies, iron oxide, lime, and magnesia to enable the material to withstand temperatures of 1,500° C or higher. It is basically kaolinite but usually contains other materials such as ball clay, bauxite clay, diaspore, and shale. Fire clays commonly occur as underclay below coal seams and are generally used for refractories.

Industrywide expansions and modernizations were slowed during the year while acquisitions and/or mergers were prevalent. Manufacturing plants continued to experience phasedowns by either operating intermittently or being put on minimal production schedules. The clay refractory industry had been in a period of low production because of decreased demand brought about by both technological changes and lower consumption levels by its major users, those being steel, nonferrous metals, ceramics, glass, and minerals processing. The technological changes in steelmaking, away from integrated pig iron systems and toward electric furnaces and/or minimills, further compounded the problem by employing shapes and specialty refractories requiring less fire clay. This industry retrenchment prompted USG Corp., at yearend, to spinoff its wholly owned subsidiary, A. P. Green Refractories Co., to its shareholders. Earlier in the year, USG's attempt to sell A. P. Green to Adience Equities Inc., Pittsburgh, PA, failed because of obstacles in financing. The new company, A. P. Green Refractories Inc., was to be operated separately and was to include transferred sections of USG's lime business. Adience, in another fire clay action, agreed to merge with J. H. France Refractories Co. Inc., Snow Shoe, PA, pending approval of both management boards. J. H. France was to be operated as a subsidiary of Adience.

Fire clay production was from mines in 11 States, 1 less than in 1986. Missouri, Ohio, and Alabama, in descending order of volume, accounted for 94% of the total domestic production. Output generally increased significantly in the major producing States, declined in the smaller producing States, and ceased in Colorado.

Exports of fire clay decreased about 8% to 174,000 tons valued at $12.7 million. The unit value of exported clay decreased about 8% to $72.76, indicating that, despite a decrease in exports, the trend of shipping a higher percentage of premium quality calcined material continued. Fire clay was again exported to 26 countries. The major recipients, in descending order, were Japan, Belgium-Luxembourg, Canada, Australia, and Mexico. No imports for consumption were reported for fire clay.

The unit value of fire clay, reported by producers, ranged from about $5.00 to $35.00 per ton, indicating a higher valued fire clay was being recovered and processed.

Table 14.—Fire clay[1] sold or used by producers in the United States, by State

State	1986		1987	
	Short tons	Value	Short tons	Value
Alabama	110,482	$3,113,913	126,840	$3,574,802
Colorado	6,051	80,395	--	--
Missouri	185,758	3,333,844	336,088	7,666,489
New Jersey	12,524	265,919	5,985	139,768
New Mexico	2,103	13,458	898	5,165
Ohio	173,110	3,720,655	291,300	4,588,541
Pennsylvania	44,670	781,657	23,373	600,202
Texas	19,670	139,400	4,225	55,897
Washington	2,676	27,854	3,562	36,004
Other[2]	34,783	738,474	11,280	118,232
Total	591,827	12,215,569	803,551	16,785,100

[1]Refractory uses only.
[2]Includes Arkansas (1986), Idaho (1986), Indiana (1987), Kentucky, and Montana (1987).

BENTONITE

Bentonite production and value decreased slightly to about 2.8 million tons and $90.8 million, respectively. The production was the lowest reported figure in the last 15 years. During that time, production rose steadily to the 1981 record-high 4.9 million tons followed by a steady decline to the 2.8-million-ton 1987 figure. Wyoming, the largest producing State, increased production by more than 22% largely to take up the shortfall brought about by the idling of the nearby Montana operations. Wyoming and Montana had traditionally been the first-and-second-largest swelling bentonite producing States, respectively. Domestic consumption for two major end uses, drilling mud and foundry sand, increased modestly in response to improvements in the overall domestic economy.

Bentonite was produced in 12 States, 1 less than in 1986. The high-swelling or sodium bentonite continued to be produced chiefly in Wyoming. The low-swelling or calcium bentonite continued to be produced in the other States, mostly east of the Mississippi River. Calcium bentonite production in Mississippi is suitable for the production of both absorbent and acid-activated products.

The major western and southern bentonite producers continued flowsheet and other modernizations to reduce plant operating costs and/or overhead. Most plants continued operating sporadically at new lower production levels until about midyear when demand started to increase across the board. The oil industry, spurred on by the increase in the number of operating domestic rigs and favorable long-term oil and gas prices, combined with improvements in the demand for steel and foundry products, brought about an upturn in bentonite demand. The yearend increase in bentonite demand essentially erased poor industry performance in the first half of the year. The foundry, oil and gas, and steel industries traditionally consume about 90% of the domestic output.

The major and captive producers of bentonite either were continuing efforts to expand their product lines in other marketing areas or were restructuring to minimize detrimental aspects of overcapacity. In this regard, American Colloid Co. (ACC), Arlington Heights, IL, purchased additional mining and processing facilities and mineral reserves in the eastern Wyoming sodium bentonite belt from Federal Ore and Chemical Inc., a wholly owned subsidiary of M/I Drilling Fluids Co., Houston, TX, a 60-40 joint venture between Dresser Industries Inc. and the IMCO Services Div. of the Halliburton Co. The purchase also included Federal's taconite-dedicated milling facility in Burnett, MN. ACC also bought the Colony, WY, bentonite operation and some related assets from Applied Industrial Materials Corp. (AIMCOR). The purchase included a processing plant, inventories of mined bentonite, mineral rights, and the assumption of certain liabilities. The purchase excluded AIMCOR's Mississippi-based calcium bentonite and absorbent assets. ACC acquired the clay desiccant product line from Culligan International Inc. and planned to reopen the Dewey County, OK, calcium bentonite mine. The Oklahoma bentonite was targeted for use in the manufacturing of carbonless paper and as a desiccant after processing in ACC's plants in either Belle Fourche, SD, or Upton, WY. American Bentonite Corp.,a newly formed company in Billings, MT, was seeking permits to mine sodium bentonite in Johnson and Montana Counties, WY.

In a Government action, the Senate approved $200,000 to study design alternatives for the underground disposal of low-level nuclear wastes in conjunction with an impervious bentonite clay buffer and/or liner. Reclamation projects under the Surface Mining Law, funded by a $3.8 million construction program approved by the U.S. Department of the Interior, were to involve 20 abandoned bentonite mines in Campbell Johnson, Natrona, and Sheridan Counties, WY. The Wyoming Department of Environmental Quality, Land Quality Div., requested permission from the Army Corps of Engineers to reclaim bentonite pits in isolated wetlands in Crook and Weston Counties.

In calcium bentonite action, Kaisertech Ltd., bought out its partner in the Harshaw/Filtrol Partnership and agreed to sell Harshaw/Filtrol to Engelhard. Harshaw/Filtrol has both a calcium bentonite derived desiccant and acid-activated product line manufactured in Jackson, MS, from local and Arizona clays.

On December 28, 1987, Chemical Marketing Reporter quoted domestic sodium bentonite, 200 mesh, bags, carload lots, f.o.b. mines, as unchanged at $43.50 per ton. The average unit value reported by domestic producers decreased slightly to $32.36 per ton. Per ton values reported in the various producing States ranged from $16 to more than $86, but the average value reported by the larger producers was near the Wyoming average of about $29.15.

Bentonite exports decreased about 7% to

Table 15.—Bentonite sold or used by producers in the United States, by State

State	Nonswelling		Swelling		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
1986						
Alabama and Mississippi	454,433	$15,822,614	--	--	454,433	$15,822,614
Arizona	16,166	394,248	25	$788	16,191	395,036
California	104,531	6,841,032	20,686	1,681,950	125,217	8,522,982
Colorado	462	5,544	38	456	500	6,000
Kansas	--	--	24,090	897,990	24,090	897,990
Montana	--	--	182,607	5,779,980	182,607	5,779,980
Nevada	--	--	10,313	583,519	10,313	583,519
Texas	11,969	547,908	20,855	426,913	32,824	974,821
Utah	--	--	7,680	296,294	7,680	296,294
Wyoming	--	--	1,738,412	51,506,278	1,738,412	51,506,278
Other	--	--	[1]220,776	[1]6,584,910	220,776	6,584,910
Total	587,561	23,611,346	2,225,482	67,759,078	2,813,043	91,370,424
1987						
Alabama and Mississippi	423,335	15,609,936	--	--	423,335	15,609,936
Arizona	28,507	904,272	23	805	28,530	905,077
California	95,737	6,867,803	20,556	1,762,662	116,293	8,630,465
Colorado	100	1,600	--	--	100	1,600
Nevada	3,013	310,580	8,786	499,914	11,799	810,494
Oregon	--	--	18,147	639,515	18,147	639,515
Texas	12,343	523,267	15,204	212,324	27,547	735,591
Utah	2,000	20,000	27,000	612,960	29,000	632,960
Wyoming	--	--	2,127,645	62,031,122	2,127,645	62,031,122
Other	--	--	[1]23,837	[1]816,740	23,837	816,740
Total	565,035	24,237,458	2,241,198	66,576,042	2,806,233	90,813,500

[1]Includes Idaho, Kansas (1987), and South Dakota (1986).

Table 16.—Bentonite sold or used by producers in the United States, by use

(Short tons)

Use	1986			1987		
	Non-swelling	Swelling	Total	Non-swelling	Swelling	Total
Domestic:						
Absorbents	75,701	--	75,701	134,371	188	134,559
Adhesives	--	11,302	11,302	7,578	7,582	15,160
Animal feed	43,262	69,164	112,426	12,594	99,162	111,756
Catalysts (oil refining)	5,232	147	5,379	16,901	--	16,901
Drilling mud	5,193	1,031,555	1,036,748	4,509	946,083	950,592
Filtering, clarifying, decolorizing:						
Animal oils, mineral oils and greases, vegetable oils	152,749	2,110	154,859	73,944	2,277	76,221
Desiccants	12,930	--	12,930	16,343	--	16,343
Foundry sand	215,004	401,784	616,788	231,771	418,984	650,755
Medical, pharmaceutical, cosmetic	--	7,321	7,321	--	7,108	7,108
Paint	--	8,446	8,446	--	7,897	7,897
Pelletizing (iron ore)	--	262,419	262,419	--	337,837	337,837
Pesticides and related products	1,163	4,214	5,377	10,403	3,277	13,680
Water treatment and filtering	4,424	935	5,359	4,638	972	5,610
Waterproofing and sealing	4,901	53,062	57,963	1,648	87,991	89,639
Miscellaneous[1]	r72,141	r57,403	r129,544	11,267	43,547	54,814
Total	525,556	1,909,862	2,435,418	525,967	1,962,905	2,488,872
Exports:						
Drilling mud	--	183,934	183,934	1,316	99,646	100,962
Foundry sand	52,760	104,972	157,732	9,054	169,149	178,203
Other[2]	9,245	26,714	35,959	28,698	9,498	38,196
Total	62,005	315,620	377,625	39,068	278,293	317,361
Grand total	587,561	2,225,482	2,813,043	565,035	2,241,198	2,806,233

rRevised.

[1]Includes data for asphalt emulsions; asphalt tile; cement, portland; floor and wall tile, ceramic; chemical manufacturing (1986); face brick; fertilizers; firebrick, blocks and shapes; gypsum products; ink; kiln furniture; mineral wool and insulation; oil well sealing (1987); paper coating and filling; plastics; pottery (1987); roofing tile; rubber; and uses not specified.

[2]Includes absorbents (1987); animal feed; asphalt emulsions; cement (1987); filtering, clarifying, decolorizing (1987); paint; plastics; waterproofing and sealing; and uses not specified.

539,000 tons valued at $40.6 million. The unit value of exported bentonite decreased 2% to $75.32 per ton; this was attributed to higher percentages of the lower cost iron ore pelletizing grades, mainly to Canada, over the costlier drilling mud and foundry grades shipped. Domestic bentonite producers, although benefiting from a softening U.S. dollar, continued to face increased competition in foreign markets, particularly the Canadian iron ore markets where Mediterranean bentonites continued to make inroads into an area traditionally served by domestic producers.

Bentonite was exported to 58 countries, 8 less than in 1986. The major recipients were Canada, Japan, Taiwan, Singapore, and the Republic of South Africa. Domestic bentonite producers reported their exports were foundry sand, 56%; drilling mud, 32%; and other, 12%.

Bentonite imports for consumption consisted mostly of both untreated clay and chemically or artificially activated materials. The total bentonite imports increased 18% to nearly 19,000 tons. The chemically activated category, which slowly increased in quantity for most of the past several years, increased 12% to nearly 15,000 tons valued $5.4 million. Imports from the Federal Republic of Germany and Mexico increased nearly 100% and 9%, respectively. Mexican imports usually make up more than 75% of total activated clay imports. The chemically activated bentonite was imported, as last year, from 11 countries, with Mexico supplying 87%; the Republic of South Africa and the Federal Republic of Germany, 11%; and the remaining countries, 2%.

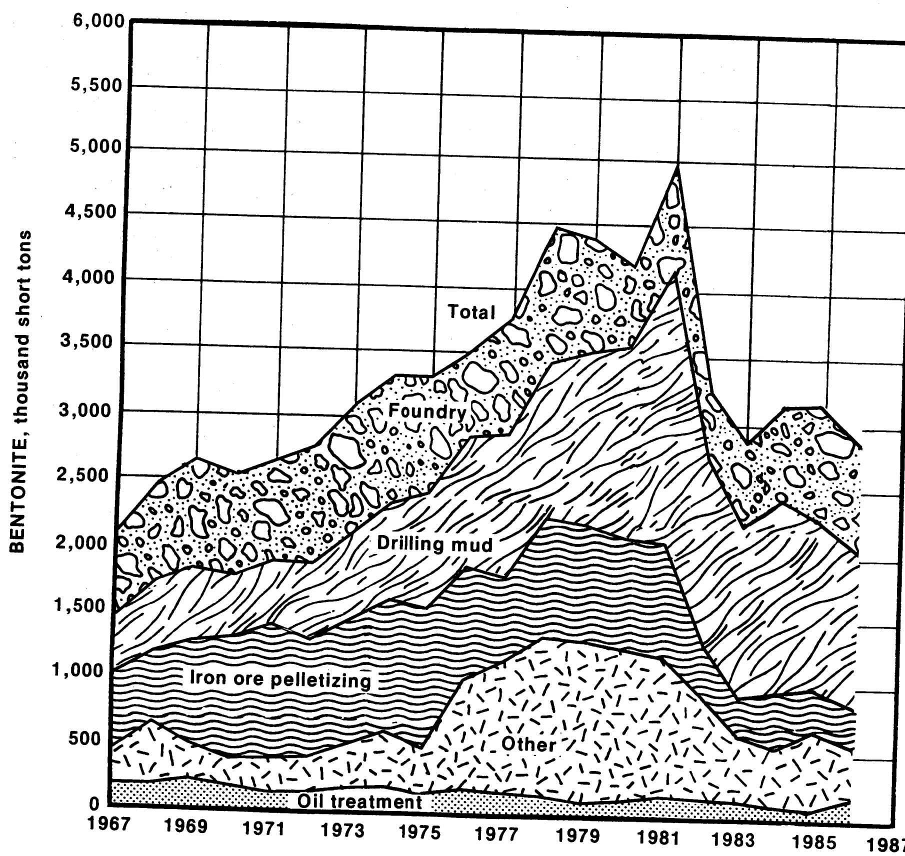

Figure 2.—Bentonite sold or used by domestic producers for specified uses.

FULLER'S EARTH

Production of fuller's earth increased 8% to nearly 2.1 million tons valued at $137 million, essentially equaling the record high of 1985. This increase in production, which followed the first reported decline in 1984 and again in 1986, continued the upward trend in production that the industry has enjoyed for more than 10 years. A general increase in absorbent-grade clay output was sufficient to offset a 7% decline in Florida attapulgite clay production. The average unit value increased slightly to $66.72 per ton, indicating a larger percentage of higher valued gelling grades in the total. Production was reported in 10 States. The two top producing States, Florida and Georgia, accounted for about one-half of domestic production. All States, except Florida and Mississippi, showed gains in production. Increases in consumption occurred across the entire product line of adsorbents, with pet waste absorbents leading the way.

Fuller's earth is a nonplastic clay or claylike material, usually high in magnesia, which has adequate absorbing, decolorizing, and purifying properties. Sepiolite-type clays are also included for statistical convenience.

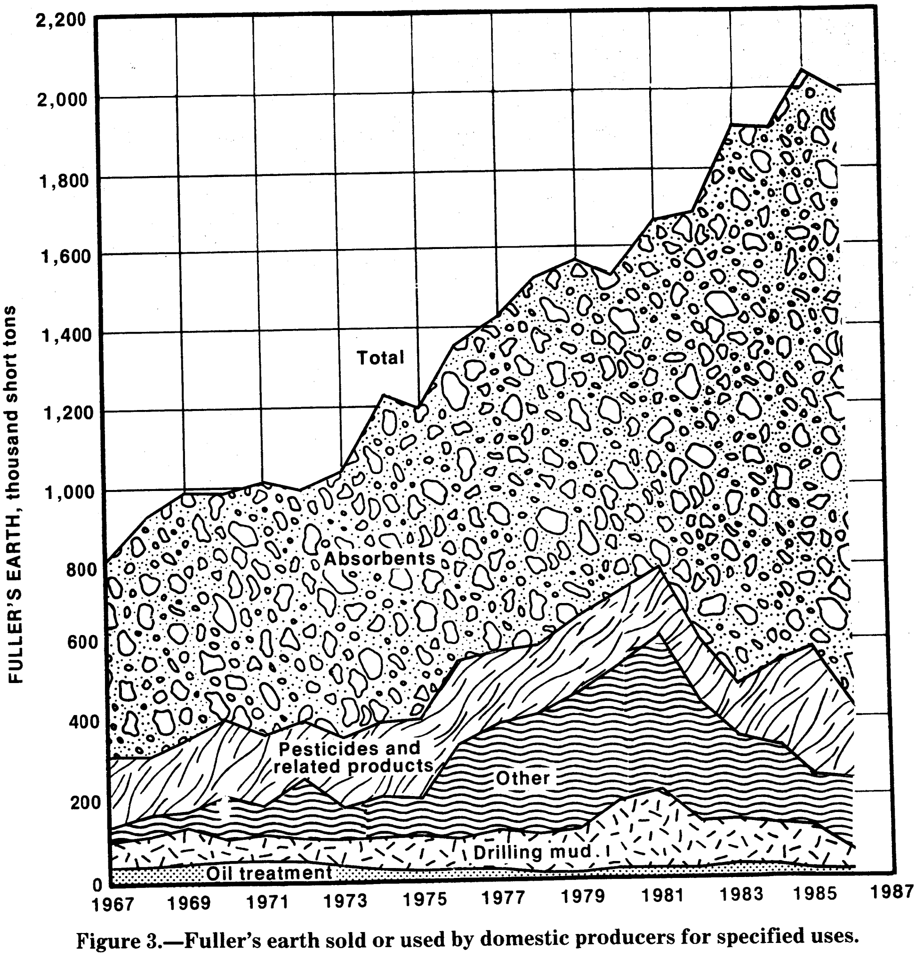

Figure 3.—Fuller's earth sold or used by domestic producers for specified uses.

Table 17.—Fuller's earth sold or used by producers in the United States, by State

State	Attapulgite		Montmorillonite		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
1986						
Florida	463,246	$38,793,558	--	--	463,246	$38,793,558
Georgia	317,972	15,656,794	213,876	$10,665,217	531,848	26,322,011
Other	[1]139,554	[1]8,172,908	r [2]775,330	r [2]52,187,912	r914,884	r60,360,820
Total	920,772	62,623,260	989,206	62,853,129	1,909,978	125,476,389
1987						
Florida	431,147	35,164,373	--	--	431,147	35,164,373
Georgia	372,411	22,770,533	218,823	12,442,578	591,234	35,213,111
Mississippi, South Carolina, Tennessee, Virginia	--	--	577,558	31,155,549	577,558	31,155
Illinois, Missouri, Nevada, Texas	16,125	1,199,378	440,727	34,499,946	456,852	35,699,324
Total	819,683	59,134,284	1,237,108	78,098,073	2,056,791	137,232,357

rRevised.
[1]Includes Illinois, Nevada, and Texas.
[2]Includes Illinois, Mississippi, Missouri, South Carolina, Tennessee, and Virginia.

Table 18.—Fuller's earth sold or used by producers in the United States, by use

(Short tons)

Use	1986			1987		
	Attapulgite	Montmorillonite	Total	Attapulgite	Montmorillonite	Total
Domestic:						
Adhesives	6,874	--	6,874	2,723	--	2,723
Cement, portland and other	--	--	--	--	36,618	36,618
Drilling mud	34,720	--	34,720	31,949	--	31,949
Fertilizers	36,247	7,379	43,626	35,540	6,493	42,033
Filtering, clarifying, decolorizing mineral oils and greases	13,579	--	13,579	13,795	--	13,795
Medical, pharmaceutical, cosmetic	379	--	379	959	--	959
Oil and grease absorbents	264,673	200,694	465,367	163,796	194,738	358,534
Paint	19,885	--	19,885	20,303	--	20,303
Pesticides and related products	71,314	92,675	163,989	17,009	104,208	175,217
Pet waste absorbents	348,710	610,457	959,167	308,320	738,114	1,046,434
Other[1]	13,132	--	13,132	--	--	--
Miscellaneous[2]	47,387	61,462	108,849	90,767	139,194	229,961
Total	856,900	972,667	1,829,567	739,161	1,219,365	1,958,526
Exports:						
Drilling mud	106	--	106	122	--	122
Oil and grease absorbents	23,917	3,031	26,948	43,309	5,908	49,217
Pesticides and related products	4,937	2,589	7,526	5,463	2,270	7,733
Pet waste absorbents	29,505	9,571	39,076	22,461	9,565	32,026
Miscellaneous[3]	5,407	1,348	6,755	9,167	--	9,167
Total	63,872	16,539	80,411	80,522	17,743	98,265
Grand total	920,772	989,206	1,909,978	819,683	1,237,108	2,056,791

[1]Includes roofing tile (1986); roofing granules (1986); tamping dummies (1986); and vegetable oils (1986).
[2]Includes animal feed (1987); animal oils (1987); gypsum products; miscellaneous absorbents; miscellaneous fillers, extenders, and binders; miscellaneous filtering, clarifying, and decolorizing (1987); mortar and cement refractories; plastics; roofing tiles (1987); vegetable oils (1987); wallboard (1987); water treatment and filtering (1987); waterproofing and sealing (1987); and other uses not specified.
[3]Includes paint and uses not specified.

Production from the region that includes Attapulgus, Decatur County, GA, and Quincy, Gadsden County, FL, is composed predominantly of the lath-shaped amphibole-like clay mineral attapulgite. Most of the fuller's earth produced in other areas of the United States contains varieties of montmorillonite and/or other clays.

Throughout the industry, enlargements, modernizations, acquisitions, and/or mergers that had been either canceled or deferred until overall economic conditions improved were starting to be acted upon again cautiously. Generally the absorbent-producing companies enjoyed a good year while the gell-grade producers experienced a mixed year.

Attapulgite, a fuller's earth-type clay, finds wide application in both absorbent and gelling and/or thickening areas. The thixotropic properties of attapulgite clays provide the important thickening and viscosity controls necessary for suspending solids. Mineral thickeners are used in such diverse markets as paint, joint compound cement, and saltwater drilling muds.

Prices for attapulgite reported by producers ranged from about $80 to $120 per ton; montmorillonite prices ranged from about $20 to $90.

Exports of fuller's earth went to 28 countries, 4 less than in 1986, but the quantity decreased nearly 12% to 107,000 tons valued at $8.7 million. The unit value of exported fuller's earth increased slightly over that of 1986 to $81.03, which was attributed to a larger percentage of the high-cost gelling and drilling-mud grades exported in 1987 compared with the percentage of absorbent grades shipped. The major recipients were Canada and the Netherlands. A minor amount of beneficiated and unbeneficiated fuller's earth was imported, mostly from France.

COMMON CLAY AND SHALE

Domestic sales or use of common clay and shale increased about 8% in both tonnage and value to 32.3 million tons and $147 million. Output of the 10 major producing States rose in Alabama, North Carolina, Ohio, South Carolina, Texas, and Virginia, and declined in California, Georgia, Michigan, and Pennsylvania. Common clay and shale represented about 70% of the quantity but only 12% of the value of total domestic clay production. Domestic clay and shale are generally mined and used captively to fabricate or manufacture products. Less than 10% of the total output is usually sold. The average unit value for all common clay and shale produced in the United States and Puerto Rico increased slightly to $4.56 per ton. The unit value ranged from $13 to nearly $30 per ton.

Common clay is a clay or claylike material that is sufficiently plastic to permit ready molding and that vitrifies below 1,100° C. Shale is a sedimentary rock composed chiefly of clay minerals that has been both laminated and indurated while buried under other sediments. Clay and shale are used in the manufacture of structural clay products such as brick, drain tile, portland cement clinker, and expanded lightweight aggregates.

Increased production capacities, new plants, and modernizations, previously deferred, were beginning to be acted on again. Mergers and/or acquisitions of domestic heavy clay producers were quite active. The construction industry, the biggest user of heavy clay products such as brick, lightweight aggregate, portland cement, sewer pipe, and tiles, was moving along at a brisk pace. The large inventories traditionally accumulated during the winter months were worked off by the first quarter, and at midyear, the industry was experiencing heavy production. Output during the last quarter was somewhat tempered by increasing interest rates. A notable exception to these boom times was the declining construction rates in the depressed oil-producing States of the Southwest.

In building brick acquisitions, Steetley PLC, through its subsidiary, Steetley Brick and Tile Ltd., purchased K-F Brick Co. Inc. and Victor Cushwa and Sons Inc., Williamsport, MD. K-F Brick, the leading New England supplier of face bricks, has plants in Connecticut and Massachusetts with a combined capacity of 80 million bricks per year (bpy). Cushwa produces about 40 million bpy of quality face bricks, mostly machine-molded with some hand-thrown brick targeted for the higher priced end of the market. Both K-F Brick and Cushwa, the latter strategically situated in the Baltimore, MD-Washington, DC, area, serve market areas that have favorable long-term growth prospects. Marley PLC, through its U.S. subsidiary, General Shale Products Corp., a major U.S. brick producer, acquired Corbin Brick Co. Inc., Corbin, KY. Corbin has a maximum production capacity of 100 million bpy of high-quality face bricks with the recent addition of its new kiln. General Shale's total capacity in the United States is now reported to be in excess of 800 million bpy. Jannock Ltd. a Toronto, Canada, brick producer, bought Payne Brick Co. of Elgin, TX, for an undisclosed amount. The Payne Brick operation has a capacity of 24 million bpy and clay reserves for at least 50 years. Tarmac-Lonestar Inc., a joint venture between Tarmac America and Lonestar Inc., purchased the assets of Old Virginia Brick Co. Inc., Salem, VA. Old Virginia is currently expanding its molded capacity to more than 40 million bpy. The enlargement includes a newly automated second kiln and other ancillary equipment. Tarmac PLC is a major producer of building raw materials and products in the United Kingdom.

In a nonbrick common clay and shale acquisition, Cement Roadstone Holdings PLC (CRH) based in Dublin, Ireland, bought Big River Industries Inc. of Baton Rouge, LA. Big River is a major U.S. producer of expanded clay and/or shale lightweight aggregate, with manufacturing plants in Alabama, Georgia, and Louisiana. Big River successfully barges expanded aggregates along the Mississippi and its tributaries. CRH already owns concrete block, pipe, and aggregate operations in the United States. In another buyout, Mission Clay Products Corp., a clay and building products manufacturer in Los Angeles, CA, acquired W. S. Dickey Clay Manufacturing Co.'s Pittsburgh, KS, and San Antonio, TX, clay sewer pipe manufacturing plants from Hepworth Ceramic Holdings Ltd. of Sheffield, United Kingdom.

Exceptions to the industrywide slowdown in expansions and modernizations were announced by Acme Brick Co., a subsidiary of Justin Industries Inc., and several other companies. Acme Brick's two new brick plants became operational in Tulsa, OK, and near Houston, TX. Hanley Brick Co., a unit of the Glen-Gery Corp., Reading, PA, began production at its new brickworks in Marion County, OH. The new plant was also producing a line of molded bricks to augment its present extruded products. A second kiln was scheduled to come onstream by yearend 1988. L. C. Holdings Inc., a Boulder, CO, operation, announced plans to reactivate the former Idealite expanded shale lightweight aggregate plant near Golden, CO. The refurbished plant was to be capable of producing about 500,000 cubic yards of lightweight material for the Denver market area, which includes the newly planned Denver airport. Increases in production capacity were announced by Robinson Brick Co. Inc. during the year. Robinson Brick fired up its idle second kiln and scheduled a second shift to handle the increased production. Watsontown Brick Corp., Watsontown, PA, opened its new grinding plant complete with a single roller crusher, screens, assorted belt conveyors, and a hammermill to feed the pugmill. In new products, Higgins Brick Co. Inc., Redondo Beach, CA, introduced a novel hollow standard-size brick with full strength and load-bearing capabilities. Previously, hollow bricks were available in larger dimensions only.

Table 19.—Common clay and shale sold or used by producers in the United States,[1] by State

State	1986		1987	
	Short tons	Value	Short tons	Value
Alabama	1,886,574	$9,318,166	2,071,690	$11,024,661
Arizona	184,919	971,190	189,621	1,000,240
Arkansas	783,588	1,845,190	706,185	1,640,259
California	2,228,871	22,393,865	2,092,234	21,332,999
Colorado	235,782	1,436,684	289,002	1,612,269
Connecticut and New Jersey	276,680	2,775,207	248,437	2,599,275
Florida	227,243	1,695,847	127,518	1,241,925
Georgia	2,516,322	7,657,913	2,439,686	7,355,968
Illinois	282,993	1,091,609	232,949	977,048
Indiana	743,859	3,043,873	1,036,669	4,055,534
Iowa	486,309	1,420,979	472,788	1,494,770
Kansas	879,358	4,397,191	603,680	2,575,572
Kentucky	661,176	2,305,585	721,111	3,450,418
Louisiana	331,982	7,669,853	356,904	9,191,774
Maine and Massachusetts	185,995	961,199	189,562	942,329
Maryland	361,729	1,757,132	283,054	1,939,968
Michigan	1,402,446	5,684,283	1,333,498	5,338,433
Mississippi	616,672	2,747,815	559,955	2,706,996
Missouri	1,130,333	3,269,320	1,139,749	2,748,092
Montana	39,212	101,724	28,879	98,270
Nebraska	221,153	668,380	223,728	721,059
New Mexico	58,081	156,663	50,350	135,945
New York	618,968	3,074,611	672,635	3,562,468
North Carolina	2,606,679	9,527,534	3,173,037	13,765,148
Ohio	2,659,675	7,794,754	2,895,970	8,125,451
Oklahoma	992,702	2,328,697	797,301	1,782,741
Oregon	203,596	288,920	249,677	346,365
Pennsylvania	1,189,121	4,278,881	1,182,748	4,150,511
Puerto Rico	110,997	222,845	148,029	317,751
South Carolina	923,165	2,392,204	1,244,886	2,726,808
South Dakota and Wyoming	141,941	691,641	194,700	1,756,372
Tennessee	548,641	1,305,695	569,303	1,452,360
Texas	2,423,685	10,609,847	3,283,652	14,032,898
Utah	296,867	1,751,735	286,154	1,325,981
Virginia	855,977	4,699,648	1,171,442	6,291,100
Washington	249,469	1,531,913	412,031	2,319,950
West Virginia	214,980	469,708	266,037	564,574
Other[2]	141,401	419,360	120,718	329,849
Total	29,979,076	135,902,494	32,327,725	146,976,294

[1]Includes Puerto Rico.
[2]Includes Idaho, New Hampshire, and North Dakota.

CONSUMPTION AND USES

The manufacture of heavy clay products including building brick; sewer pipe; and drain, roofing, structural, terra cotta, and other tile; portland cement clinker; and lightweight aggregate accounted for 38%, 18%, and 10%, respectively, of total domestic consumption. In summary, 70% of all clay produced was consumed in the manufacture of these clay- and shale-based construction materials.

Heavy Clay Products.—The value reported by the Bureau of the Census for shipments of heavy clay products increased 11% to about $1.8 billion. The million standard brick count for building or common face brick increased slightly. Shipments of vitrified clay and sewer pipe fittings increased 9%, while clay floor and wall tile increased 4%. Increases in common clay and shale used in building brick manufacturing occurred in most States with total domestic production increasing 6%. Increases were less than 13% with an average State upturn of less than 20%.

Lightweight Aggregates.—Consumption of clay and shale in the manufacture of lightweight aggregate increased about 24% to nearly 4.6 million tons. The upturn in overall construction of commercial buildings and highway resurfacing was largely responsible for the increase in demand. Concrete block, the largest category (61% of total production), rose 15% while the second biggest consuming area, highway surfacing (19% of total production), increased markedly. The third largest segment, structural concrete (18% of production), declined 20% and the other category, the smallest segment consisting essentially of new market areas such as recreational and horticultural uses, also rose 94%.

Refractories.—All types of clay were used in manufacturing refractories. Kaolin, bentonite, and fire clay accounted for 32%, 27%, and 26%, respectively, of total clay used for this purpose. The remainder, ball clay, common clay and shale, and fuller's earth, was used chiefly as bonding agents. Bentonite, both swelling and nonswelling, was used as a bonding agent in proprietary foundry formulations imparting both green- and hot-strength to the sand.

The tonnage of clays used for refractories increased 12% and constituted 5% of total clay produced. The continued use of refractories, mostly calcined kaolin grogs, in monoliths, and the upturn in demand for the more conventional refractory bricks and shapes was largely responsible. The major refractory-consuming industries—cement, foundry, glass, and ferrous and nonferrous metals—continued to undergo major changes in technology and production levels for their products.

Filler.—Bentonite, fuller's earth, and kaolin, are the principal filler clays. Kaolin, either air-floated, water-washed, low-temperature calcined, and/or delaminated, was used in the manufacture of adhesives, paint, paper, plastics, and rubber. Fuller's earth was used primarily in pesticides and fertilizers. Clays are in pesticides and fertilizers as either thickeners, carriers, diluents, or prilling agents. Bentonites were used mainly in animal feeds.

Of the total clay produced, 11% was used in filler applications; of this, kaolin accounted for 88%; fuller's earth, 5%; bentonite, 3%; and ball clay, common clay and shale, and fire clay, the remaining 4%. Kaolin consumed as fillers increased to 4.8 million tons. An approximate 15% increase in paint and a slight increase in paper filling, which together constitute 30% of the total filler and extender category, were largely responsible. The paper-coating grade kaolin, animal feed, and gypsum products and wallboard, together made up a 7% increase. The total quantity of fuller's earth used in pesticides and related products such as fungicides, increased nearly 7% from that of 1986.

Absorbent Uses.—Absorbent uses for clays accounted for nearly 1.7 million tons, or 4% of total clay consumption. Demand for absorbents increased slightly. Fuller's earth was the principal clay used for absorbent purposes, and this application accounted for 69% of the entire output. Demand for clays in pet waste absorbents, representing 61% of absorbent uses, increased 9%. Use in floor absorbents, chiefly to absorb hazardous oily substances, accounted for another 21% of the absorbent demand, which decreased from that of 1986. An increase in the use of pet waste absorbents offset the decline in the industrial sector, which consumes large quantities of floor absorbents.

Table 20.—Clays sold or used by producers in the United States[1] in 1987, by use

(Short tons)

Use	Ball clay	Bentonite	Common clay and shale	Fire clay (refractory only)	Fuller's earth	Kaolin	Total
Absorbents:							
Oil and grease	--	W	W	--	358,534	--	358,534
Pet waste	--	W	W	--	1,046,434	--	1,046,434
Other[2]	--	142,396	155,198	--	11,850	--	309,444
Ceramics and glass:							
Catalysts (oil refining)	--	16,901	--	--	--	112,172	129,073
Crockery and other earthenware	--	--	W	7,080	--	9,164	16,244
Electrical porcelain	27,462	--	35	--	--	8,853	36,350
Fine china and dinnerware	13,204	--	--	--	--	21,827	35,031
Glazes, glass, enamels	--	--	--	--	--	638	638
Mineral wool and insulation, fiberglass	W	W	--	--	--	458,529	458,529
Pottery	211,996	10	19,748	4,000	--	65,238	300,992
Roofing granules	--	--	48,530	4,033	--	7,335	59,898
Sanitary ware	178,451	--	--	300	--	59,437	238,188
Other[2]	73,943	2,541	3,731	4,232	--	61,149	145,596
Chemical manufacturing	--	--	--	--	--	212,752	212,752
Civil engineering and sealing	--	99,026	183,115	530	139,364	16,052	438,087
Drilling mud	--	950,592	--	--	31,949	632	983,173
Fillers, extenders, binders:							
Adhesives	--	15,160	--	--	2,723	67,987	85,870
Animal feed	W	111,756	W	--	W	41,409	153,165
Fertilizers	--	W	--	--	42,033	2,886	44,919
Gypsum products and wallboard	W	--	--	--	24,783	13,772	39,555
Ink	--	W	--	--	--	2,328	2,328
Medical, pharmaceutical, cosmetic	--	7,108	--	--	959	3,241	11,308
Paint	--	7,897	1,750	--	20,303	287,245	317,195
Paper coating	--	W	--	--	--	2,487,279	2,487,279
Paper filling	--	--	W	--	--	1,345,162	1,345,162
Pesticides and related products	W	13,680	3,368	--	175,217	40,804	233,069
Plastics	--	W	--	--	W	57,309	57,309
Rubber	W	W	1,411	W	--	254,665	256,076
Other[2]	128,994	19,655	83,882	5,400	16,534	188,302	442,767
Filtering, clarifying, decolorizing:							
Animal oils, mineral oils and greases, vegetable oils	--	76,221	--	--	34,538	606	111,365
Desiccants	--	16,343	--	--	--	--	16,343
Floor and wall tile:							
Ceramic	144,433	--	203,147	805	--	W	348,385
Quarry tile	--	--	154,704	135	--	--	154,839
Other[2]	--	12	196,000	--	--	38,019	234,031

See footnotes at end of table.

Table 20.—Clays sold or used by producers in the United States[1] in 1987, by use —Continued

(Short tons)

Use	Ball clay	Bentonite	Common clay and shale	Fire clay (refractory only)	Fuller's earth	Kaolin	Total
Heavy clay products:							
Brick, extruded	24,785	3,958	12,592,804	19,393	--	269,031	12,909,971
Brick, other	--	--	4,088,510	14,574	--	84,210	4,187,294
Cement, portland and other	--	1,171	8,410,247	1,625	36,618	81,288	8,530,949
Drain tile	--	--	34,004	--	--	--	34,004
Flower pots	--	--	39,967	310	--	--	40,277
Flue linings	--	--	36,907	65,179	--	28,800	130,886
Roofing tile	--	136	200	--	191	--	527
Sewer pipe, vitrified	--	--	388,398	--	--	6,885	395,283
Structural tile	--	--	55,805	--	--	392	56,197
Terra cotta	--	--	16	523	--	--	539
Other	--	--	719,491	--	--	19,387	738,878
Lightweight aggregate:							
Concrete block	--	--	2,792,779	--	--	125	2,792,904
Highway surfacing	--	--	802,364	--	--	--	802,364
Structural concrete	--	--	845,557	--	--	--	845,557
Other	--	--	122,287	--	--	--	122,287
Pelletizing iron ore	--	337,837	--	--	--	--	337,837
Refractories:							
Firebrick, blocks and shapes	W	W	92,136	417,334	--	118,589	628,059
Foundry sand	--	650,755	--	42,657	--	--	693,412
Grogs and calcines	--	--	--	138,355	--	598,211	736,566
High alumina brick and specialties	22,219	--	--	43,154	--	40,694	106,067
Kiln furniture	--	538	2,943	--	--	W	3,481
Mortar and cement, refractory	--	--	235,099	--	22	--	235,121
Other[2]	9,162	13,360	--	--	--	32,250	54,772
Other[3]	7,242	1,819	2,000	26,506	15,474	10,241	63,282
Exports	141,914	317,361	11,592	7,426	98,265	1,672,315	2,248,873
Total	983,805	2,806,233	32,327,725	803,551	2,056,791	8,827,210	47,805,315

W Withheld to avoid disclosing company proprietary data; included with "Total" and/or "Other."
[1]Includes Puerto Rico.
[2]Includes uses indicated by symbol W.
[3]Uses not specified.

Table 21.—Shipments of principal structural clay products in the United States

Product	1983	1984	1985	1986	1987
Unglazed common and face brick:					
Quantity million standard brick	5,792	6,510	6,605	7,204	7,313
Value million	$704	$836	$887	$972	$1,060
Unglazed structural tile					
Quantity thousand short tons	30	32	55	72	[1]93
Value million	$5	$7	$12	$28	[1]$50
Vitrified clay and sewer pipe fittings:					
Quantity thousand short tons	375	397	368	298	325
Value million	$64	$79	$78	$66	$74
Unglazed, salt-glazed, ceramic-glazed structural facing tile including glazed brick:					
Quantity million standard brick	W	W	W	W	32
Value million	W	W	W	W	$11
Clay floor and wall tile including quarry tile:					
Quantity million square feet	333	340	370	444	462
Value million	$388	$421	$450	$536	$587
Total value[2] do	$1,161	$1,342	$1,428	$1,602	$1,782

W Withheld to avoid disclosing company proprietary data.
[1]Includes first 9 months only.
[2]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census Report Form M32-D(87), Current Industrial Reports—Clay Construction Products.

Table 22.—Common clay and shale used in building brick production in the United States, by State

State	1986		1987[1]	
	Short tons	Value	Short tons	Value
Alabama	865,906	$4,034,526	973,878	$4,392,725
Arizona[2] and New Mexico[2]	137,740	407,962	141,992	483,466
Arkansas	486,068	1,421,375	192,388	447,054
California	485,354	8,095,174	456,618	8,036,489
Colorado	234,462	1,423,154	289,002	1,551,504
Connecticut, New Jersey,[2] New York[2]	422,071	2,921,398	403,161	2,759,099
Georgia	2,003,505	5,597,706	2,104,724	5,919,878
Idaho, Washington, Wyoming[2]	172,540	963,046	318,543	1,274,167
Illinois	118,675	561,858	131,787	614,170
Indiana and Iowa	391,850	1,010,698	432,908	1,364,579
Kansas	229,216	601,563	191,783	554,907
Kentucky[2]	307,918	1,409,109	384,692	2,100,514
Louisiana	98,982	253,463	73,672	176,499
Maine, Massachusetts,[2] New Hampshire[2]	199,995	1,093,499	207,062	1,035,799
Maryland and West Virginia[3]	388,472	1,781,917	422,113	1,976,791
Michigan[2] and Minnesota[2]	148,206	538,794	208,872	586,815
Mississippi	515,854	2,415,116	479,955	2,429,796
Missouri	98,471	423,519	105,823	469,798
Nebraska and North Dakota[2]	217,351	559,753	187,619	493,162
North Carolina	2,290,572	8,671,986	2,806,044	10,844,565
Ohio	1,617,522	4,492,329	1,252,827	3,872,507
Oklahoma	462,895	1,374,819	374,343	973,542
Oregon	19,840	51,446	21,297	58,521
Pennsylvania	885,694	2,621,105	967,313	3,212,185
South Carolina	608,616	1,606,223	922,223	2,310,141
Tennessee[2]	430,668	951,776	442,786	1,053,831
Texas	1,114,128	4,581,541	1,185,246	4,925,894
Utah[2]	126,357	920,910	141,625	723,399
Virginia	729,196	2,188,494	870,018	2,681,587
Total	15,808,124	62,974,259	[4]16,681,314	[4]67,323,384

[1]Includes extruded and other brick.
[2]Extruded brick only (1987).
[3]Other brick only (1987).
[4]Includes 1.5 million tons used in other brick production.

Drilling Mud.—Demand for clays in rotary-drilling muds decreased 8% to about 983,000 tons and accounted for 2% of total clay production. This decrease reflected the downward trend, except for the increase noted in 1984, begun in 1982 when a combination of excess oil production and economic uncertainties resulted in lower oil- and gas-well-drilling activities, which depressed bentonite demand. Oil- and gas-well-drilling activity picked up at yearend because of price stability and a favorable long-term outlook. Swelling-type bentonite remained the principal clay used in drilling mud mixes, although fuller's earth, used mostly in saltwater drilling techniques, and nonswelling sodium-activated bentonites, were also used to a limited extent. Bentonite and fuller's earth accounted for nearly 100% of the total amount of clay used in this category. Small amounts of kaolin were used in specialized formulations.

Floor and Wall Tile.—Common clay and shale, ball clay, kaolin, fire clay, and bentonite, in order of volume, were used in manufacturing floor, wall, and quarry tile. This end-use category accounted for 2% of total clay production. The competitive and/or declining interest for most of the year spurred the demand for more attractively appointed tiled homes.

Pelletizing Iron Ore.—Bentonite continued to be used as a binder in forming indurated iron ore pellets. Demand increased nearly 29% to about 338,000 tons. Inroads of inexpensive foreign bentonites into the Great Lakes markets traditionally served by exclusively U.S. bentonite producers, lower production levels, metal imports, and changing technology have all combined to reduce the long-term demand for domestic bentonite in this category.

Ceramics and Glass.—Total demand for clay in the manufacture of pottery, sanitary ware, china and dinnerware, and related products (excluding clay flower pots) accounted for 3% of the total clay output. This demand, principally ball and kaolin clays, increased slightly to 1.42 million tons. The strong upturn in residential housing, large consumers of whiteware and sanitary ware, was partially offset by the soft demand for these products at yearend owing to rising interest rates.

Table 23.—Common clay and shale used in lightweight aggregate production in the United States, by State

State	Short tons					Total value
	Concrete block	Structural concrete	Highway surfacing	Other	Total	
1986						
Alabama and Arkansas	489,707	228,638	12,491	8,487	739,323	$4,455,545
California	52,180	219,322	--	--	271,502	2,331,579
Florida and Indiana	236,923	38,550	--	--	275,473	3,714,804
Kansas, Kentucky, Louisiana	466,170	139,350	12,320	5,400	623,240	13,175,358
Mississippi and Missouri	182,431	7,057	10,082	--	199,570	1,229,367
Montana and New York	181,766	172,550	--	--	354,316	5,602,754
North Carolina	231,300	77,100	--	--	308,400	6,797,136
Ohio, Oklahoma, Pennsylvania	216,643	35,580	2,199	--	254,422	637,623
Texas	181,969	32,301	142,965	48,002	405,237	1,686,181
Utah and Virginia	187,112	51,820	14,809	1,040	254,781	3,025,714
Total	2,426,201	1,002,268	194,866	62,929	3,686,264	42,656,061
1987						
Alabama and Arkansas	743,549	91,433	16,674	25,348	877,004	6,015,176
California	57,000	57,000	--	--	114,000	592,572
Florida and Indiana	202,832	28,750	--	--	231,582	1,508,486
Kansas, Kentucky, Louisiana	380,563	132,349	26,674	4,019	543,605	10,359,005
Mississippi	50,000	10,000	20,000	--	80,000	277,200
Montana and New York	243,610	163,717	--	--	407,327	2,992,566
North Carolina	270,000	90,000	--	--	260,000	2,836,800
Ohio, Oklahoma, Pennsylvania	295,678	14,759	2,016	--	312,453	754,220
Texas	228,194	134,547	771,568	91,880	1,226,189	5,154,821
Utah and Virginia	321,353	79,809	8,625	1,040	410,827	4,071,305
Total	2,792,779	802,364	845,557	122,287	4,562,987	34,562,151

Table 24.—Shipments of refractories in the United States, by product

Product	Unit of quantity	1986 Quantity	1986 Value (thousands)	1987 Quantity	1987 Value (thousands)
CLAY REFRACTORIES					
Superduty fire clay brick and shapes	1,000 9-inch equivalent.	21,968	$26,697	27,070	$27,914
Other fire clay including semisilica brick and shapes, glasshouse pots, tank blocks, feeder parts, upper structure parts used only for glass tanks.	do	56,685	40,603	62,006	46,126
High-alumina (50% to 60% Al_2O_3) brick and shapes made of calcined diaspore or bauxite.[1]	do	65,716	118,042	76,004	128,404
Insulating firebrick and shapes	do	--	--	21,158	20,344
Ladle brick	do	30,330	9,985	10,302	3,272
Sleeves, nozzles, runner brick, tuyeres	do	25,279	29,327	9,679	28,315
Hot-top refractories	Short tons	W	W	W	W
Kiln furniture, radiant heater elements, potter's supplies, other miscellaneous-shaped refractory items.	do	27,185	21,965	42,432	33,246
Refractory bonding mortars	do	79,042	37,156	56,619	29,296
Plastic refractories and ramming mixes, containing up to 87.5% Al_2O_3.[2]	do	75,893	36,669	64,051	32,816
Castable refractories	do	207,150	78,075	251,808	110,578
Gunning mixes	do	144,882	37,497	144,940	50,475
Other clay refractory materials sold in lump or ground form.[3 4]	do	502,625	93,252	885,558	106,707
Total clay refractories		XX	529,268	XX	617,493
NONCLAY REFRACTORIES					
Silica brick and shapes	1,000 9-inch equivalent.	4,582	11,825	6,861	19,028
Magnesite and magnesite-chrome brick and shapes.	do	19,467	94,933	21,745	107,987
Chrome and chrome-magnesite brick and shapes.	do	22,914	82,347	27,640	101,124
Shaped refractories containing natural graphite.	Short tons	11,548	32,728	17,251	40,117
Zircon and zirconia brick and shapes; other carbon refractories: Forsterite, pyrophyllite, dolomite, dolomite-magnesite molten-cast,[5] other brick and shapes.	1,000 9-inch equivalent.	1,557	31,669	1,716	21,924
Other mullite, kyanite, sillimanite, or andalusite brick and shapes.	do	2,825	15,980	2,702	19,108
Other extra-high (over 60%) alumina brick and fused bauxite, fused alumina, dense-sintered alumina shapes.[6]	do	4,141	63,508	3,287	58,119
Silicon carbide brick, shapes, kiln furniture	do	979	28,880	1,105	33,936
Refractory bonding mortars	Short tons	21,094	11,539	29,843	16,944
Hydraulic-setting nonclay refractory castables	do	19,023	18,227	28,837	21,999
Plastic refractories and ramming mixes	do	120,306	75,922	136,738	89,385
Gunning mixes	do	364,806	150,950	323,330	111,939
Dead-burned magnesia or magnesite[3 7]	do	250,990	64,347	141,967	34,374
Dead-burned dolomite	do	324,691	46,393	331,982	19,682
Other nonclay refractory material sold in lump or ground form.[3]	do	280,886	74,655	202,486	42,137
Total nonclay refractories		XX	803,903	XX	737,803
Grand total refractories		XX	1,333,171	XX	1,355,296

W Withheld to avoid disclosing company proprietary data. XX Not applicable.

[1]Heat 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 that, after the addition of any water needed, are rammed into place.

[3]Materials for domestic use as finished refractories and all exported material.

[4]Includes 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.

Source: Bureau of the Census Report Form MQ32C(87), Current Industrial Reports—Refractory.

Table 25.—U.S. exports of clays in 1987, by country

(Thousand short tons and thousand dollars)

Country	Ball clay		Bentonite		Fire clay		Fuller's earth		Kaolin		Clays, n.e.c.		Total[1]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Argentina	--	--	(2)	63	--	--	(2)	2	16	3,717	(2)	190	17	3,972
Australia	(2)	4	--	--	21	1,385	--	--	16	4,901	3	3,840	40	10,130
Belgium-Luxembourg	--	--	5	264	25	1,753	(2)	9	54	8,440	2	2,338	86	12,804
Brazil	(2)	10	8	1,767	(2)	6	(2)	42	3	1,352	13	15,034	25	18,211
Canada	26	1,043	244	9,985	24	1,874	82	5,862	413	104,140	80	13,271	869	136,175
Chile	1	29	4	459	(2)	4	--	--	6	1,739	1	554	12	2,785
Colombia	--	--	(2)	235	(2)	18	--	--	8	1,772	6	4,109	15	6,134
Ecuador	1	91	1	104	(2)	13	--	--	5	474	1	562	8	1,244
Finland	--	--	--	--	--	--	--	--	95	11,646	1	1,002	96	12,648
France	--	--	4	272	1	183	(2)	45	13	2,784	1	843	19	4,127
Germany, Federal Republic of	(2)	6	3	196	(2)	33	(2)	42	24	4,151	11	5,127	39	9,555
Hong Kong	(2)	4	1	238	--	--	--	--	1	149	(2)	54	3	445
Italy	1	12	4	330	5	433	(2)	85	201	22,131	1	241	212	23,232
Japan	1	204	114	9,904	38	2,970	1	227	561	83,958	57	12,709	772	109,972
Korea, Republic of	(2)	36	3	1,737	1	41	(2)	7	84	15,584	2	350	91	17,755
Mexico	143	4,194	7	418	19	882	(2)	61	96	10,074	59	13,401	324	29,030
Netherlands	(2)	3	4	624	(2)	49	18	1,152	192	17,697	18	7,873	233	27,398
Peru	(2)	13	1	103	--	--	--	--	2	456	1	491	4	1,063
Philippines	3	254	4	899	--	--	(2)	7	4	1,188	1	265	12	2,613
Saudi Arabia	--	--	--	--	--	--	(2)	56	(2)	22	1	473	2	551
Singapore	--	--	15	1,332	--	--	(2)	13	1	213	1	469	17	2,027
South Africa, Republic of	(2)	4	14	744	(2)	2	1	176	20	4,013	1	407	37	5,346
Spain	--	--	(2)	141	--	--	--	--	16	2,511	(2)	160	17	2,812
Sweden	(2)	3	(2)	16	3	278	(2)	23	49	8,190	9	1,277	62	9,787
Switzerland	--	--	(2)	8	17	1,346	--	--	1	227	(2)	41	19	1,622
Taiwan	(2)	6	20	2,276	2	162	--	--	64	11,503	2	420	8	14,367
Thailand	(2)	4	3	443	--	--	--	--	7	1,856	1	140	11	2,443
United Kingdom	(2)	16	9	1,411	15	946	1	171	10	1,994	16	10,843	51	15,381
Venezuela	(2)	112	19	1,913	(2)	228	1	422	23	4,802	4	1,885	48	9,362
Other	2	225	50	4,715	1	55	(2)	265	40	8,792	10	5,921	103	19,973
Total[1]	179	6,274	539	40,596	174	12,661	107	8,670	2,026	340,475	301	104,292	3,332	512,964

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

Source: U.S. Department of Commerce.

Table 26.—U.S. imports for consumption of clays in 1987, by kind

Kind	Quantity (short tons)	Value (thousands)
China clay or kaolin:		
Canada	20	$3
China	3	1
Germany, Federal Republic of	226	56
Netherlands	52	14
United Kingdom	10,223	1,321
Total[1]	10,524	1,397
Fuller's earth, not beneficiated:		
France	119	15
India	48	6
Total[1]	167	22
Fuller's earth, beneficiated:		
Canada	34	6
United Kingdom	63	12
Total	97	18
Bentonite:		
Brazil	1	4
Canada	1,677	420
France	10	1
Germany, Federal Republic of	454	285
Hong Kong	20	3
India	24	3
Japan	249	13
Mexico	1,341	54
Philippines	76	10
Switzerland	65	111
United Kingdom	122	39
Total[1]	4,039	945
Common blue and other ball clay, not beneficiated:		
Canada	44	8
United Kingdom	513	39
Total	557	47
Canada	2	4
Japan	231	34
United Kingdom	969	154
Total	1,202	192
Other clay, not beneficiated:		
Canada	272	16
Germany, Federal Republic of	2,500	20
Italy	196	34
Korea, Republic of	118	21
Mexico	50	15
Netherlands	265	24
Switzerland	9	7
Taiwan	2	2
United Kingdom	737	104
Total[1]	4,149	242
Clay, n.e.c., beneficiated:		
Brazil	27	22
Canada	198	97
Denmark	15	3
France	128	74
Germany, Federal Republic of	66	63
Italy	22	42
Japan	38	85
Morocco	7	2
Netherlands	44	44
United Kingdom	1,828	665
Total[1]	2,373	1,098
Artificially activated clay:		
Belgium	20	33
Brazil	6	8
Canada	23	7
Chile	1	3
France	8	10
Germany, Federal Republic of	1,102	2,471

See footnote at end of table.

Table 26.—U.S. imports for consumption of clays in 1987, by kind —Continued

Kind	Quantity (short tons)	Value (thousands)
Artificially activated clay —Continued		
Korea, Republic of	78	$14
Mexico	12,686	2,767
South Africa, Republic of	560	1,006
Sweden	2	4
United Kingdom	85	108
Total[1]	14,571	5,431
Grand total[1]	37,679	9,392

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

Source: U.S. Department of Commerce.

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Australia.—Comalco Kaolin's kaolin clay mining and processing operation at its Weipa bauxite mine in northern Queensland, with an initial capacity of 100,000 tpy, was officially inaugurated.[2] Indicated reserves, just below the bauxite layer, totaled 25 million tons, but further exploration suggests that the total reserves could easily be twice this tonnage.

Comalco aims to be a major supplier to the paper coating industries of Western Europe, Japan, and the entire Pacific Basin. Exports, valued at $16 million, were expected to rapidly consume the plant's initial capacity.

In another kaolin event, ECC-Pacific completed an expansion at its Pittong plant with further expansion to be completed by 1988, bringing capacity up to 75,000 tpy.[3] Further increases were planned within the next 2 years to eventually raise production up to 120,000 tpy. Increases in capacity at Pittong have been matched by improvements in the wet- and dry-distribution facilities at the port of Fowey. With these strategically aimed expansions, ECC International planned not only to hold on to its present position in the world marketplace, but also to increase its market share internationally.

Belgium.—The Belgian chemical group, Solvay & Cie. S.A., purchased a further 1.17 million common shares in Laporte Industries (Holdings) PLC, raising its total share in the company to 22%.[4] (See "United Kingdom" and "Fuller's Earth" sections of this chapter.)

Brazil.—The Azevedo Antunes Group continued investing in its kaolin mines in the northern part of Amapá Territory.[5] The expansion program, scheduled for completion by yearend, was to nearly double production to 400,000 tpy. In another kaolin action, ECC's existing operation at Maji das Cruzes was extended to greater than 100,000-tpy capacity after a series of newly completed expansions.[6] ECC was the largest supplier of pigments to the Brazilian paper industry.

Canada.—A drilling and coring program was successfully concluded at the Wood Mountain kaolin project in Saskatchewan by Ekaton Industries Inc.[7] The drilling program was designed for both reserve evaluations and pilot plant testing. Earlier testing revealed a 200-million-ton ore body with a low 80's GE brightness, good optical characteristics, and a marketable calcined variety. The calcined clay is being targeted for eastern Canada, the Pacific Basin, and European markets. The pilot plant cost $1.5 million, and the entire project was estimated at $25 million for a 150,000-tpy facility. In midyear, Ekaton also signed a letter of intent with Esso Minerals Canada Ltd. whereby Esso acquired an option to accumulate up to 65% of the property due for completion by yearend 1988. In another action, Ekaton started construction of a $3 million absorbent plant in Kamploops, British Columbia.[8] Ekaton will become the only Canadian producer of clay-base pet waste and industrial absorbents. The project was approved only after an extensive market study showed that market share for clay-base absorbents had increased dramatically in western Canada.

In a common clay action, Brampton Brick Ltd. signed a contract with Agemac Ltd. to build a 120-million-bpy turnkey plant in Brampton, Ontario, by the spring of 1988.[9] The fully automated plant, requiring only eight people for overall operation, will feature a primary grinding installation, two tunnel dryers each with a 32-kiln-car capacity, and two 415-foot top- and side-fired tunnel kilns with a firing capacity of 178,000 bpy. Another common clay event saw Canada Brick Co. select Frame Engineering Inc., Anniston, AL, to provide a turnkey facility for the first dry fluoride scrubber system in a North American brick plant.[10]

Chile.—A newly completed feasibility and requirements study, in terms of investment, by Corporación de Fomento de la Producción's Servicio de Cooperación Téchnica (SERCOTEC) revealed the viability of several new medium- and small-scale mineral-related businesses.[11] One venture of interest was a brick manufacturing requirement for the midsouthern market area of the country. The brick facility would have an annual capacity of 3.2 million bricks requiring an initial investment of less than $1 million.

Finland.—The Government's Geological Research Institute was mounting a major exploration program designed to make the country self-sufficient in kaolin clays. The Finnish paper industry's demand for kaolin paper grade clays was estimated to be 1.5 million tons by 1990. In other kaolin developments, Kemira Oy was examining a promising deposit at Virtasalmi. Kemira planned to build a 100,000-tpy plant if the deposit contains more than 10 million tons of reserves. Partek Oy signed a cooperative agreement with a Swedish research organization to prepare a feasibility study on developing the Swedish Rostanga kaolin deposit.[12]

Germany, Federal Republic of.—Watts Blake Bearne Co. plc, United Kingdom, purchased a West German prepared-ceramic-body producer, Kannenbaeckerland, for about $6 million through its wholly owned subsidiary, Fuchs'she Tongruben (FT). FT, a major clay and prepared-ceramic-body producer, is one of the largest suppliers to the European stoneware and earthenware industry.[13] The European Darex Div. of W. R. Grace & Co. began construction to double capacity of its FCC plant in Worms.[14] The $20 million expansion, scheduled for completion by midyear 1989, was in response to increasing demand for these kaolin-derived FCC in Europe and the Middle East. W. R. Grace mines kaolin in the United States and manufactures its catalyst line in Aiken, SC, Cincinnati, OH; and Chattanooga, TN.

Indonesia.—The Government's Mining and Mineral Research Center predicted that by 1990 Indonesia will become one of the world's preeminent kaolin producers. The Center further stated that in 1987 there were 27 kaolin producers (all domestic companies because of Government regulations) in Indonesia. There were 7 mines on Bangka Island, 17 on Belitung, 2 in West Java, and 1 in North Sulawesi. P.T. Tambang Timah, a major producer, completed a new kaolin mining and processing complex at Tanjung Pandan on Belitung Island, South Sumatra, with an installed capacity of 22,000 tpy. The new plant's total production was to be equally divided between domestic and overseas Japanese consumers. Domestic kaolin production was consumed mostly by ceramic roof tile, cosmetic, paint, paper, and rubber manufacturers.[15]

Malaysia.—A kaolin deposit at Telagus, western Sarawak, was being evaluated by the recently formed Sarawak China Clay Trust.[16] The deposit lies 65 miles southwest of the proposed shipping terminal at Kuching on the South China Sea. Preliminary studies indicated a reserve of approximately 20 million tons and low viscosity characteristics combined with a brightness in the 70% to 86% range. A wet-processing facility with a capacity of 150,000 tpy is planned, with consideration given to an additional 150,000 tons at some later date.

Netherlands.—Redland PLC, under its right of first refusal, acquired the other half of its Dutch subsidiary, Redland-Brass-Bredero Europa BV, from Venenigde Bedrijven Bredero (VBB).[17] VBB is a major Dutch producer of bricks, ceramic tiles, concrete roofing tiles, and other building products.

Pakistan.—Residual buried kaolin deposits, formed as alteration products from granitic feldspars, are found near Nagar Parker in the Thar Parker District of southeast Sind, about 400 miles from Karachi. The Pakistan Mineral Development Corp. Ltd. (PMDC) identified more than 35 of these kaolin pockets overlain either by alluvium and/or laterite beds. Proven reserves were estimated at more than 4 million tons. PMDC plans to install a 50,000-tpy capacity raw kaolin elutriation plant for producing paper-, filler-, and ceramic-grade clays. Thar Mineral Processing Enterprise Ltd., in the same area, and Sind Minerals Ltd. in Mirpurkhas were reportedly also interested in establishing washing plants in the Nagar

Parker. In a fuller's earth development, the Punjab Mineral Development Corp. (Punjmin) started mining a montmorillonite clay at Dalona for use as an acid-activated bleaching earth. Presently, activated clays are largely imported for processing ghee and other edible oils. Expansions were also planned to eventually replace imported bleaching earths.[18]

Spain.—English China Clays PLC, through its subsidiary ECC Overseas Investments Ltd., increased its involvement in Spanish kaolin by acquiring 75% of the stock in Caosil S.A. for an undisclosed sum.[19]

ECC also had a 81.6% controlling interest in Ciá. Española de Caolines S.A. (Cedecsa). The Caosil and Cedecsa kaolinitic sand deposits will be operated separately. Caosil's quarries were at Peñalen in Guadalajara and wet-processed at Villaneuva. Kaolin from this complex, roughly 30,000 tpy, was mainly for the ceramics and paper industries. Cedecsa produced paper-grade kaolins, both coater and filler, from an operation at Poveda de la Sierra, also in Guadalajara. Coproduct bottle glass and ceramic grit sands were also produced at these locations.

U.S.S.R.—A large fully automated ceramic wall tile factory capable of producing about 75 million tiles per year was to be constructed in Novosibirsk.[20]

United Kingdom.—In view of a steady increase in demand worldwide for white pigments for the paper industry, ECC International Ltd. reported a number of developments to enable more marketplace efficiencies. In Cornwall and Devon, a major drive was authorized to boost production from the company's existing plants. Additional flotation and new comminution equipment had been added to permit both recovery of the valuable large particle-size kaolin and to increase output from the flotation units. Two new pits also were scheduled to come on-stream along with the newly recommissioned Lower Longstones clayworks, idle since the mid-1970's. A new greenfield site also was said to be near development in the St. Austell clay-bearing area and was expected to be completed by yearend 1988. In addition to seeking extra sources of clay and improved recovery, ECC was also contemplating further expansions at its Par Clay Slurry plant and Blackpool works. Improved filtration systems at the clay-drying plants were added to increase efficiency and throughput and reduce overhead. In total, the package of improvements reportedly represented an increase of more than 20% in production.[21]

The major increased production in Cornwall and Devon, largely targeted for export, required the upgrading of ECC's marshalling and discharge facilities in the port of Fowey.[22] Railfreight, in addition, also announced plans to build specialized hopper cars to transport china clay from ECC's clayworks to the port and to modernize British Rail's depot at St. Blazey. The Goonwean and Rostowrack China Clay Co. Ltd., the long- established independent producer with three Cornish pits, installed a new powder blend plant in St. Austell, Cornwall.[23] The new materials handling equipment included storage and handling systems with both mechanical and pneumatic conveyors.

Steetley Berk Ltd., a subsidiary of Steetley PLC, commissioned a new fully automated absorbent products mineral packing and distribution plant at Flixborough near Scunthorpe in South Humberside. The plant, to be opened at midyear, was to provide a full line of pet waste and industrial absorbent products. In addition, the plant was also designed with the ability to pack Spanish sepiolite clays from the producing Provinces of Madrid and Toledo. The Flixborough location was chosen solely because of its proximity to nearby Trent ports and important domestic freight routes for market distribution.[24] The international chemicals group of Laporte Industries disclosed plans to begin recovering fuller's earth from new deposits in Surrey, pending results of a scheduled public inquiry.[25] Hepworth Ceramic Holdings PLC bid for Thomas Marshall (Loxley) PLC, a fire clay refractory manufacturer.[26] Hepworth had three main areas of interest: the manufacture of clay pipes and plastic products for the building industry, the processing of silica sands mainly for the glass and foundry industries, and the manufacture of clay and basic refractory products. The Marshall acquisition will enable Hepworth to merge its other refractory subsidiary, G. R. Stein, and to exploit Marshall's presence in North America and Stein's extensive export base.

Table 27.—Kaolin: World production, by country[1]

(Thousand short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Algeria	[e]19	9	14	16	15
Argentina	160	100	81	129	110
Australia[3]	127	[4]241	[4]183	[e]140	165
Austria (marketable)	92	110	110	51	50
Bangladesh[5]	3	3	5	3	[6]14
Belgium	66	76	41	[e]44	[6]42
Brazil (beneficiated)	463	536	578	588	710
Bulgaria	267	282	283	292	290
Burundi	4	2	5	6	6
Chile	45	54	54	46	[6]48
Colombia	1,114	1,034	1,148	1,714	[6]1,346
Costa Rica[e]	1	1	--	--	--
Czechoslovakia	730	736	[e]720	[e]720	[6]768
Denmark[e]	11	15	14	[6]11	12
Ecuador	1	[r]3	3	[e]2	2
Egypt	110	159	119	141	145
Ethiopia (including Eritrea)[e]	10	10	10	10	6
France[7]	319	338	1,664	1,488	1,540
German Democratic Republic (marketable)[e]	220	190	190	180	165
Germany, Federal Republic of (marketable)	448	397	452	564	550
Greece	67	101	97	156	160
Hong Kong	1	([8])	11	1	--
Hungary	41	43	32	33	[6]37
India:					
Salable, crude	610	555	645	808	[6]870
Processed	[e]110	128	121	[e]110	165
Indonesia	66	92	118	138	140
Iran[e]	110	110	110	110	110
Israel[e]	[6]30	30	30	30	30
Italy:					
Crude	58	58	66	39	[6]134
Kaolinitic earth	28	28	29	21	[6]26
Japan	254	248	245	225	[6]175
Kenya	1	([8])	([8])	2	2
Korea, Republic of	754	795	726	937	[6]695
Madagascar[e]	3	3	[6]7	[r]7	[6]2
Malaysia	63	80	91	94	104
Mexico	179	144	311	[e]220	220
Mozambique	([8])	([8])	([8])	[e]([8])	([8])
New Zealand	26	28	[e]30	[e]30	30
Nigeria[e]	1	([6] [8])	([8])	([8])	([8])
Pakistan	14	13	7	41	35
Paraguay	50	55	66	[e]66	66
Peru	1	1	([8])	7	6
Poland	54	50	53	54	54
Portugal	114	115	88	60	[6]63
Romania[e]	450	450	450	[r]450	440
South Africa, Republic of	143	150	142	139	[6]167
Spain (marketable)[9]	281	352	456	413	420
Sri Lanka	9	12	6	7	[6]8
Sweden	([8])	([8])	[e]([8])	[e]([8])	([8])
Taiwan	113	88	84	70	[6]74
Tanzania	1	2	2	[e]2	2
Thailand	40	65	118	[7]146	[6 7]228
Turkey	[e]60	61	76	86	[6]148
U.S.S.R.[e]	2,900	3,100	3,200	3,300	3,300
United Kingdom	3,000	3,296	3,472	[e]3,400	3,500
United States[10]	7,203	7,953	7,793	8,549	[6]8,827
Venezuela	12	24	[e]25	24	32
Vietnam[e]	1	1	1	1	1
Yugoslavia	230	222	[r e]225	[r e]230	235
Zimbabwe	1	1	1	1	1
Total	21,289	[r]22,750	24,608	26,152	26,491

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

[1]Table includes data available through July 15, 1988.

[2]In addition to the countries listed, China, Lebanon, and Suriname also produced kaolin, but information is inadequate to make reliable estimates of output levels. Guatemala and Morocco each produced less than 500 tons in each of the years covered by this table.

[3]May include ball clay and other clays grouped for statistical purposes as kaolin.

[4]Excludes Western Australia.

[5]Data are for year ending June 30 of that stated.

[6]Reported figure.

[7]Includes kaolinitic clay.

[8]Less than 1/2 unit.

[9]Includes crude and washed kaolin and refractory clays not further described.

[10]Kaolin sold or used by producers.

Table 28.—Bentonite: World production, by country[1]

(Short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Algeria[3]	[e]38,100	[r]27,007	36,376	33,069	33,000
Argentina	149,439	[r]138,564	162,111	161,148	159,800
Australia[3]	33,098	43,180	32,044	27,494	27,500
Brazil	141,857	221,592	260,168	227,099	231,500
Burma	783	799	783	938	900
Cyprus[4]	[r]35,274	35,715	57,320	60,627	62,800
Egypt[e]	2,800	4,200	3,300	[r]5,650	5,700
France	3,407	3,831	16,424	[e]11,000	9,000
Greece	759,427	858,400	977,718	1,452,652	1,322,800
Guatemala[e]	8,800	9,400	[5]3,006	[r]2,800	2,900
Hungary	87,972	70,722	65,966	88,061	[5]108,391
Iran	15,432	38,581	29,762	[r e]30,000	30,000
Israel (metabentonite)	7,538	6,501	[e]6,600	[e]6,600	6,600
Italy	327,183	335,102	327,239	336,890	[5]364,149
Japan	486,034	452,034	508,749	527,184	[5]458,347
Kenya[e]	220	220	220	220	220
Mexico	249,276	294,700	295,083	160,937	165,300
Morocco	4,515	2,012	3,171	4,226	[5]3,250
Mozambique	276	446	398	1,226	1,200
New Zealand (processed)	2,158	7,075	[e]6,600	[e]6,600	6,600
Pakistan	735	1,918	1,776	1,501	2,600
Peru	16,656	14,298	2,223	36,464	33,100
Philippines	739	42,162	27,526	[e]22,000	22,000
Poland[e]	77,000	77,000	83,000	83,000	83,000
Romania[e]	195,000	198,000	198,000	204,000	198,000
South Africa, Republic of	43,573	46,131	47,910	53,203	[5]53,961
Spain	90,976	80,008	99,471	[e]88,000	89,000
Tanzania[e]	83	83	83	83	83
Turkey	[e]34,200	30,967	51,649	61,032	[5]94,631
U.S.S.R.[e]	3,163,600	3,174,700	3,185,700	3,196,700	3,196,700
United States	2,886,870	3,437,940	3,195,280	2,813,043	[5]2,806,233
Zimbabwe	69,552	[e]77,000	--	--	--
Total	[r]8,927,573	[r]9,730,288	9,685,656	9,703,447	9,579,265

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through July 22, 1988.
[2]In addition to the countries listed, Canada, China, the Federal Republic of Germany, and Yugoslavia are believed to produce bentonite, but output is not reported, and available information is inadequate to make reliable estimates of output levels.
[3]Includes bentonitic clays.
[4]Includes bleaching earths.
[5]Reported figure.

Table 29.—Fuller's earth: World production, by country[1]

(Short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Algeria[e]	5,500	[3]3,858	3,900	3,900	3,900
Argentina	7,431	3,980	1,921	[r e]2,200	2,200
Australia (attapulgite)[e]	16,500	16,500	16,500	16,500	16,500
Italy	[e]22,000	[e]33,000	33,500	34,127	[3]42,449
Mexico	45,827	50,372	63,934	[e]49,600	49,600
Morocco (smectite)	30,187	36,824	26,924	38,691	[3]51,005
Pakistan	23,298	21,097	11,736	16,785	18,700
Senegal (attapulgite)	110,644	127,315	105,774	90,232	[3]122,409
South Africa, Republic of	344	--	--	--	--
Spain (attapulgite)	49,223	48,399	65,805	[e]56,000	58,400
United Kingdom	211,644	222,666	[e]220,000	[e]220,000	220,000
United States[4]	1,911,634	1,899,145	2,059,281	1,909,978	[3]2,056,791
Total	2,434,232	2,463,156	2,609,295	2,438,013	2,641,954

[e]Estimated. [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. Table includes data available through July 22, 1988.
[2]In addition to the market economy 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.
[3]Reported figure.
[4]Sold or used by producers.

A $2 million contract was awarded to a Cardiff-based engineering group by ARC Powell Duffryn Brick Ltd., Risca, Gwent, for the reported construction of Europe's most modern brick factory to meet the increased demand for the company's bricks.[27] The new 35-million-bpy plant at Cirencester, Gloucestershire, to be commissioned at midyear, was to be fully automated and to incorporate the latest computer-aided technology. The factory, ARC Powell Duffryn Brick's sixth, is to be built adjacent to the quarry on a 4-acre site. Baggeridge Brick PLC announced a $15 million enlargement at its Kingsbury brickworks.[28] Contracts were signed with several brickmaking equipment companies and included a Clay Fawcett clay preparation plant and Lingl setting equipment and tunnel kiln, jointly designed by the latter and Baggeridge. Steetley acquired Lumley Brickwork Ltd., a well-established manufacturer of face brick in the northeast.[29] Steetley was planning to invest substantially in the Lumley business as part of its expansion north of England. Steetley's present brick holdings in 1987, Steetley Brick and Tile, headquartered in Newcastle-under-Lyme already was a leading supplier of facing brick and clay roof tiles in central England. Steetley was also actively increasing production capacity through major expansions at Parkhouse (bricks), Keele, and Knutton (tile).

TECHNOLOGY

The high-temperature properties of two clay fluids, formulated from commercially available domestic sodium bentonite and bentonite-saponite mixtures, were evaluated in the temperature range 300° to 600° F under appropriate confining pressures up to 16,000 pounds per square inch.[30] The study was designed to evaluate the effects of common drilling mud additives (such as sodium polyacrylates, lignite, and lignosulfonates) and formation contaminates (such as potassium, sodium, and calcium salts) in a geothermal well environment. The addition of saponitic clays to the bentonitic fluids exhibited a balanced viscosity at all temperatures and conditions tested. A constant viscosity is mandatory for optimizing drilling systems. The catalytic properties of layered aluminosilicate smectite-type clays were reviewed.[31] These catalysts have long been used for cracking hydrocarbons. More recent applications of intercalated clay catalysts and/or supports along with new clay-related chemistry, have burgeoned in recent years. There was further information about specific uses of clays in carbocatonic reactions and condensations of clay surfaces to cycloadditions and rearrangements and to redox reactions. The role of clay in biogenesis and/or prebiotic synthesis of the first biomolecules also was explored. The selective sorption of water-soluble oligomers, ethylene glycol, and ethylenimine, were observed on synthetic sediments containing predetermined amounts of kaolinite, illite, and montmorillonite clays.[32] This type of research should aid the design of inexpensive clay-base systems that preferentially strip unwanted contaminates and/or toxins from environmentally sensitive air and water systems. The tremendous diversity of modifying reagents in the rapidly advancing surface modification of minerals area, including kaolin and complex organic coupling agents to improve a particular mineral's mechanical, decorative, and thermal properties, are detailed.[33] The article cited specific examples of surface treatment describing the coating chemistry evaluated, the mode of application, and principal market outlets. A similar work focused on surface treatment of kaolins to improve the performance of filled nylon products.[34] Listed were improvements in flexural modulus heat deflection temperature and impact strength. Surface-treated calcined kaolin reinforcement is used in engineered high-tech compounds. Silane loading levels were also identified and compared for both medium- and fine-particle kaolins. Articles reviewed the growing mineral markets in plastics and paper. One article on plastics examined selected market sectors technically, specifically resins and thermosets, and related their consumption of mineral fillers in reinforcements and pigments for interior and exterior applications.[35] Another article outlined the technical means whereby plastics producers and fabricators can improve market position and/or penetration through innovation.[36] The area of greatest potential appeared to be product modification and/or redesign. The sales of unaltered minerals and surface-modified minerals also were examined. An article on paper reviewed the world sources of kaolin and its major markets.[37] The individual companies in each country, their products, capacities, locations, plans, and other pertinent data were highlighted. The other paper stressed the current and future technical trends in Western European graphic paper production.[38] The impact of mineral usage in graphic paper also was discussed. One section of the work presented a discussion on the industry structure, on a countrywide basis, stressing features such as mill capacities and output, paper grades, and new investment programs.

Statistical process control (SPC) in the mining and processing of air-floated kaolin was detailed.[39] SPC in this context is basically a cooperative agreement between a raw material supplier and a manufacturer that provides for quality assurance. The costly and time-consuming aspects of SPC are apparently being overridden by an ever-growing customer base of clay purchasers demanding improved and reliable product quality. Thermally activated kaolin and montmorillonites in a fixed-bed reactor were shown to have excellent pozzolanic activity when mixed with lime and water.[40] The material, readily available as an inexpensive raw clay, apparently possesses sufficient strength to permit use as a low-cost binder in developing countries. It is of interest to evaluate swelling-type clays for use as a pozzolana because they are conventionally excluded from consideration for building construction.

A comprehensive treatise looked at kaolin and associated clay minerals, such as ball, fire, and flint clays, from a geological viewpoint and described the classifications, origins, and mineralogy of worldwide kaolin deposits.[41] The paper, highlighting the deposits in the United States and the United Kingdom, also reviewed the main sources of kaolin and its major markets. A noteworthy aspect of the report was the exhaustive tables of typical kaolin filler, coating, and ceramic grade clays containing both physical and chemical properties. Similar tables are also shown for ball clays, flint clays, fire clays, and chamotte. An article focusing on the clay mineral potential of Turkey was published.[42] The article looks at the geology and formation of the Turkish clay deposits followed by the classification and outlook of the clay minerals encountered. Reserves, production, quality, and markets for kaolin, ball clays, refractory clays, bentonite (both white and sodium bentonite), sepiolites, and saponites are given in detail. A concise study on the industrial minerals of Pakistan included sections on kaolin, fuller's earth, bentonite, and fire clays in the four Provinces.[43] Geology, mining, production flowsheets, and operating companies were presented. A number of clay-testing techniques that must be applied in the proper technical evaluation of clays for use in ceramics was summarized.[44] The author exhorted those in the extractive industry to employ testwork programs specifically designed to assess the manufacturing potential of the clay raw materials to eliminate the ubiquitous downstream problems.

A series of papers described the technical aspects of mullite in the binary system Al_2O_3-SiO_2. One paper investigated the alumina-silica phase relations of samples annealed in oxygen, quenched, and studied by optical microscopy, image analysis, X-ray diffraction, and by the transmission electron microscope (TEM).[45] Careful analyses of data revealed that the solid solution boundaries of mullite changed with increasing temperature up to its peritectic melting at 1,890° C. A similar investigative technique, including differential thermal analysis (DTA), showed that the spinel phase form during the 980° C exothermic reaction in the kaolinite-mullite reaction series was nearly a pure Al_2O_3 composition.[46] Detailed TEM characterization indicated that the spinel formation is preceded by a phase separation in the amorphous dehydroxylated kaolinite matrix. The remaining two papers characterized mullites formed by sol-gel methods classified as either colloidal or polymeric.[47] The specimens formed from mullitic compositions from colloidal powders had mullite grains of prismatic shape and a liquid phase. With polymeric powders, mullite grains were equigranular with no liquid phase. The colloidal mullites were considered to be metastable, resulting from the nature of the starting material and processing conditions employed. The other research showed that mullite derived from slow-hydrolysis methods from silanes and hydrous aluminum nitrates gradually approached the stoichiometry of the bulk composition as the firing temperature increased and slightly departed again on further heating.[48] The mullites, which are end products of solid-state reactions involving kaolin, are widely used in refractory bricks and specialty products. The results of this basic research should allow refractory manufacturers to better control the physical properties of the mullite component to optimize the density of the resulting high-performance refractories.

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Cobalt

By William S. Kirk[1]

The cobalt market was characterized by stable prices and an increase in consumption. The major markets for cobalt, representing diverse sectors of the economy—aircraft, magnetic materials, and driers used in paint—were not particularly strong.

Domestic Data Coverage.—The Bureau of Mines surveyed superalloy recyclers to determine the quantity of cobalt recycled in superalloy scrap. Thirteen recyclers processed the vast majority of superalloy scrap. Eight of the recyclers responded to requests concerning the quantity of cobalt contained in scrap sold to superalloy producers.

Table 1.—Salient cobalt statistics

(Thousand pounds of contained cobalt unless otherwise specified)

	1983	1984	1985	1986	1987
United States:					
Consumption:					
Reported	11,319	12,944	13,541	14,442	15,099
Apparent	15,712	17,895	15,692	17,373	17,820
Imports for consumption	17,221	25,310	17,708	12,288	19,472
Stocks, Dec. 31:					
Consumer	1,441	1,368	1,131	1,479	2,056
Processor	1,366	1,781	1,557	1,441	2,632
Price: Metal, per pound[1]	$5.76	$10.40	$11.43	$7.49	$6.56
World: Production:[2]					
Mine	r83,499	r90,555	106,504	p107,812	e103,246
Refinery	r39,869	r52,089	59,317	p67,622	e59,391

eEstimated. pPreliminary. rRevised.
[1]Based on weighted average of Metals Week prices.
[2]In 1986, the units for "World: Production" were changed from short tons to thousand pounds. Some differences between these and previously published data might be encountered owing to differences in conversion methods.

Legislation and Government Programs.—The Institute of Scrap Iron and Steel (ISIS) urged the Environmental Protection Agency (EPA) to remove cobalt from EPA's extremely hazardous substances interim final test. ISIS pointed out that cobalt did not meet EPA's original listing criterion of toxicity. If cobalt were allowed to stay on the list, many scrap processors and scrap consumers would become subject to emergency planning requirements because of the presence of cobalt in the scrap metal that they routinely handle.

The administration presented Congress with a National Defense Stockpile plan that foresaw the total sale of as much as $775 million worth of material by 1990. Cobalt was included in the list of materials.

Table 2.—U.S. cobalt products[1] produced and shipped by refiners and processors

(Thousand pounds of contained cobalt)

	1986		1987	
	Production	Shipments	Production	Shipments
Driers (organic compounds)	1,563	1,423	1,838	1,751
Hydrate (hydroxide)	109	962	1,386	1,014
Salts[2] (inorganic compounds)	748	810	745	797
Total	2,420	3,195	3,969	3,562

[1]Figures on oxide withheld to avoid disclosing company proprietary data.
[2]Various salts combined to avoid disclosing company proprietary data.

CONSUMPTION AND USES

Reported consumption was 15.1 million pounds compared with 14.4 million pounds in 1986. Apparent consumption, calculated from net imports, secondary (scrap) consumption, and changes in industry and Government stocks, increased to 17.8 million pounds. Of the 6.3 million pounds of cobalt reported to have been used in the production of superalloys during the year, approximately 500,000 pounds was used in the production of prosthetic devices (surgical implants), according to industry sources. In general, alloys used in prosthetic devices and superalloys were produced in the same facilities.

Table 3.—U.S. consumption of cobalt, by end use

(Thousand pounds of contained cobalt)

End use	1986	1987
Steel:		
Full-alloy	W	W
High-strength, low-alloy	W	W
Stainless and heat-resisting	76	57
Tool	256	383
Superalloys[1]	6,446	6,273
Alloys (excludes alloy steels and superalloys):		
Cutting and wear-resistant materials[2]	726	1,174
Magnetic alloys	1,791	1,719
Nonferrous alloys	W	W
Welding materials (structural and hard-facing)	W	W
Other alloys	118	94
Mill products made from metal powder	W	W
Chemical and ceramic uses:		
Catalysts	1,445	1,096
Drier in paint or related usage	1,593	1,968
Feed or nutritive additive	46	53
Glass decolorizer	40	37
Ground coat frit	771	794
Pigments	462	570
Miscellaneous and unspecified	672	883
Total	14,442	[3]15,099

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."
[1]Data not comparable to those prior to 1986 because of the addition of statistical canvass coverage of the superalloy recycling industry.
[2]Cemented and sintered carbides and cast carbide dies or parts.
[3]Data do not add to total shown because of independent rounding.

Table 4.—U.S. consumption of cobalt, by form

(Thousand pounds of contained cobalt)

Form	1983	1984	1985	1986	1987
Chemical compounds (organic and inorganic) other than oxide	2,297	2,226	1,850	1,738	2,167
Metal	7,165	8,746	9,463	8,594	9,212
Oxide	938	915	1,201	1,233	1,129
Purchased scrap	723	879	897	2,638	2,509
Other	196	178	130	239	82
Total	11,319	12,944	13,541	14,442	15,099

PRICES

The year was marked by price stability as Zaire and Zambia were moderately successful in their efforts to maintain the producer price of $7.00 per pound. Representatives from the two countries met in November to hold discussions on prices and reaffirmed the price of $7.00 per pound set in 1986. They further agreed that Zaire would concentrate on high-quality cobalt while Zambia would focus on the lower grade markets. Although the two producers considered $7.00 to be a ceiling price, they naturally wanted to sell their cobalt as close to that level as possible. To this end, they withheld cobalt from merchants and took steps to see that consumers did not sell excess cobalt on the open market. The price of electrolytic cobalt began the year at a range of $6.25 to $6.50 per pound, ending at $6.50 to $6.85 per pound, while averaging $6.56 per pound.

Table 5.—Yearend published prices of cobalt materials[1]

(Dollars per pound)

Material	1983	1984	1985	1986	1987[2]
Cobalt:[3]					
Fine powder	10.11	16.63	19.05	15.30	16.75
Powder	6.91	13.24	14.87	14.47	13.84
Cobalt oxide:					
Ceramic-grade (70% cobalt)	4.90	9.40	9.98	6.08	8.80
Ceramic-grade (72% cobalt)	5.04	9.66	10.26	6.24	9.04
Metallurgical-grade (76% cobalt)	5.21	9.86	10.61	6.51	9.41

[1]Metals Week.
[2]Represents prices as of Jan. 21, 1988, yearend 1987 prices were not available.
[3]See table 1 for cathode price.

FOREIGN TRADE

Exports of unwrought cobalt metal and waste and scrap totaled 806,000 pounds, gross weight, valued at $7.0 million. These exports were shipped to 34 countries, with Japan, Belgium, and Canada, in descending order, receiving the largest quantities.

Exports of wrought metal totaled 567,000 pounds, gross weight, valued at $11 million. Of the 21 countries to which cobalt was shipped, the major recipients, in descending order, were Canada, Japan, and France.

Imports for consumption of cobalt metal originating in south-central Africa, that is, imports from Belgium (Zairian origin), Zaire, and Zambia, represented 66% of total cobalt imports compared with 40% from that area in 1986.

Table 6.—U.S. imports for consumption of cobalt, by class

(Thousand pounds and thousand dollars)

Class	1985	1986	1987
Metal:[1]			
Gross weight	16,613	11,669	18,612
Cobalt content[e]	16,613	11,669	18,612
Value	$181,379	$83,295	$122,791
Oxide:			
Gross weight	246	511	795
Cobalt content[e]	182	378	588
Value	$2,258	$4,202	$5,293
Salts and compounds:			
Gross weight	1,413	805	903
Cobalt content[e]	424	241	271
Value	$4,413	$2,669	$2,004
Other forms:[2]	489	NA	NA
Value	$3,356	NA	NA
Total content	17,708	12,288	[3]19,472

[e]Estimated. NA Not available.
[1]Includes unwrought metal and waste and scrap.
[2]Contained cobalt in nickel-copper and nickel matte.
[3]Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

Table 7.—U.S. imports for consumption of cobalt, by country

(Thousand pounds and thousand dollars)

Country	Metal[1]				Oxide[2]				Other forms				Total content[3 4]	
	1986		1987		1986		1987		1986		1987			
	Gross weight	Value	Gross weight	Value	Gross weight	Value	Gross weight	Value	Cobalt content	Value	Cobalt content	Value	1986	1987
Australia	6	22	3	11	NA	NA	--	--	--	--	--	--	6	3
Belgium	512	2,535	281	2,618	325	2,602	331	2,414	15	136	6	85	768	532
Canada	3,324	24,643	3,317	20,774	19	161	73	497	17	134	19	108	3,355	3,390
Finland	583	6,494	363	4,160	2	16	51	349	6	172	9	93	590	410
France	84	566	85	428	6	184	3	80	--	--	([5])	10	88	87
Germany, Federal Republic of	227	1,507	146	1,726	35	433	45	87	13	139	2	99	266	181
Japan	620	4,392	1	75	--	--	([5])	3	34	382	13	373	654	14
Netherlands	33	227	262	1,636	34	147	178	1,142	--	--	--	--	58	394
Norway	1,807	18,015	1,551	9,320	--	--	--	--	--	--	1	3	1,807	1,552
South Africa, Republic of	22	179	1	7	--	--	--	--	23	51	191	799	45	192
United Kingdom	138	626	151	546	90	659	44	266	116	1,535	27	409	321	211
Zaire	694	3,931	9,361	63,835	--	--	49	337	9	69	1	18	703	9,398
Zambia	3,501	19,834	2,919	17,040	--	--	--	--	--	--	--	--	3,501	2,919
Other	118	325	171	618	--	--	21	115	9	50	1	7	127	187
Total[4]	11,669	83,295	18,612	122,791	511	4,202	795	5,293	241	2,662	271	2,004	12,288	19,472

NA Not available.
[1]Includes unwrought metal and waste and scrap.
[2]Gross weight figures for cobalt oxide do not indicate cobalt content.
[3]Estimated contained cobalt.
[4]Data may not add to totals shown because of independent rounding.
[5]Less than 1/2 unit.

Source: Bureau of the Census.

Table 8.—U.S. import duties for cobalt

Item	TSUS No.	Most favored nation (MFN) Jan. 1, 1987	Non-MFN Jan. 1, 1987
Alloys, unwrought[1]	632.88	5.5% ad valorem	45% ad valorem.
Chemical compounds:			
Oxide	418.60	1.2 cents per pound.	20 cents per pound.
Sulfate	418.62	1.4% ad valorem	6.5% ad valorem.
Other	418.68	4.2% ad valorem	30% ad valorem.
Ore and concentrate	601.18	Free	Free.
Unwrought metal, waste and scrap	632.20	do	Do.

[1]Duty on unwrought alloys of cobalt, containing by weight 76% or more but less than 99% cobalt, temporarily suspended (on or before Dec. 31, 1987).

WORLD REVIEW

Australia.—Freeport-McMoRan Inc., New Orleans, LA, sold its 50% share of the Greenvale nickel-cobalt facilities in Queensland to Dallhold Investments Pty. Ltd., an Australian investment company. Later in the year, Dallhold purchased the other 50% of the Greenvale project from another Australian company, Metals Exploration Ltd.

Brazil.—Companhia Niquel Tocantins, a Brazilian nickel producer, was planning to start production of electrolytic cobalt at its new São Miguel Paulista plant in São Paulo State by January 1988. The company had been producing a cobalt concentrate, which was sent to Falconbridge Ltd.'s refinery in Norway for processing. Initial production capacity for the plant was to be 330 short tons per year, rising to 660 tons by 1990. Although these quantities were minuscule on a global scale, they were expected to make Brazil self-sufficient in cobalt. The country had been dependent on imports from Canada, Norway, Zaire, and Zambia. Brazilian cobalt consumption had been growing by more than 10% annually.

Canada.—Inco Ltd. reached an agreement in September on a new 3-year contract with mining and production workers at its Thompson plant in Manitoba. Under the terms of the contract, which received approval from 58% of union members, workers were to receive a 50-cent-per-hour salary increase the first year and a 25-cent increase each of the next 2 years plus a cost-of-living increase over the life of the agreement.

Finland.—Outokumpu Oy, the state-owned cobalt and nickel producer, restructured its cobalt operations by suspending production of standard-grade cobalt powder and briquets. Sherritt Gordon Mines Ltd., Canada, was left as the only major source of standard-grade cobalt powder. Outokumpu decided to focus instead on producing extra fine powder and cobalt chemicals. The cobalt content of the materials produced was to stay at the same level.

Outokumpu was granted a Government subsidy to maintain processing operations at its Keretti copper-cobalt mine until the end of June 1988. The mine was then slated to close because its cobalt production had become unprofitable.

India.—Hindustan Zinc Ltd. (HZL), a metals producer, announced plans to establish India's first cobalt recovery plant. Cobalt was to be extracted from lead-zinc ores at HZL's facility in Udaipur, using a process similar to the one that was being used to recover silver from zinc concentrates.

Japan.—Metal Mining Agency of Japan and National Nonferrous Metals Industry Corp. of China signed an agreement in August 1986 to explore for cobalt and other metals in China. The agreement took effect in October 1987, with surveying in Heilongjiang Province, northern China. Exploration, which was also to be done in Guangdong Province in southern China, was scheduled to end in 1991.

Philippines.—According to reports, the U.S.S.R. made a proposal to provide financial and technical assistance to Nonoc Mining and Industrial Corp. Nonoc, a Philippine cobalt and nickel mining company, shut down its operations in 1986 owing to a lack of funds.

South Africa, Republic of.—The Lonrho Corp., United Kingdom, gained almost full ownership of Western Platinum Ltd. (Wesplat) by purchasing a 49% share from Falconbridge, a Canadian nickel and cobalt producer. Wesplat produced cobalt as a byproduct of its platinum mining operations in the Republic of South Africa. Lonrho had the right of first refusal over the Falconbridge shares owing to an agreement entered into 17 years ago when the mine was first developed.

Zaire.—Angola, Zaire, and Zambia announced plans to reopen the Benguela Railway, which had been closed for 12 years. The 800-mile line, which once carried most of Zaire's and Zambia's copper exports to the Angolan Port of Lobito, was seen as an alternative to trade routes through the Republic of South Africa, and if rehabilitated, could be used to transport cobalt. The railway ran from Zambia's northern Port of Lobito. The three countries were planning to set up a new company to repair and operate the line.

Similarly, representatives of the nine-member Southern African Development Corporation Conference were seeking support for their efforts to upgrade the Tanzania-Zambia Railway, a main shipping route from Zambia that ends in Dar es Salaam, Tanzania. The route allows shipping of Zambian copper and cobalt without going through South African ports.

Table 9.—Cobalt: World production, by country[1]

(Thousand pounds)

Country	Mine output, metal content[2]					Metal[3]				
	1983	1984	1985	1986[p]	1987[e]	1983	1984	1985	1986[p]	1987[e]
Albania[e]	1,000	1,300	1,300	1,300	1,300	--	--	--	--	--
Australia[4]	[e]2,540	[e]2,380	6,693	5,357	5,500	--	--	--	--	--
Botswana	491	570	489	357	[5]401	--	--	--	--	--
Brazil[e]	[5]260	220	220	330	330	--	--	--	--	--
Canada[6]	3,492	5,125	4,556	5,481	5,700	2,918	4,680	4,460	4,387	4,850
Cuba	3,573	3,079	[r e]3,280	[r e]3,300	3,500	--	--	--	--	--
Finland	2,281	[r]1,896	1,587	1,382	600	3,417	3,203	3,146	2,972	[7]2,721
France	--	--	--	--	--	288	255	[e]240	[e]220	240
Japan	--	--	--	--	--	3,022	1,995	2,813	2,949	[5]273
New Caledonia[e 8]	880	1,100	1,490	1,540	1,650	--	--	--	--	--
Norway	--	--	--	--	--	1,937	2,625	3,608	3,483	[5]3,527
Philippines	363	141	2,008	200	--	--	--	--	--	--
South Africa, Republic of[e]	1,500	1,500	1,500	1,500	1,600	1,100	1,100	1,100	1,100	1,150
U.S.S.R.[e]	5,300	5,700	6,000	6,200	6,200	9,700	10,400	10,600	10,800	10,800
United States	--	--	--	--	--	205	--	--	--	--
Zaire	54,602	57,194	64,375	[r e]68,000	64,000	11,816	20,006	23,539	31,967	26,400
Zambia	7,052	10,185	12,786	[e]12,700	12,300	5,306	7,654	9,609	9,576	9,260
Zimbabwe	[e]165	[e]165	[e]220	[r e]165	165	160	171	202	168	170
Total	[r]83,499	[r]90,555	106,504	107,812	103,246	[r]39,869	[r]52,089	59,317	67,622	59,391

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

[1]Table includes data available through May 13, 1988. In 1986, the units in this table were changed from short tons to thousand pounds. Some differences between these and previously published data might be encountered owing to differences in conversion methods.

[2]Figures represent recoverable cobalt content. In addition to the countries listed, Bulgaria, the German Democratic Republic, Greece, Indonesia, Poland, Spain, and Uganda are known to produce ores that contain cobalt. Information is inadequate for reliable estimates of output levels. Other copper- and/or nickel-producing nations may also produce ores containing cobalt as a byproduct component, but recovery is small or nil.

[3]Figures represent elemental cobalt recovered unless otherwise specified. In addition to the countries listed, Czechoslovakia presumably recovers cobalt from Cuban nickel-cobalt oxide and oxide sinter; Belgium has imported small quantities of partly processed materials containing cobalt, but available information is inadequate to form reliable estimates of cobalt recovery from these materials.

[4]Australia does not refine cobalt. Figures represent quantities of cobalt contained in intermediate metallurgical products (cobalt oxide and nickel-cobalt sulfide). Actual quantities of cobalt mined were as follows, in thousand pounds: 1983—5,041; 1984—4,700 (estimated); 1985—4,000 (estimated); 1986—3,600 (estimated); and 1987—3,600 (estimated).

[5]Reported figure.

[6]Actual output is not reported. Data for mine output are total cobalt content of all products derived from ores of Canadian origin, including cobalt oxide 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.

[7]Includes salts.

[8]Series reflects recovery from ores and intermediate metallurgical products exported from New Caledonia to France, Japan, and the United States. The estimated content of total ores mined is as follows, in thousand pounds: 1983—6,929; 1984—9,025; 1985—11,433; 1986—11,000; and 1987—12,787.

TECHNOLOGY

Cobalt-rich manganese crusts in the Exclusive Economic Zone (EEZ) represented a resource of cobalt and other metals. The EEZ is the area within 200 nautical miles of the coastline of the United States, Puerto Rico, the Northern Mariana Islands, and the U.S. overseas territories and possessions. Three promising chemical processes for extracting metals from the crusts were investigated: sulfuric acid oxidation pressure leaching, aqueous sulfur dioxide leaching, and acid sulfation. Each resulted in metal extractions exceeding 95%. The advantages of each were described.[2]

The International Strategic Minerals Inventory (ISMI) Summary Report on cobalt was published by the U.S. Geological Survey.[3] ISMI was a cooperative data-collection effort of earth-science and mineral-resource agencies in Australia, Canada, the Federal Republic of Germany, the Republic of South Africa, the United Kingdom, and the United States. Part I of the two-part report presented an overview of the resources and potential supply of cobalt on the basis of inventory information that covered only discovered deposits. Part II contained tables of some of the geologic information and mineral-resource and production data that were collected by ISMI participants.

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Columbium and Tantalum

By Larry D. Cunningham[1]

The United States remained dependent on imports of columbium and tantalum materials, and there continued to be no domestic mine production of either mineral. Imports for consumption of columbium concentrates increased substantially to the highest level since 1980, with Canada continuing as the leading supplier. However, imports for consumption of tantalum concentrates fell to the lowest level since 1983 as processors continued to draw from inhouse inventories.

Overall reported consumption of columbium in the form of ferrocolumbium and nickel columbium was up slightly, most improvement occurring in the carbon and stainless steel end-use categories. The tantalum market showed some signs of recovery, evidenced by modest increases in the reported shipments of tantalum products and the sales of tantalum capacitors. Columbium and tantalum corporate restructuring continued.

Columbium price quotations were little changed, whereas tantalum concentrate prices reached the highest level since midyear 1985. Net U.S. trade for both columbium and tantalum continued at a deficit. Overall trade volume and value increased modestly for both exports and imports.

The President approved plans for construction of the proposed Superconducting Super Collider (SSC), pending appropriation of funds by Congress. The SSC's superconducting magnets will require about 1 million pounds of a columbium-titanium alloy. Also, the President announced an 11-point superconductivity initiative intended to promote the rapid commercialization of superconductor technology.

Domestic Data Coverage.—Domestic production data for ferrocolumbium are developed by the Bureau of Mines from the annual voluntary domestic survey for ferroalloys. Of the four operations to which a survey request was sent, all responded, representing 100% of total production. Ferrocolumbium production data are withheld for 1987 to avoid disclosing company proprietary data.

Table 1.—Salient columbium statistics

(Thousand pounds of columbium content unless otherwise specified)

	1983	1984	1985	1986	1987
United States:					
Mine production of columbium-tantalum concentrates	--	--	--	--	--
Releases from Government excesses	--	--	--	--	--
Consumption of raw materials[e]	1,900	2,600	2,000	W	W
Production of ferrocolumbium	W	W	W	W	W
Consumption of primary products: Ferrocolumbium and nickel columbium[e]	4,318	5,399	5,968	[r]4,995	5,179
Exports: Columbium metal, compounds, alloys (gross weight)[e]	100	100	120	120	130
Imports for consumption:					
Mineral concentrates[e]	730	1,790	1,290	1,320	2,010
Columbium metal and columbium-bearing alloys[e]	2	10	1	5	42
Ferrocolumbium[e]	2,539	4,343	4,699	[r]3,432	4,016
Tin slags[e 1]	W	W	W	W	W
World: Production of columbium-tantalum concentrates[e]	18,911	[r]30,690	[r]32,729	[r]32,122	29,370

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Receipts reported by consumers; includes synthetic concentrates and other miscellaneous materials, after deduction of reshipments.

Table 2.—Salient tantalum statistics

(Thousand pounds of tantalum content unless otherwise specified)

	1983	1984	1985	1986	1987
United States:					
Mine production of columbium-tantalum concentrates	--	--	--	--	--
Releases from Government excesses	--	--	--	--	--
Consumption of raw materials[e]	900	1,300	1,100	W	W
Exports:					
Tantalum ores and concentrates (gross weight)[1]	121	156	122	71	103
Tantalum metal, compounds, alloys (gross weight)	211	352	369	392	413
Tantalum and tantalum alloy powder (gross weight)	123	151	143	160	193
Imports for consumption:					
Mineral concentrates[e]	180	680	230	280	220
Tantalum metal and tantalum-bearing alloys[2]	27	47	32	46	60
Tin slags[e 3]	W	W	W	W	W
World: Production of columbium-tantalum concentrates[e]	690	710	[r]732	[r]430	523

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Includes reexports.
[2]Exclusive of waste and scrap.
[3]Receipts reported by consumers; includes synthetic concentrates and other miscellaneous materials, after deduction of reshipments.

Table 3.—Columbium and tantalum materials in Government inventories as of December 31, 1987

(Thousand pounds of columbium or tantalum content)

Material	Stockpile goals	National Defense Stockpile inventory		
		Stockpile-grade	Nonstockpile-grade	Total
Columbium:				
Concentrates	5,600	1,150	869	[1]2,019
Carbide powder	100	21	--	21
Ferrocolumbium	--	598	333	[1]931
Metal	--	45	--	[1]45
Total	(2)	1,814	1,202	3,016
Tantalum:				
Minerals	8,400	1,686	1,152	[3]2,838
Carbide powder	--	29	--	[3]29
Metal	--	201	(4)	[3]201
Total	(2)	1,916	1,152	3,068

[1]All surplus ferrocolumbium and columbium metal were used to offset the columbium concentrates shortfall. Total offset was 1,148,000 pounds.
[2]Overall goals, on a recoverable basis, total 4,850,000 pounds for the columbium metal group and 7,160,000 pounds for the tantalum metal group.
[3]All surplus tantalum carbide powder and tantalum metal were used to offset the tantalum minerals shortfall. Total offset was 271,000 pounds.
[4]100 pounds.

Sources: Federal Emergency Management Agency and General Services Administration.

Legislation and Government Programs.—At yearend, Government stocks of columbium and tantalum in the National Defense Stockpile were the same as those of 1986. Under the offset concept, 57% of the goal for columbium concentrates and 37% of the goal for tantalum minerals were met (table 3).

In January, the President approved construction of a $4 billion SSC, particle accelerator. The SSC is targeted for completion in 1996 if funding is approved by Congress. The United States intends to seek cost-sharing commitments from other nations as well as from private industry and State and local governments wherever the SSC is to be located. More than 40 States expressed interest in the project. It is estimated that more than 10,000 superconducting magnets using about 1 million pounds of a 50% columbium—50% titanium alloy will be needed for the project.

In July, the President also announced an 11-point superconductivity initiative intended to promote the rapid commercialization of superconductor technology. The initiative includes amending antitrust and patent laws and freedom-of-information policies; establishing an Advisory Group on Superconductivity under the White House Science Council; establishing new offices, programs, and research funds for the U.S. Departments of Commerce, Defense, Energy, and the National Science Foundation; and seeking reciprocal opportunities for Japan and the United States to participate in each other's research and development programs.

DOMESTIC PRODUCTION

No domestic mineral production of either columbium or tantalum was reported in 1987.

Domestic production of ferrocolumbium, expressed as contained columbium, increased 20% more than that of 1986. The value of ferrocolumbium production increased to an estimated $11 million. The regular grade continued to be favored over the high-purity grade of ferrocolumbium in the production mix.

Tantalum content of raw materials consumed by processors in the production of tantalum compounds and metals was virtually unchanged from that of 1986. Consumption of purchased metal scrap was estimated to be about 130,000 pounds.

Bayer AG, Federal Republic of Germany, acquired the remaining 50% interest of NRC Inc., Newton, MA, from Samincorp Inc. Bayer already held a 50% share in NRC, a major U.S. producer of tantalum products, through its 90% subsidiary Hermann C. Starck Berlin KG, which was acquired in 1986.

Metallurg Inc. announced that the two companies representing it in the United States, Metallurg Alloy Corp. and Shieldalloy Corp., were to be merged into a single company to improve efficiency. The merger was to take effect on January 1, 1988, with the new company adopting the name Shieldalloy Metallurgical Corp. Metallurg Alloy is a supplier of bulk and specialty ferroalloys, and Shieldalloy is a supplier of specialty ferroalloys, aluminum master alloys, and a variety of metal powders, carbides, and vanadium chemicals.

Fansteel Inc. reportedly planned to install a 1.2-megawatt electron-beam furnace at its plant in Muskogee, OK. The furnace, to be operational by early 1989, was to meet company needs foreseen for high-purity columbium and tantalum metals in products ranging from weapon systems to superconductors.

Table 4.—Major domestic columbium and tantalum processing and producing companies in 1987

Company	Plant location	Products[1] Metal[2] Cb	Metal[2] Ta	Carbide Cb	Carbide Ta	Oxide and/or salts Cb	Oxide and/or salts Ta	FeCb and/or NiCb
Cabot Corp	Boyertown, PA	X	X	--	--	X	X	--
Do	Revere, PA	--	--	--	--	--	--	X
Fansteel Inc	Muskogee, OK	X	X	--	--	X	X	--
Do	North Chicago, IL	--	X	--	--	--	--	--
Kennametal Inc	Latrobe, PA	--	--	X	X	--	--	--
Metallurg Inc.: Shieldalloy Corp	Newfield, NJ	--	X	X	X	--	--	X
NRC Inc.[3]	Newton, MA	X	X	--	--	--	--	--
Reading Alloys Inc	Robesonia, PA	--	--	--	--	--	--	X
Teledyne Inc.: Teledyne Wah Chang Albany Div.	Albany, OR	X	--	--	--	X	--	X

X Indicates processor and/or producer.

[1]Cb, columbium; Ta, tantalum; FeCb, ferrocolumbium; NiCb, nickel columbium.

[2]Includes miscellaneous alloys.

[3]Jointly owned by Bayer U.S.A. and Hermann C. Starck Berlin KG.

CONSUMPTION, USES, AND STOCKS

Overall reported consumption of columbium as ferrocolumbium and nickel columbium was up by about 4% compared with that of 1986. Consumption of columbium by the steelmaking industry increased by 6%, affected by a modest increase in raw steel production, with a slight decrease in the percent of columbium usage per ton of steel produced. Columbium consumption in carbon steel and stainless and heat-resisting steel increased by about 15% each, influenced by production increases in the respective steel end-use categories.

Demand for columbium in superalloys continued to be depressed. This was the first year since 1983 that consumption in this category was less than 1 million pounds. That portion used in the form of nickel columbium continued to decline by 30% to about 300,000 pounds. However, columbium usage in superalloys reportedly was on the rise at yearend, owing to increased demand for Alloy 718 and the apparent reduced availability of Alloy 718 scrap feed material. Alloy 718, a columbium-containing nickel-base alloy, is widely used in aircraft turbine engines.

The Tantalum Producers Association reported an increase of almost 10% in overall tantalum shipments, indicating the tantalum market was recovering somewhat from the downturn that started in 1985. The alloy additive segment had the most significant gain, more than 50%. The growth of tantalum as an alloying element in superalloys, having application in heat-resisting turbine engine components, continued on the upswing. However, tantalum for cemented carbide was down substantially after increasing significantly in 1986. The use of tantalum in cemented carbides was affected by the growing use of coated cutting tools and improved tool life.

Factory sales of tantalum capacitors were up by 16% to the highest level since 1984, as reported by the Electronic Industries Association. Industry sources reported that tantalum capacitor sales should continue to increase for the short term, owing to the introduction of new computer models, a major market. The Penn Central Corp. (PCC) completed the spin-off of its Sprague Technologies Inc. (STI) subsidiary. STI was the holding company that owned the stock of Sprague Electric Co., a major manufacturer of tantalum capacitors, and Solid Scientific Inc., which comprised PCC's electronic operations. Approximately 94% of STI common stock was distributed to holders of PCC common stock, with the remaining shares being retained by PCC for corporate purposes. Union Carbide Corp. transferred its electronic capacitor business to newly formed KEMET Electronics Corp. KEMET, 50% owned by Union Carbide and 50% by senior management of KEMET, was to manufacture tantalum, ceramic, and film capacitors under the KEMET trademark. General Electric Credit Corp., which provided financing for the venture, reportedly had future rights to acquire a 35% interest in KEMET, to be drawn from the remaining 50% interest held by senior management of KEMET.

Data on aggregate stocks of columbium and tantalum raw materials reported by processors for 1987 were incomplete at the time this chapter was prepared. Aggregate stocks for yearend 1986 were down from those of yearend 1985 by about 10% for columbium and more than 20% for tantalum.

Table 5.—Reported shipments of columbium and tantalum materials

(Pounds of metal content)

Material	1986	1987
Columbium products:		
Compounds including alloys	846,900	914,900
Metal including worked products	375,000	399,800
Other	--	600
Total	1,221,900	1,315,300
Tantalum products:		
Oxides and salts	19,910	20,120
Alloy additive	111,700	174,200
Carbide	127,000	69,500
Powder and anodes	482,900	556,300
Ingot (unworked consolidated metal)	8,600	100
Mill products	261,200	282,500
Scrap	7,600	13,400
Other	--	--
Total	1,018,910	1,116,120

Source: Tantalum Producers Association.

Table 6.—Consumption, by end use, and industry stocks of ferrocolumbium and nickel columbium in the United States

(Pounds of contained columbium)[1]

	1986	1987
END USE		
Steel:		
Carbon	1,395,792	1,613,710
Stainless and heat-resisting	801,370	919,807
Full alloy	([2])	([2])
High-strength, low-alloy	1,715,846	1,653,853
Electric	--	--
Tool	([3])	([3])
Unspecified	48,607	12,803
Total	3,961,615	4,200,173
Superalloys	1,008,364	883,149
Alloys (excluding alloy steels and superalloys)	18,813	90,974
Miscellaneous and unspecified	6,000	4,500
Total consumption	4,994,792	5,178,796
STOCKS		
Dec. 31:		
Consumer	W	W
Producer[4]	W	W
Total stocks[e]	780,000	710,000

[e]Estimated. W Withheld to avoid disclosing company proprietary data; included in "Total stocks."
[1]Includes columbium and tantalum in ferrotantalum-columbium, if any.
[2]Small; included with "Steel: High-strength, low-alloy."
[3]Included with "Steel: Unspecified."
[4]Ferrocolumbium only.

PRICES

Prices continued to be stable for pyrochlore concentrates and for columbium products based on them. The published price for pyrochlore concentrates produced in Canada was quoted throughout 1987 at $2.60 per pound of contained columbium pentoxide (Cb_2O_5), f.o.b. Canada, for concentrates with a nominal content of 57% to 62% Cb_2O_5. A published list price for Brazilian-produced pyrochlore concentrates was not available. The quoted spot price of regular-grade ferrocolumbium containing 63% to 68% columbium remained unchanged at $5.66 per pound of contained columbium, f.o.b. shipping point.

The quoted price for high-purity ferrocolumbium containing 62% to 68% columbium remained at $17.00 to $17.50 per pound of contained columbium, f.o.b. shipping point. The spot price for columbite concentrates was unchanged at $2.00 to $2.50 per pound of combined Cb_2O_5 and tantalum pentoxide (Ta_2O_5), c.i.f. U.S. ports. At yearend, nickel columbium was reported to be selling for about $15 per pound of contained columbium, and columbium oxide was reported to be selling for less than $7 per pound of oxide.

The published spot-market price for tantalite, on the basis of 60% combined Cb_2O_5 and Ta_2O_5, c.i.f. U.S. ports, which began the year at $18.50 to $23.00, was being quoted at $24.00 to $28.00 by yearend, the highest level since midyear 1985. The contract price for tantalite from both the Canadian tantalum producer, Tantalum Mining Corp. of Canada Ltd. (TANCO), and from Greenbushes Ltd. of Australia remained suspended. Published price quotations for tantalum mill products and powders, quoted in the range of $100 to $160 per pound throughout the first quarter, were suspended in mid-April. At the same time, the published price for tantalum carbide was suspended at $52 to $54 per pound.

FOREIGN TRADE

Net trade continued at a deficit for both columbium and tantalum. Overall trade volume and value were up by more than 10% for both exports and imports. Exports and reexports of tantalum ore and concentrates increased by 45% to 103,000 pounds valued at $812,000. The Netherlands was the principal recipient with about 80% of total shipments.

The value of imports of raw materials and intermediates, such as ferrocolumbium and columbium oxide, again exceeded the value of reported columbium and tantalum exports by more than 50%. Imports for consumption from Brazil included about 6.2 million pounds of ferrocolumbium with a value of $20.4 million, compared with 5.3 million pounds valued at $16.4 million in 1986. Imports for consumption of columbium oxide from Brazil increased to 1.6 million pounds valued at $9.5 million, compared with 1.3 million pounds valued at $7.6 million in 1986. Contained in the columbium oxide imports were an estimated 37,000 pounds of tantalum oxide valued at more than $900,000, compared with an estimated 28,000 pounds valued at more than $800,000 in 1986. Estimated data for the ferrocolumbium and the columbium and tantalum oxides were based on entries in nonspecific classes.

Imports for consumption of columbium mineral concentrates increased by 60% to the highest level since 1980. As in 1986, Canada was the leading supplier and again provided almost all of both total quantity and total value. Imports were estimated to contain 1.88 million pounds of columbium and 10,000 pounds of tantalum at an average grade of approximately 59% Cb_2O_5 and less than 1% Ta_2O_5.

Imports for consumption of tantalum mineral concentrates declined by more than 20% to the lowest level since 1983, with the average unit value for overall imports decreasing by more than 10%. Tantalum ore demand and prices remained depressed. Imports from the Federal Republic of Germany and the Netherlands, both of which are nonproducing countries, together provided 70% of total quantity and more than 60% of total value. Imports were estimated to contain 210,000 pounds of tantalum and 130,000 pounds of columbium at an average grade of approximately 37% Ta_2O_5 and 27% Cb_2O_5.

Data on receipts of raw materials other than mineral concentrates were incomplete.

Imports for consumption of columbium-tantalum synthetic concentrates continued to decline: 457,000 pounds valued at $2.6 million, compared with 927,000 pounds valued at $3.5 million in 1986. These figures are not included in the salient statistics data.

Table 7.—U.S. foreign trade in columbium and tantalum metal and alloys, by class

(Thousand pounds, gross weight, and thousand dollars)

Class	1986 Quantity	1986 Value	1987 Quantity	1987 Value	Principal destinations and sources, 1987
EXPORTS[1]					
Tantalum:					
Powder	160	14,172	193	16,129	Japan 48, $4,526; France 49, $4,075; West Germany 41, $3,167; Spain 18, $1,885.
Unwrought and waste and scrap	318	5,041	322	5,012	West Germany 192, $3,029; Canada 42, $1,107; Austria 78, $303; Japan 5, $246.
Wrought	74	10,391	91	12,842	Japan 41, $5,546; United Kingdom 16, $2,218; West Germany 11, $1,908; France 11, $1,627.
Total	XX	29,604	XX	33,983	Japan $10,300; West Germany $8,100; France $5,800; United Kingdom $3,900.[2]
IMPORTS FOR CONSUMPTION					
Columbium:					
Ferrocolumbium[e]	5,280	16,443	6,179	20,434	All from Brazil.
Unwrought metal and waste and scrap	8	56	28	399	Brazil 11, $277; West Germany 9, $68; United Kingdom 5, $27; Austria ([3]), $11.
Unwrought alloys	4	87	19	186	Brazil 15, $121; West Germany 4, $65.
Wrought	1	31	2	102	Belgium-Luxembourg 2, $98; West Germany ([3]), $4.
Tantalum:					
Waste and scrap	[r]101	[r]3,414	176	4,891	Japan 91, $2,872; West Germany 28, $1,013.
Unwrought metal	45	3,225	57	3,236	West Germany 25, $1,858; Belgium-Luxembourg 20, $874; China 7, $239.
Unwrought alloys	([3])	2	([3])	29	Canada ([3]), $24; West Germany ([3]), $5.
Wrought	1	7	2	214	Japan 2, $197; Austria ([3]), $14; United Kingdom ([3]), $3.
Total	XX	[r]23,265	XX	29,491	Brazil $20,800; Japan $3,100; West Germany $3,000; Belgium-Luxembourg $970.[2]

[e]Estimated. [r]Revised. XX Not applicable.
[1]For columbium, data on exports of metal and alloys in unwrought and wrought form, including waste and scrap, are not available; included in basket category.
[2]Rounded.
[3]Less than 1/2 unit.

Sources: Bureau of the Census and Bureau of Mines.

Table 8.—U.S. imports for consumption of columbium mineral concentrates, by country

(Thousand pounds and thousand dollars)

Country	1986 Gross weight	1986 Value	1987 Gross weight	1987 Value
Brazil	--	--	4	16
Canada	2,850	4,534	4,488	6,480
Netherlands[1]	2	4	--	--
Nigeria	2	2	89	116
Total	2,854	[2]4,541	4,581	6,612

[1]Presumably country of transshipment rather than original source.
[2]Data do not add to total shown because of independent rounding.

Sources: Bureau of the Census and Bureau of Mines.

Table 9.—U.S. imports for consumption of tantalum mineral concentrates, by country

(Thousand pounds and thousand dollars)

Country	1986		1987	
	Gross weight	Value	Gross weight	Value
Australia	--	--	45	293
Belgium-Luxembourg[1]	2	37	--	--
Brazil	146	994	54	337
Canada	186	2,119	--	--
French Guiana[1]	1	12	--	--
Germany, Federal Republic of[1]	--	--	378	2,250
Netherlands[1]	256	1,846	113	1,099
South Africa, Republic of	--	--	27	254
Taiwan[1]	(2)	1	--	--
United Kingdom[1]	202	1,330	--	--
Zaire	111	1,374	81	953
Total[3]	905	7,713	697	5,186

[1]Presumably country of transshipment rather than original source.
[2]Less than 1/2 unit.
[3]Data may not add to totals shown because of independent rounding.

Sources: Bureau of the Census and Bureau of Mines.

WORLD REVIEW

World production data on columbium and tantalum minerals exclude columbium or tantalum recovered from contemporary and old tin slags and from struverite. Tantalum contained in tin slags produced in 1983, 1984, 1985, 1986, and 1987 was, in thousand pounds, 1,049, 828, 877, 622, and 543, respectively, according to data from the Tantalum-Niobium International Study Center.

Regarding the shipment of old tin slags, data were only available from Thailand. Shipments of old tin slags from Thailand were unchanged at 55 short tons. Data were not available as to the disposition of the shipments.

Australia.—For its fiscal year, Greenbushes reported that the company's mine facilities operated at approximately 40% of installed capacity for both tantalum and tin products, with emphasis on the continued mining of high-grade tin alluvial deposits. Ore treated decreased by about 17% to 1.4 million tons compared with that of 1986, and tantalum oxide produced in concentrates was down by 15% to 75,600 pounds. Greenbushes' chemical plant produced 16,400 pounds of Ta_2O_5 and 12,700 pounds of Cb_2O_5. Tantalum oxide contained in tantalum glass (slag) production decreased by more than 10% to 56,000 pounds, with the two-stage electric arc, tin-smelting facility operating on 5-day-per-month smelting campaigns. The solvent extraction plant was restarted and was undergoing expansion to increase annual production capacity of Ta_2O_5 and Cb_2O_5 to about 55 tons and 33 tons, respectively.

Greenbushes and its joint-venture partner, Kokan Mining Co. Ltd. of Japan, reportedly were to mine tin and tantalum ore in the Pilbara mining district of Western Australia, about 125 miles south of Port Hedland, starting in the spring of 1988. Western Australia Rare Metals Co., a subsidiary of Kokan Mining, conducted feasibility studies on the property between mid-1986 and mid-1987 with financial backing from the Metal Mining Agency of Japan (MMAJ). The expected annual production of more than 2,000 tons of tin metal and about 550 tons of tantalum oxide were to be shared equally by the partners, with Kokan Mining's share to be marketed in Japan.

West Coast Holdings Ltd. reportedly gave the go-ahead for a pilot plant to be built to confirm the proposed flow sheet for its Brockman rare-earths project near Halls Creek in Western Australia. The plant was expected to be operational in early 1988 and was to treat 2.2 tons of ore per day over an 8-month period. Samples of anticipated products were to be produced for distribution to potential customers. The ore contains recoverable quantities of columbium, tantalum, and yttrium.

Brazil.—Paranapanema S.A. Mineração Indústria e Construção, Brazil's largest tin producer, announced plans to construct a columbium oxide plant at its Pitinga tin property in the Amazonas State. The plant, with a planned annual capacity of about 2 million pounds of columbium oxide, would process Pitinga's byproduct columbite material. Also, about 200,000 pounds of tantalum oxide would be produced as a byproduct of the columbium oxide production.

Brazil's total production and exports of all columbium products were 12,000 and 12,800 tons, respectively, compared with 19,200 and 13,500 tons, respectively, in 1986.

Canada.—As reported by Teck Corp. for its fiscal year, plant operations at the Niobec Mine at St. Honoré, Quebec, were shut down for 2 months to reduce inventories. Mine inventories reportedly had built up, owing to weak columbium consumption, particularly in Europe and Japan. Columbium oxide production was down about 15% to 6.4 million pounds. Ore milled declined about 10% to 754,000 tons, as the mill operated on the average of 2,251 tons of ore per day. Recovery was 64.1%, with Cb_2O_5 grade of ore decreasing to 0.66%. Ore reserves decreased to 12.1 million tons assaying 0.66% Cb_2O_5.

The Hudson Bay Mining and Smelting Co. Ltd. reported that tantalum mining and milling activity at the Bernic Lake, Manitoba, operation of TANCO remained suspended. However, late in the year, it was announced that TANCO planned to resume tantalum mining operations by mid-1988, ending a shutdown of more than 5 years. Production capacity, when resumed, is expected to be about 200,000 pounds of contained tantalum annually. The decision to reopen the tantalum mine and mill was made after the company reportedly secured several multiyear contracts.

Gabon.—The Gabonese Government, following a mineral survey, reported the discovery of a large columbium deposit about 50 miles east of the city of Lambarene. The survey was part of a state mineral inventory program conducted by the French Government's Bureau de Recherches Géologiques et Minières, with financing from the Government of Gabon and the European Economic Community. The report compared the deposit, estimated at 40 million tons of ore grading 1.5% columbium, to that of the Brazilian columbium producer, Cia. Brasileira de Metalúrgia e Mineração (CBMM). CBMM is the world's largest columbium producer and supplier of upgraded columbium products. In addition to columbium, the Gabonese deposit contains as-yet-undefined quantities of rare earths as well as cadmium- and titanium-bearing minerals. Gabon was seeking interested parties regarding investment opportunities in future survey-exploration activities.

Japan.—Production of ferrocolumbium fell to 787 tons from the 950 tons produced in 1986. Ferrocolumbium imports totaled 1,961 tons compared with 2,122 tons in 1986. The bulk of imports came from Brazil.

To secure and diversify its supply sources for rare metals and rare-earth minerals, Japan reportedly signed a 3-year joint minerals exploration agreement with Kenya. Under the agreement, the MMAJ will provide technical assistance to the Department of Natural Resources of Kenya to explore for tantalum and rare earths in a 6,000-square-mile area of Homabay in Kenya. Under a separate 5-year joint minerals exploration agreement with China, the MMAJ sent a team to China to explore for tantalum, columbium, ilmenite, zinc, and rare earths in southwestern Guangdong Province.

Thailand.—The Thailand Tantalum Industry Corp. Ltd. (TTIC) decided to rebuild its columbium and tantalum processing plant, which was destroyed by fire in June 1986. TTIC reportedly made the decision to proceed with the new plant after the Thai Government agreed to take a 20% stake in the $35 million project, supply soft loans, and provide an 8-year tax exemption. The facility, which is planned for completion by mid-1990, will be reconstructed at the Mab Ta Pud Industrial Estate in Rayond Province. However, the timetable for startup of the new plant could be delayed pending the outcome of an arbitration hearing in the Federal Republic of Germany. The hearing will decide if Hermann C. Starck will be required to supply technology to TTIC for the project. The validity of the technology transfer agreement between the two companies is being contested, owing to the change in plant location from Phuket Island to Mab Ta Pud. The plant will have an initial annual production capacity of about 300 tons each of columbium and tantalum oxide.

Zimbabwe.—Kamativi Tin Mines Ltd. reportedly planned to double its production of tantalite concentrates to about 10 tons per month. The company was to install an additional high-intensity magnetic separator and a secondary drying facility for operation by early 1989.

[1]Physical scientist, Branch of Ferrous Metals.

Table 10.—Columbium and tantalum: World production of mineral concentrates, by country[1]

(Thousand pounds)

Country[2]	Gross weight[3]					Columbium content^{e} [4]					Tantalum content^{e} [4]				
	1983	1984	1985	1986^{p}	1987^{e}	1983	1984	1985	1986	1987	1983	1984	1985	1986	1987
Australia: Columbite-tantalite	258	^{e}340	^{e}350	^{e}195	351	45	70	70	40	60	90	120	120	70	115
Brazil:															
Columbite-tantalite	582	375	589	604	661	134	86	135	139	152	170	110	170	175	190
Pyrochlore	37,099	^{r}61,233	64,816	63,354	58,791	15,582	25,719	27,223	26,610	24,692	--	--	--	--	--
Canada: Pyrochlore^{e}	6,700	9,700	10,900	11,500	9,490	2,770	4,380	4,900	5,160	4,270	--	--	--	--	--
Malaysia: Columbite-tantalite	148	99	176	474	480	22	15	26	71	72	10	7	12	33	33
Mozambique:															
Microlite	51	22	14	^{e}13	13	NA	NA	NA	NA	NA	25	8	7	7	7
Tantalite	31	15	9	^{e}9	9	NA	NA	NA	NA	NA	10	5	3	3	3
Namibia: Tantalite	6	15	10	^{e}11	11	2	4	3	3	3	2	4	3	3	3
Nigeria:															
Columbite	192	^{e}265	^{e}220	^{e}30	30	85	120	90	12	12	11	16	13	2	2
Tantalite	^{e}2	^{e}2	^{e}2	--	--	(5)	(5)	(5)	--	--	1	1	1	--	--
Portugal: Tantalite	7	7	4	--	--	2	2	1	--	--	2	2	1	--	--
Rwanda: Columbite-tantalite	111	115	61	--	--	33	34	18	--	--	24	25	13	--	--
South Africa, Republic of:															
Columbite-tantalite	1	1	(5)	--	(5 6)	(5)	(5)	(5)	--	(5)	(5)	(5)	(5)	--	(5)
Spain: Tantalite	104	70	40	^{e}26	22	NA	NA	NA	NA	NA	[6]33	[6]21	[6]10	7	6
Thailand: Columbite-tantalite	1,210	1,052	952	267	397	205	180	162	46	67	278	284	257	73	107
Zaire: Columbite-tantalite	112	220	324	$^{r\,e}$110	110	30	60	88	30	30	32	62	91	31	31
Zimbabwe: Columbite-tantalite	5	130	88	73	77	1	[6]20	13	11	12	2	[6]45	31	26	26
Total	46,619	^{r}73,661	78,555	76,666	70,442	18,911	30,690	32,729	32,122	29,370	690	710	732	430	523

^{e}Estimated. ^{p}Preliminary. ^{r}Revised. NA Not available.

[1]Excludes columbium- and tantalum-bearing tin ores and slags. Table includes data available through July 1, 1988.

[2]In addition to the countries listed, China, the U.S.S.R., and Zambia also produce, or are believed to produce, columbium and tantalum mineral concentrates, but available information is inadequate to make reliable estimates of output levels.

[3]Data on gross weight generally have been presented as reported in official sources of the respective countries, divided into concentrates of columbite, tantalite, and pyrochlore where information is available to do so, and reported in groups such as columbite and tantalite where it is not.

[4]Unless otherwise specified, data presented for metal content are Bureau of Mines estimates based, in most part, on reported gross weight. Metal content estimates are revised as necessary to reflect changes in gross weight data.

[5]Less than 1/2 unit.

[6]Reported in official country sources.

Copper

By Janice L. W. Jolly and Daniel Edelstein[1]

As a result of escalating prices in the second half, 1987 proved to be a profitable year for almost all copper producers. Refined copper inventories reached the lowest levels since World War II as world copper consumption reached record-high levels. The shortage of spot copper was not ameliorated even though some new capacity from U.S. mines started operation by yearend. As a result, the domestic producer price of refined copper reached a record high $1.51 per pound at the end of December.

Table 1.—Salient copper statistics

(Metric tons unless otherwise specified)

	1983	1984	1985	1986	1987
United States:					
Ore produced ---- thousand metric tons--	177,930	171,814	162,210	169,238	202,632
Average yield of copper -----percent--	0.51	0.58	0.62	0.62	0.58
Primary (new) copper produced:					
From domestic ores, as reported by:					
Mines	1,038,098	1,102,613	1,105,758	1,147,277	1,255,914
Value ---------- thousands--	$1,751,476	$1,625,116	$1,632,483	$1,670,660	$2,284,156
Smelters	888,130	989,924	939,257	[1]908,087	[1]972,141
Percent of world total	11	12	11	10	11
Refineries	1,028,423	1,089,584	1,003,636	r [2]1,073,975	[2]1,146,107
From foreign ores, matte, etc., as reported by refineries	153,667	75,016	53,529	W	W
Total new refined, domestic and foreign	1,182,090	1,164,600	1,057,165	r1,073,975	1,146,107
Refined copper from scrap (new and old)	401,668	324,949	377,457	r405,944	414,738
Secondary copper recovered from old scrap only	449,478	460,695	503,407	r477,469	499,362
Exports:					
Refined	81,397	91,414	37,937	12,452	9,197
Unmanufactured[3]	239,190	317,167	435,069	442,441	387,245
Imports for consumption:					
Refined	459,568	444,699	377,725	501,984	469,159
Unmanufactured[3]	675,343	551,802	443,932	597,523	568,470
Stocks, Dec. 31: Total industry and COMEX:					
Refined	692,000	564,000	320,000	225,000	113,000
Blister and materials in solution	174,000	245,000	146,000	135,000	150,000
Consumption:					
Refined copper (reported)	1,803,931	2,122,732	1,976,038	r2,102,625	2,151,829
Apparent consumption, primary and old copper (old scrap only)	2,012,739	2,106,580	2,144,360	r2,135,976	2,217,431
Price: Weighted average, cathode, cents per pound, producers	76.53	66.85	66.97	66.05	82.50
World:					
Production:					
Mine ------- thousand metric tons--	r7,659	r7,999	8,080	p8,125	e8,475
Smelter ----------------do----	r8,120	r8,391	8,664	p8,715	e8,865
Refineries ----------------do----	r9,202	r9,116	9,375	p9,503	e9,647
Price: London, high-grade, average cents per pound	72.13	62.45	64.27	62.28	80.88

eEstimated. pPreliminary. rRevised. W Withheld to avoid disclosing company proprietary data.
[1]Includes production from foreign ores and concentrates.
[2]Includes primary copper produced from foreign ores, matte, etc. to avoid disclosing company proprietary data.
[3]Includes copper content of alloy scrap.

U.S. apparent consumption of copper remained high, as did import reliance, which was estimated to be 26% in 1987. Refined copper imports continued to be high, but the ratio of domestic copper production to demand was increasing at yearend. U.S. mine production was recovering, and plans were being implemented to increase domestic production further. U.S. copper producers became increasingly competitive as they benefited from cost-reduction efforts of the past several years and from the weakened U.S. dollar. Restructuring of the industry continued with copper properties changing owners. Implementation of new technology leading to lower production costs also continued as one of the Nation's largest producers restarted its mine and processing plants, and another was well under way with construction of a new larger smelter.

Domestic Data Coverage.—Domestic production data for copper were developed by the Bureau of Mines from seven separate surveys of U.S. operations. Typical of these surveys is the mine production survey. Of 112 operations to which a survey request was sent in 1987, 90% responded, representing an estimated 99.9% of the recoverable copper content in the total mine production shown in tables 6, 8, 9, and 31. Production for the remaining 11 copper companies was estimated using data from other surveys.

Legislation and Government Programs.—Although current copper goals remained at 907,000 tons[2] of refined copper, only 20,000 tons was in the National Defense Stockpile. By yearend, Congress passed a measure contained in the fiscal year 1988 Defense Authorization Bill that would transfer management responsibilities for the stockpile to the U.S. Department of Defense.

Brass and bronze foundries were reportedly threatened by more stringent Occupational Safety and Health Administration (OSHA) standards for airborne transmission of lead. If forced to meet the 50-microgram-per-cubic-meter lead standard, many foundries reportedly would be forced to close.[3] An additional burden for the small foundry was the annual community right-to-know report that was required under Public Law 99-499, the Superfund Amendments and Reauthorization Act, 1986 (SARA). The requirement called for any facility that prepared a Material Safety Data Sheet under OSHA's Hazard Communication Standard to submit that sheet or a list of chemicals to the local emergency planning committee, to the State emergency response commission, and to the local fire department.

The Generalized System of Preferences (GSP) of the Trade Act of 1974 was amended through Presidential Proclamation 5758 of December 24, 1987, to suspend GSP treatment for Chilean imports, which included copper scrap. The suspension was the result of a determination that Chile had not taken steps to afford internationally recognized worker rights as defined under section 502 of the Trade Act.

In April, the Interstate Commerce Commission ruled that U.S. railroads had not complied until January 1981 with its 1979 order to reduce rail rates on nonferrous metals. The Commission ordered the railroads to reimburse shippers, with interest, for excessive charges levied between September 24, 1979, and December 31, 1980. Refunds for shippers of copper matte will amount to about 3% of the original charges, and shippers of copper or alloy copper scrap will receive refunds amounting to about 4.3%. An investigation was to continue to determine if other discriminations in rate structure existed.[4]

Two meetings were held in Geneva, Switzerland, under the auspices of the United Nations Conference on Trade and Development on the formation of an international producer-consumer forum for copper. A consensus developed among participating countries that there was sufficient basis to proceed toward the formation of such a forum and that a negotiating session would be convened in 1988 to develop functions and rules of procedure.

DOMESTIC PRODUCTION

Mine and Plant Labor.—Productivity, in terms of metric tons of copper produced and average hours worked at copper mines and mills, was 18.2 hours per ton of copper in 1987, down slightly from 17.7 hours per ton in 1986. The average number of U.S. copper mine and mill workers, including office workers, for 1987 was 11,924; 23,197,110 hours were worked. Although these statistics do not include mines producing byproduct copper, they do include staffing at mines that were closed or on care and maintenance status. U.S. Department of Labor statistics indicated that the average number of employees at primary copper smelters and refineries was 5,600 workers in 1987, and 12,409,600 hours were worked. A total of 29.3 hours was spent per ton of primary copper processed through mine, mill, smelter, and refinery. This compared with 72.2 hours per ton in 1975.

Productivity continued to be an item of high interest among copper companies as a cost factor. In the first full year of operation, BP Minerals America expected its renovated Bingham Canyon operation to achieve a much higher level of labor productivity than that achieved previously. The work force, required to produce 185,000 tons of refined copper per year, was expected to be 1,800 people, or about one-fourth the size it was in 1980.

Copper Range Co. employed about 940 workers at the White Pine Mine; peak employment at the mine was 3,000 workers in 1978. Although technical and mandatory safety training played a vital role in the startup of the White Pine Mine, the need for extensive labor-management training, employee-ownership training, and cross-training for more than one job were equally important. More than $3 million in Federal and State funds helped provide the necessary training. Roughly two-thirds came from State-funded programs. The remainder came from the Federal Job Training Partnership Act, including title III, and the U.S. Reserve Fund for Dislocated Copper Workers. As a result of a better trained and involved work force, productivity increased sharply above that of 5 years prior when the mine was shut down.

Workers throughout the industry were paid various bonuses, reflecting the much improved copper market. The rise in Commodity Exchange Inc. (COMEX) copper prices triggered bonus payments, as negotiated in the 1986 labor contracts, and allowed most hourly copper workers to recoup some wages lost by salary and benefit-package concessions. About 4,100 copper workers in Arizona received contract-mandated bonuses totaling more than $10.4 million. The Magma Copper Co. workers reportedly recouped about one-half of the wage concessions made for 1987. The higher COMEX prices triggered Magma bonus payments during the third quarter that averaged $312 per employee and for the final quarter of the year that averaged about $2,600 per worker, or the equivalent of $5 per hour for each hour of paid time in the quarter. Magma employed 2,973 union-contract workers at its mine and smelter in San Manuel and 420 at its Pinto Valley Mine and concentrator at Miami. Magma was offering a starting wage of $10.50 per hour for new miners at the underground copper mine at San Manuel.

Inspiration Consolidated Copper Co. (ICC) issued bonuses to about 700 workers, averaging $2,346 per worker, or $4.50 per hour for each hour worked during the fourth quarter. Despite a lack of contractual obligation to do so, Phelps Dodge Corp. and BP Minerals America's Utah Copper Div. announced at yearend that all hourly employees would receive $1,000 each as a bonus.

Copper Range distributed $5,500 each to 800 union workers at the White Pine copper mine in the first payout under employee ownership. The distribution came under an employee stock ownership plan that allowed the enterprise to reopen in 1985 after a 3-year shutdown. The money and stock went to union workers who worked at least 870 hours in 1986. Copper Range stock, which was not traded publicly, was valued at $24.40 per share. According to the company, an average of 175 shares per worker were distributed, with a similar distribution to be made in each of the next 4 years. Copper Range also released about $1 million in incentive pay to the workers at the rate of 50 cents for each hour worked since January 1, 1986.

A total of 325 employees had been laid off at Tennessee Chemical Co. by yearend as a result of the company's decision to cease mining in Tennessee. The mining operation was completely shut down, as was the mill. Most of the employees at the iron roasters and on the maintenance staff were to remain until their work was completed. The mining company began its layoff procedures in late July for permanent closure of the mines.

Cost of Production.—The weighted-average, cash cost (including byproduct credits and taxes, but excluding depreciation) of producing refined copper in the United States was estimated to have decreased to about 53 cents per pound in 1987. When recovery of capital was included, the average production cost was 58 cents per pound.

ASARCO Incorporated estimated the cost to process 1 ton of material through crushing and concentrating at the Ray Mine to be $2.20 per ton. The recovery rate was 83.7% from heads of 0.88% copper and the concentrate grade was 26.7%. The cost to process Ray silicate ore through heap leaching, solvent extraction, and electrowinning (SX-EW) was estimated at $1.67 per ton.[5]

BP Minerals America claimed that its renovated Bingham Canyon, UT, property will easily be the lowest cost major copper producer in North America and one of the lowest cost producers in the world in terms of cash costs.[6] Inefficiencies and low productivity were addressed through better management and attention to operational improvement. Labor costs were reduced by about 35%, including the effects of work rule and practice changes, as a result of the 1986 labor contract settlement. Ore crushing, transportation, milling, and concentration systems were streamlined through the $400 million modernization project.

The modernization at Bingham Canyon used large-scale production to cut costs through less maintenance, fewer employees, and improved metal recoveries. Multiple haulage units were being replaced by large continuous transport systems, and many crushing, grinding, and flotation units were being replaced by fewer but larger pieces of equipment. About one-third of the project was directed at ore transport improvement through elimination of rail transport. In the pit, a large, single, mobile crusher replaced three fixed crushers, and a conveyor system was installed that extended 5 miles through a railway tunnel to a new concentrator. Three grinding lines, each consisting of one semiautogenous grinding mill and two ball mills, replaced more than 100 secondary crushing and grinding mills in the existing plants. A flotation circuit of fewer than 100 flotation cells, which included thirty-three 3,000-cubic-foot cells, replaced over 2,000 smaller cells in the existing plants. The final part of the system was a 13-mile slurry pipeline to carry tailings to the disposal pond. A second pipeline will return process water to the grinding plant, and a third will carry concentrates to the smelter.

Copper Range reported production costs at its White Pine, MI, mine to be about 60 cents per pound. High productivity was related more to the new employee-management relationship and cross-training than to implementation of new technology. Other than the modern refining plant, most equipment, mining methods, and smelting dated to the 1950's and 1960's. A conveyor-belt system was used for ore transport to the surface.

Solvent extraction and leaching played a significant part in reducing production costs for ICC. ICC, which built its SX-EW plant in the late 1960's and enlarged it in 1980, obtained its entire mine production from SX-EW in 1987. The company's 1987 costs were reported to be about 50 cents per pound. A new $15 million expansion of SX-EW plant capacity was expected to be completed in 1988.[7]

Magma announced in late 1987 that its copper-production cost goal was to reduce costs from 50 to 55 cents per pound to 45 cents per pound. Underground mining costs had been cut by about 9 cents per pound of copper through a reduction in the number of employees and a 20% reduction in wages and benefits. The implementation of a new underground mining plan was expected to further reduce costs by about 4 cents per pound. The company increased the cutoff grade of sulfide ore from 0.40% copper to 0.50% copper in its underground mine. The company planned to return to mining the 0.40% ore on an incremental basis. Mining the lower grade ore would add about 2 to 3 cents per pound to the average production costs. The 1986 cost had been unusually high owing to development work being done to expand future production. Costs for 1987 also were higher than what was anticipated in the future, since Magma's underground mine operated at reduced levels and was expected to do so until the availability of the new smelter in late 1988.

Magma was installing the flash furnace, which was expected to reduce smelting costs by 39% to about 7 cents per pound of copper. Since 1984, the addition of lower cost copper produced by the Pinto Valley Div. had reduced the weighted-average cost of production for the company. In addition, Magma anticipated electrowon copper could be produced at a cost of about 30 cents per pound from its new project at Pinto Valley with the addition of only 21 new employees. The cost of sulfuric acid used in copper-leaching processes at Magma's San Manuel SX-EW plant reportedly was reduced from $20 per ton to $9 per ton.[8] An annual cost savings of $498,000 was also realized through conversion of 20-inch cyclones to 26-inch cyclones; savings were derived from reducing the amount of power used and from the amount of scoop and cyclone maintenance that would be needed at the mill. In addition, the conversion paved the way for entry of a 6,000-ton-per-day, smelter-slag, grinding campaign. The cyclone modification allowed for easier transport of slag in the grinding circuit from the rod mill to the ball mill. Magma's $267 million capital expansion program, aimed at an annual production goal in 1991 of about 272,000 tons of copper, was about 20% complete at yearend.

Since 1984, Phelps Dodge had invested about $275 million to reduce production costs. The investment included the acquisition of a two-thirds interest in Chino Mines Co. from Kennecott, which enabled Phelps Dodge to coordinate and rationalize costs for processing.[9] To date, costs had been reduced to about 55 cents per pound of copper from a high of more than 80 cents in 1981. Substantial capital programs had been completed or were planned, including various SX-EW programs and an in-pit crushing and conveying project at the Morenci Mine. Another $275 million was to be invested between 1988 and 1991 to further reduce costs. It was anticipated that as much as 40% of the company's production eventually would come from SX-EW production at its mines. Mining of the Tyrone ore body would be finished in the early 1990's, but SX-EW production from ore previously mined would continue for about 15 additional years. At this point, the corporation's costs, in 1987 dollars, were expected to be less than 50 cents per pound of copper.

Company Earnings and Ownership Changes.—Most major U.S. copper mining companies were profitable during the year, even though some had sold copper forward at prices lower than the escalating yearend COMEX spot prices. All companies had strengthened their financial positions by yearend and were producing copper at a profit for the first time in many years. Phelps Dodge announced a record-high income in 1987 of $207 million, almost double that of 1986.[10] Asarco reported a thirtyfold increase in earnings despite a significant loss from equity in foreign companies that were adversely affected by the devaluation of the U.S. dollar against the major foreign currencies in which the debts were denominated.[11]

Asarco's earnings improved as a result of lower operating costs in the United States, combined with higher metal prices. Costs for products and services were higher because of higher metal prices for raw materials. Asarco acquired the Ray Mine and associated smelter and SX-EW refinery from Kennecott in 1986 and the Eisenhower property from Anamax Mining Co. in 1987.

In a major restructuring during 1987, the British Petroleum Co., Plc transferred its 55% majority interest in the Standard Oil Co. to BP America (formerly BP North America Inc.), a wholly owned subsidiary.[12] On May 13, 1987, BP America gained control of the 45% minority interest of Standard Oil through a tender offer. The aggregate purchase price for the minority interest was about $7.8 billion. BP America then announced the formation of BP Minerals America, a new minerals company that combined the assets of Kennecott with those of Amselco Minerals Inc. From headquarters in Salt Lake City, UT, BP Minerals America was to manage British Petroleum's mining and mineral processing interests in the United States and select international locations. Higher copper prices, coupled with resumption of the copper operations at BP Minerals America's Bingham Canyon Mine near Salt Lake City, UT, were responsible for BP Minerals America's income improvement.

Cyprus Minerals Co. acquired two copper-producing properties during the year, the Pinos Altos, NM, underground mine and the in situ leach copper oxide mine at Casa Grande, AZ. According to the company's 1987 annual report, Cyprus also planned to complete acquisition of the Twin Buttes, AZ, mine in early 1988.[13]

The Bagdad copper mine operated at full capacity, and Sierrita's production was increased to take advantage of strong copper prices. Cyprus' participation in the higher copper prices was limited by forward sales of a large portion of second-half production.

Inspiration Resources Corp.'s (IRC) U.S. subsidiary, ICC, also was profitable, realizing for the full year an average COMEX-based price of 71 cents per pound.[14] Every one-cent-per-pound increase in the price of copper translated into between $1.5 and $2.0 million in annual pretax income for IRC, depending upon factors such as the continued impact of price participation bonuses that were paid to mine employees under the current labor contracts.

Magma's losses in the final quarter of 1987 included a $25 million reserve to close out forward-sales contracts covering about 47 million pounds of copper for the first quarter of 1988.[15] Instead of delivering copper, Magma paid the difference between the contract and market prices. The company bought out the forward contract in order to sell more copper at full market price and to make earnings more predictable.

On March 10, 1987, Newmont Mining Corp. declared as a dividend to its shareholders 80% of its equity in Magma, then a wholly owned subsidiary. Newmont retained 15% of Magma's common stock and 5% was placed in an incentive plan for Magma management. A services agreement between Magma and Newmont allowed Newmont to provide Magma with certain exploration, marketing, electronic data processing, and other administrative services until December 31, 1989. As part of the spinoff arrangement, a $225 million financing agreement was organized with several banks, which set tight operating and spending targets for Magma's capital expenditure program. Newmont guaranteed the first $75 million in term loans. The capital expenditure program was subject to certain spending covenants and a completion deadline of yearend 1989.

Montana Resources Inc. (MRI) made its last payment to the Montana State Board of Investments at yearend.[16] The board arranged for a $12 million line of credit for MRI, which borrowed a total of $7.1 million from the fund. The total economic impact of the mine in the first year of operation upon the Butte, MT, community was reportedly more than $34 million, including $16.1 million in salaries and other worker compensations, $4 million in property and severance taxes, and $14.5 million in direct purchases throughout the State. MRI based its operational budget for the Continental Mine, Montana, on copper selling at 65 cents per pound and molybdenum at $2 per pound; both of these prices were exceeded during the year.[17]

Mine Production and Reserves.—Copper was mined in 11 States during 1987, with Arizona yielding 61% of the total, followed by New Mexico and Utah. There were 52 copper-producing mines, down from a total of 87 mines in 1986. Of these, 23 were producing copper mines and 29 were mines from which copper was produced as a byproduct or coproduct of gold, lead, silver, or zinc. Total U.S. operating mine capacity, in terms of recoverable copper per year, was estimated to be 1.52 million tons. The Bingham Canyon open pit was reactivated in late 1987, and increased leaching and SX-EW capacity was added at the Morenci, Tyrone, and San Manuel Mines. Tennessee Chemical's copper operations at Copperhill, TN, closed at midyear. Capacity utilization at operating mines was 83%.

Asarco acquired the balance of the Eisenhower general partnership interest of the Anamax Mining Co. in April 1987 for $1 million. Asarco's combined Mission Complex comprised the Mission, Eisenhower, Pima, and San Xavier Mines, the ores from which were processed through the Mission mill. Average mill recovery rates for 1987 were as follows:

Mine	Quantity milled (metric tons)	Recovery rate (percent)	Copper (metric tons)	Silver (thousand troy ounces)
Coeur	141,000	97.90	998	2,449
Galena	182,000	97.00	907	3,288
Mission Complex	9,004,718	88.60	53,161	810
Ray	8,807,859	84.20	97,704	378
Silver Bell	--	--	5,806	--
Troy	2,852,190	87.60	16,783	4,287

Source: ASARCO Incorporated 1987 Annual Report.

The reserve base for the Ray Mine, which consisted of 630 million tons of ore averaging 0.71% copper, was defined by a 0.35% cutoff and included 65 million tons of silicate ore averaging 0.89% copper. However, the current 13-year mine plan was based on a 0.52% copper cutoff. Metal production for 1987 shown above for Ray included electrowon recovery of 29,000 tons and precipitate production of 2,360 tons. Only copper precipitates were produced at Silver Bell.

Leaching at the Ray Mine was carried out on four active, run-of-mine, sulfide, waste dumps and several silicate ore heaps. Ore was precrushed for the silicate leach system and then treated with dilute sulfuric acid solutions. Cost of processing material through heap leaching was estimated to be $1.67 per ton of ore. Silicate ore grade for the silicate ore heap-leaching process was 1.14% copper, with 0.87% of the ore readily soluble. About 122 pounds of acid was consumed per ton of ore leached. Primary crushing was done at the mine, followed by secondary and tertiary crushing at nearby Hayden. Concentrate grade from milled ore at Ray was 26.7% copper. About 25 tons was milled per worker-hour. Tailings deposits covered 1,405 acres.[18]

The following is a summary of Asarco's properties, ore reserves, and percentage ownership:

Mine	ASARCO (percent owned)	Ore reserves (thousand metric tons)	Percent of reserves			Silver (troy ounce per ton of ore reserves)
			Copper	Lead	Zinc	
Coeur	50.00	450	0.77	--	--	16.64
Galena	37.50	1,087	.59	10.04	0.11	16.09
Mission Complex	100.00	333,360	.64	--	--	.12
Quiruvilca	80.00	5,332	.99	1.26	3.57	5.96
Ray	100.00	614,373	.70	--	--	--
Silver Bell	100.00	19,011	.68	--	--	.07
Troy	75.00	34,451	.75	--	--	1.52
West Fork	100.00	9,796	.04	7.07	1.94	.30

Source: ASARCO Incorporated 1987 Annual Report.

BP Minerals America was building its competitive position in copper and other precious metals and minerals markets. The $400 million modernization of the Bingham Canyon Mine was nearing completion, with production costs reportedly lower than expected. Operating improvements at all plants had raised labor productivity to twice that of 1980. According to the company, when byproduct credits for gold, silver and molybdenum were translated into equivalent copper grade, the equivalent "grade" at the Utah mine exceeded the average grade of the seven largest mines in the United States other than Bingham, and the stripping ratio was as low as that of any of these mines. In addition to the high equivalent "grade" and low-stripping ratio, the Utah mine had large ore reserves that could support an operating life of about 30 years under current mine plans. If metal prices improve, additional years could be added. The cutoff grade was raised to 0.45% copper, which lowered the reserves, but raised the average mill-head grade and lowered unit costs. Revised mining plans also reduced the stripping ratio. Production expectations for the Bingham Canyon Pit were 173,000 tons of copper, 300,000 troy ounces of gold, 2.3 million troy ounces of silver, and 12 million pounds of molybdenum per year. Phase-in of the new facilities was scheduled to begin in the second quarter of 1988, with full operation to follow by October.

BP Minerals America listed Bingham Canyon copper reserves as 7.3 million tons of copper in 1986 and 7.1 million tons of copper in 1987, including proven and probable, contained in 891 million tons of ore in 1986 and in 899 million tons of ore in 1987.[19] As a result of the divestiture of the Ray and Chino Mines in 1986, all of the company's remaining reserves were at Bingham Canyon.

At midyear, BP Minerals America announced its intention to reapply for a permit to mine its Ladysmith, WI, copper-gold ore deposit, a relatively small deposit near the Flambeau River. Kennecott had withdrawn its 1975 environmental impact report and request to open the mine owing to the depressed metals market. The tabular-shaped, nearly vertical, quartz-sulfide vein averaged about 50 feet in width and was about 2,400 feet long. The upper 200 feet of the vein, which had been secondarily enriched, was to be mined in an open pit operation. The overburden, consisting of sandstone and glacial gravels, could be removed easily using bulldozers and used for road construction, plantsite preparation, and dressing of the slopes of the waste storage areas. The mine, which would employ about 35 people, would produce about 13,600 tons of ore per day and would cost between $15 and $20 million to develop.

The Ladysmith deposit contained 4 to 5 million tons of ore with 4% copper and traces of gold and silver. Mining by open pit methods was to last about 5 years; however, underground mining could follow if it proves economically viable for recovery of material from the lower 600 feet of the ore body.

Butte's old underground mines were purchased by Montana Mining Properties (MMP) from Washington Corp. of Missoula in April. In August, MMP, a group of Australian and European investors, incorporated several new mining companies with claims on Butte Hill. They included Butte Precious Metals, the Central Butte Mining Co., Mountain Con Mining Co., North Butte Mining Co., West Butte Metals Inc., the Tzarina and Travona Mining Co., and the Blue Bird Mining Co., according to county court records.[20] A new firm, Butte Mining Plc, with stock listed on the London Stock Exchange, was announced in October.

Butte Mining announced intentions of investing up to $100 million for the purpose of resuming surface and underground mining on a portion of the Butte Hill and construction of a new mill in the city. The mouth of the mile-long Alice-Lexington Tunnel was rehabilitated so that easy access could be made to Butte's underground mines. The tunnel, which ended under the Alice Pit, was a key underground access connecting the Lexington Mine (at the 400-foot level), the Missoula Mine, and the Syndicate Pit. Butte Mining was to develop only 2 of the 14 different blocks of claims that had been purchased by MMP, the Tazarena and Rainbow blocks, which were near the Lexington and Travona Mines. The minesites were last active in the 1950's. After positive recommendations from international mining consultants who did research on Anaconda Minerals Co.'s old records, Butte Mining decided not only to resume mining in Rainbow and Tazarena, but to conduct further exploration for more reserves. The Kelley Mine offices were serving as headquarters for both MMP, which will serve as a property management company engaged in trying to bring the Butte Hill mines back into production, and Butte Mining, which will also have offices in London, United Kingdom.

Cyprus continued to diversify into new markets and to acquire new copper-producing mines. In 1987, Cyprus acquired two more copper properties in Arizona and New Mexico. In late 1987, Cyprus began operations at Pinos Altos, an underground copper mine in New Mexico, which was acquired from Boliden Minerals Inc. The mine was situated on a combination of unpatented mining claims and fee properties and was held by Cyprus under a long-term lease. Cyprus expected to produce 3 to 5 million pounds of low-cost copper and some silver at Pinos Altos in 1988 and was evaluating the gold potential of the mine. The company also formed a joint venture with St. Cloud Mining Co. to mine silica flux in New Mexico for sale to a local smelter.

Cyprus acquired the Casa Grande (formerly Lakeshore) underground copper mine in western Arizona from Noranda Inc. in June. The mine was on Indian reservation lands leased from the Tohono O'odham Nation. Cyprus mined the oxide ore by in situ leaching and produced copper cathode from an SX-EW plant at the mine. During 1988, Cyprus planned to produce about 45,000 tons of leached copper at Casa Grande, some of which would be derived from its other mines. Cyprus planned to roast some of the copper concentrates from its Sierrita Mine at an on-site roaster at Casa Grande. The roaster could process 136,000 tons of concentrates per year. By using the low-cost, roast-leach operations, Cyprus expected to reduce Sierrita's concentrate-treatment costs. Work also was to continue on the development of in situ recovery of additional leachable copper from large deposits on the Casa Grande property.[21]

At yearend, Cyprus was negotiating to acquire the Twin Buttes, AZ, open pit copper mine near Sierrita. Sulfide ore from this mine was to be shipped to Sierrita for processing. The Twin Buttes SX-EW plant was to be refurbished and reactivated in 1988. Cyprus expected to produce about 11,000 tons of copper from the Twin Buttes Mine in 1988.

Cyprus mined copper sulfides, molybdenite, and a small amount of oxide ore for leaching at the Bagdad Mine, Arizona. The operation consisted of an open pit, a 50,000-ton-per-day sulfide concentrator, and an oxide heap leach system with an SX-EW plant. The mine, mill, and plant operated at full capacity in 1987, producing about 83,000 tons of copper, according to the company annual report.[22]

Cyprus also owned and operated the Sierrita copper and molybdenum mine, which consisted of an open pit, an 84,000-ton-per-day sulfide ore concentrator, a molybdenum plant and roaster, and related mining equipment. Copper concentrates were shipped to domestic smelters for processing. Sierrita also used an oxide ore heap-leaching system with a SX-EW plant to produce copper cathode. Sierrita operated at near capacity during the year.

At yearend, Cyprus' proven reserves at the Sierrita Mine totaled 295.5 million tons of ore, containing an average grade of 0.30% copper and 0.037% molybdenum. The company's proven reserves at Bagdad totaled 387 million tons of ore, averaging

0.45% copper at yearend 1987. Cyprus' newly acquired Pinos Altos Mine had proven reserves of 830,000 tons of ore, containing an average of 4.91% copper. The Casa Grande (Lakeshore) Mine had proven reserves totaling 14 million tons of ore, containing an average of 0.80% copper, and the Twin Buttes Mine had proven reserves of 34 million tons of sulfide ore, containing an average of 0.92% copper and 9.6 million tons of oxide ore, containing an average of 0.73% copper.[23]

ICC reported mining 30 million tons of ore, containing 0.589% copper. During 1987, ICC increased its proven reserves of copper through successful drilling. Reserves at active surface mines and properties at ICC were given as 151 million tons containing 0.60% copper. This compared with 111.3 million tons with 0.57% copper reported in 1986. Reserves (reserve base) at inactive mines totaled 99.6 million tons of 0.51% copper and included sulfide reserves at the open pit. ICC's inactive underground mine was given as 18.2 million tons of 1.84% copper.[24]

Magma and Cyprus agreed in principle to form a joint venture under which Cyprus would explore for gold on Magma's San Manuel, AZ, property. Cyprus would have the right to earn a 50% stake in the gold property by carrying out exploration activities. Cyprus also would become operator of the gold property when developed.

Magma's San Manuel concentrator had a rated capacity of 56,000 tons of ore per day. The mill feed was reportedly averaging 0.65% copper and 0.026% molybdenum. Concentrates containing 29.5% copper and 1.00% molybdenum were produced. Magma started test production from its mechanized load-haul-dump system during the last week of June. However, technical problems encountered in the test runs made it unlikely that the system would be cost-effective. Therefore, it would not be used to replace the existing manual system in the mine as planned.

A formal test program began for recovering copper using in situ leaching in an area overlying the mined-out portion of the mine. In addition, Magma was actively mining in an open pit that was developed in the oxide ore contained within an active subsidence zone over the underground mined-out area. Magma used a prepared, 86-acre, dump-leach site with an impermeable liner for leaching the mined oxide ore.

Construction of a $19.6 million SX-EW project at Pinto Valley started during the year; the project was to be fully operational in 1988. About 7,000 tons of low-cost copper cathode per year was to be recovered from the 220-acre No. 2 tailings pile at the Pinto Valley Mine, which contained 32 million tons of material grading 0.33% copper. Pinto Valley will reclaim the copper by hydraulic mining, followed by processing through the expanded Miami SX-EW Unit.

Early drilling campaigns by Magma identified an oxide ore reserve in the open pit, dump-leach area of about 51 million tons of 0.47% copper ore and, in the in situ area, an oxide reserve of about 97 million tons containing 0.36% copper.[25] In 1987, however, the company reported that exploration drilling had resulted in an increase of oxide reserves by more than 64 million tons. Previous reports had put San Manuel sulfide reserves at 270 million tons of 0.69% copper, which included 94 million tons contained in the shaft pillar.[26] A reevaluation of the mine plan at Pinto Valley caused the company to increase minable sulfide reserves by 174 million tons.[27] Previous reports had put Pinto Valley sulfide reserves at 323 million tons of 0.40% copper ore. Favorable drilling results were also obtained in an area known as Cactus Claims.[28]

MRI marked its first full year of operation in July 1987. Silver production was reported as just about covering the company's monthly diesel fuel costs for the trucks that haul ore from the pit to the concentrator. MRI was shipping copper concentrates to Japan and molybdenum concentrates to the United Kingdom.[29]

Phelps Dodge was the largest domestic producer. According to the company's 1987 annual report, its mines and electrowinning facilities produced a record high 498,680 tons of copper in 1987, including a share belonging to Japanese partners Sumitomo Metal Mining Corp. and Mitsubishi Corp., which owned parts of Chino and Morenci production. Of the total, about 42,000 tons was electrowon cathode from the Morenci and Tyrone Mines. A substantial tonnage of concentrates, which was in excess of the company's smelting capacity, was either sold or toll refined. In addition to the electrowon copper, the following was recovered at each mine:

Mine	Ore mined (thousand metric tons)	Grade (percent of copper)	Precipitates recovered (metric tons)
Bisbee	--	--	9,900
Chino	9,437	0.81	15,694
Morenci	30,647	.82	11,430
Tyrone	15,564	.88	7,600

Source: Phelps Dodge Corp. 1987 Annual Report.

Ore reserves and reserve base in the United States were reported by Phelps Dodge as follows, including partner shares:

Mine	Ore reserves (thousand metric tons)	Average grade (percent)
Ajo	189,800	0.51
Chino	318,000	.71
Copper Basin	159,000	.55
Dos Pobres	210,100	.89
Lonestone	100,000	.41
Morenci	670,000	.76
Tyrone	97,200	.79
West Cu/NW Extension	219,000	.69

Source: Phelps Dodge Corp. 1987 Annual Report.

Sumitomo owned 15% of Morenci and adjacent Western Copper reserves. Mitsubishi owned 33-1/3% of the Chino Mine reserves. Ajo, Dos Pobres, and Western Copper were yet to be developed, hence, were considered as reserve-base copper rather than reserves. The Lone Star property near Safford, AZ, which was acquired from Kennecott in 1986, was also in this category. A potentially significant copper deposit was delineated by diamond drilling near Bisbee, AZ. At yearend, preliminary estimates had indicated about 154 million tons averaging 0.50% copper. Secondary chalcocite occurred near the surface and was thought to be amenable to heap-leaching and SX-EW recovery. Phelps Dodge was to continue sampling and feasibility studies through 1988.

In April, Sharon Steel Corp. filed for bankruptcy under chapter 11 of the Federal Bankruptcy Act seeking protection from its creditors. Although Sharon Steel's Continental Mine in New Mexico was shut in 1982, Texas-New Mexico Power Co. alleged in a lawsuit that Sharon Steel's termination of an electric service contract was not effective until June 30, 1985. The mine has been kept on care and maintenance by a crew of 10 where about 500 mining and milling personnel were once employed. Substantial reserves reportedly remain.[30]

The State of Tennessee purchased the 16.4-acre Burra Burra Mine site, the oldest in the Copper Basin, to help preserve the historic industrial complex. This was to be Tennessee's first State-owned historical industrial site, which includes the sealed entrance to the copper mine and 13 buildings that date from 1900 to 1922. Mining was discontinued here in 1958. The site was placed on the National Register of Historic Places in 1983.

After 144 years of commercial copper mining in Copper Basin, TN, Tennessee Chemical's mines were closed in early August. About 250 employees had already left through attrition and early retirement programs following the closing announcement 30 months prior to shutdown. The company will continue to manufacture sulfuric acid and copper chemicals, retaining 325 jobs. Eventually, a total of 650 workers will have been laid off.

Mine Environmental Issues.—The Environmental Protection Agency (EPA) reportedly spent more than $20 million since 1983, when it began negotiating with the Atlantic Richfield Co. for testing and remedial action of land and water damages that resulted from decades of mining, smelting, and other industrial processes in Montana. Of the total, about $17.1 million was spent for various public and private contracts at five sites. Most of that, $9.2 million, was spent on the Silver Bow Creek-Butte site for testing and removal of contaminated soils in Walkerville and for monitoring flooding in the Berkeley Pit and underground workings. The agency also spent $4.1 million at Anaconda, which includes Mill Creek, Smelter Hill, the old reduction works, the Arbiter plant, and the tailings ponds north of Smelter Hill. An additional $2.7 million was spent at Milltown Reservoir, which was contaminated with arsenic and other heavy metals carried downstream from the Butte mining district and the Anaconda smelter. An additional $1.3 million was spent on studies along the Clark Fork River. EPA and Montana agencies identified 77 potential contamination problems within the Clark Fork Basin, which reportedly was the largest Superfund site in the country.[31]

Projects involving concrete capping of old mine shafts and hauling away tailings were also completed or under way during the year. Three shafts, east of North Main in the Mountain Consolidated complex of Montana, were capped, and tons of tailings were hauled away. Similar capping and hauling at the West Grey Rock (at the end of Center Street) and the Belle of Butte (east of the Alice Pit and the Steward Mine) were being carried out as part of a reclamation and mine-shaft capping project on Butte Hill.[32]

Smelter Production.—Even though several smelters closed during the year, primary and scrap smelter production increased in 1987 compared with that of 1986. Nine primary smelters with a combined capacity of 1.2 million tons operated most of the year. In addition, five secondary smelters with a combined capacity of 282,000 tons operated. Two primary smelters with a combined capacity of 148,000 tons per year closed permanently during the year; one was a reverberatory smelter in Arizona and the other was an electric smelter in Tennessee. One new flash smelter was under construction in Arizona, and one large smelter reopened in Utah.

U.S. smelter capacity, by process category, was as follows:

Process	Smelter capacity (metric tons, copper in blister)	
	1975	1987
Outokumpu flash	--	160,000
Inco flash	--	288,000
Noranda modified	--	210,000
Electric	336,000	112,000
Reverberatory (primary)	1,444,500	386,000
Reverberatory (secondary)	208,400	281,000
Total	1,988,900	1,437,600

The significant shift in type and amount of smelter capacity was indicative of the rapid change since 1975 toward energy-efficient capacity with greater sulfur dioxide capture. The White Pine smelter was the only U.S. smelter operating without a sulfuric acid plant, which was not practical owing to the low sulfur content of its ores.

Asarco produced blister copper from two domestic smelters, one at El Paso, TX, and another in Hayden, AZ. The company's Hayden-Ray smelter, with a 100,000-ton-per-year capacity, was acquired from Kennecott late in 1986 but remained closed during 1987. Asarco's smelter production was down slightly from that of 1986. The annual capacities for the Hayden flash smelter and for El Paso were estimated to be 168,000 tons and 104,000 tons, respectively.

Pyrite from the Ropes Gold Mine at Ishpeming, MI, was tested for use at Copper Range's smelter at White Pine, MI. The pyrite was to be used along with that imported from Canada, which was received by barge across Lake Superior. The pyritic ore, used as a smelter flux, was shipped by truck from the Ropes Mine and was less expensive. Copper Range also received coal for its company-owned electric plant through the Ontonagon pier on Lake Superior.

Cyprus planned to process a small portion of its concentrate production at its newly purchased, 136,000-ton-per-year roasting plant at Casa Grande, AZ. In addition, Cyprus had toll smelting and refining and concentrates sales agreements with Magma and three other domestic and foreign custom smelters. These contracts were expected to cover about 75% of estimated 1989 production and 45% of estimated production between 1990 and 1997. A 1986 agreement with Magma, which covered a minimum of 300,000 tons or about 50% of Cyprus concentrates production, was to commence in 1988. The agreement was to terminate in 1997 and was contingent upon the availability of Magma's new smelter capacity in the second quarter of 1988.

ICC continued to operate its smelter at full capacity, treating purchased and tolled concentrates. ICC had arranged for enough concentrates (345,000 tons of concentrates per year) to operate at capacity through 1989. ICC's smelter and acid plant produced 92% of the sulfuric acid required by the leaching operations. ICC completed several smelter improvements, including the installation of a new anode-casting facility and two gas coolers that permitted it to reduce costs and increase smelter efficiency.

According to its annual report, Phelps Dodge produced only 238,400 tons of blister copper at its U.S. smelters in 1987, down considerably from 325,200 tons reported in 1984. Phelps Dodge had smelted and refined most of its own mine production, but owing to smelter capacity cutbacks of recent years was selling the excess concentrates, or having them toll smelted both domestically and abroad. The company's Douglas smelter in Arizona was closed permanently in January 1987, as a result of environmental noncompliance.

An Outokumpu flash-smelting furnace was under construction at Magma's San Manuel smelter in Arizona. The design capacity was to be 2,722 tons of concentrates per day, capable of producing about 272,000 tons of copper per year, based on predicted feed grade.[33] It will be the world's largest furnace of its type. Startup was planned for August 1988. Outokumpu Engineering Inc. was awarded the contract for the smelter modernization program, which included concentrate drying, a flash furnace, furnace feeding systems, flue-dust handling, and gas cleaning and handling systems. Davy McKee Corp. of California was the general contractor for the project. Other major contracts were awarded to Lurgi Inc. for converter gas handling, Monsanto Chemical Corp. for the acid plant, and Liquid Air Corp. for the oxygen plant. The gases from the new flash furnace were expected to run about 31% sulfur dioxide. Only four converters were required to process the matte, which would average 63% copper. Four new jet scrubbers were to replace the current gas-handling system from the converter. Both the slurry produced by the scrubbers and the dust captured by the electrostatic precipitators contain copper and were to be recycled. Slag cleaning for the furnace was to be done by flotation.

Smelter Environmental Issues.—Minproc Ltd. of Australia, which was a substantial shareholder of Artech Recovery Systems Inc., was preparing the final feasibility study for the recovery of metals from flue dust at the Anaconda Copper Reduction Works in Anaconda, MT. The site contained an estimated 327,000 tons of flue dust. Artech Recovery and CSS Management Corp. formed a joint venture, called Artech Ventures, to recover bismuth, copper, gold, lead, mercury, silver, and zinc from the arsenic-bearing flue dust. A hydrometallurgical process for economic recovery of the metals was being tested. Earlier testing indicated that arsenic in the treated flue dust would be chemically bound in insoluble precipitate and would not be hazardous. The processing method, called the Cashman process, was developed following 5 years of joint research and development with the Bureau of Mines. Processing operations were planned to begin in 1988 with 97 tons of flue dust per day, expanding to 363 tons per day. About 20 to 35 people would be employed during construction and operation of the plant.[34]

However, at yearend, Artech was waiting for EPA to determine if the encapsulated arsenic could be stored on Smelter Hill and whether the now closed Arbiter SX-EW plant could be used for processing the material. U.S. Department of Transportation regulations also would apply to the project if moving the hazardous dust across Highway 1 to the Arbiter plant was determined to constitute public transportation. A Montana Water Quality Bureau discharge permit would also be required.

EPA ordered the eight remaining families of Mill Creek, MT, to leave the 160-acre community owing to health problems that ostensibly were related to heavy-metals contamination from the now closed Anaconda smelter. Permanent relocation was ordered to address the imminent health risks from high levels of arsenic, cadmium, and lead in the area. The residents filed a lawsuit against Anaconda seeking damages for health problems associated with living near the smelter. Under a proposed EPA-Anaconda consent agreement, Anaconda had 1 year to buy the remaining eight homes. EPA began investigating Mill Creek after urine samples taken in 1985 revealed elevated arsenic levels in several young children. Anaconda had since purchased 24 lots and had moved 19 families.[35]

Asarco received notices from EPA concerning releases or threatened releases of hazardous substances, pollutants, or other contaminants under the 1980 Superfund law regarding the former Houston plantsite of Federated Metals Corp., a wholly owned subsidiary. Federated Houston's scrap-processing plant in Texas was closed permanently in 1984. In January 1987, this plant was listed on the Texas State Superfund Registry.

A settlement reached with the Arizona Department of Health Services and the EPA allowed Magma to continue operating its San Manuel reverberatory smelter until the new flash furnace was completed. The consent decree, completed February 23, established a November 1, 1988 deadline for completion of its smelter project, which will fully comply with Federal and State air-quality standards. Interim air-quality standards that the reverberatory smelter must meet were established, along with penalties, if these standards are violated. A past air-quality violation penalty of $600,000 was to be paid by Magma, in addition to posting a $20 million letter of credit guaranteeing compliance with the November 1988 deadline. The Federal Clean Air Act had set January 1, 1988, as the deadline for full compliance with air-quality standards.

Refinery Production.—Refinery production was considerably higher than that of

1986 owing to the reactivation of some capacity, as well as to the startup of expanded or new electrowinning capacity. During 1987, 26 refineries operated, including 10 electrowinning plants, 9 primary and secondary electrolytic plants, and 7 secondary fire-refining facilities; no primary fire refining was reported during the year. Annual U.S. refinery capacity was estimated to be 1,980,000 tons of primary and secondary refined copper. Primary refinery capacity consisted of 1,425,000 tons of electrolytic cathode and 182,000 tons of electrowon cathode.

Asarco reported capacity at its Amarillo, TX, refinery as 414,000 tons and at its recently acquired Ray SX-EW plant in Arizona as 36,000 tons. Asarco's refined copper production was 53% from purchased material, 13% from tolled material for others, and only 34% from the company's own mines. Copper cathodes were produced at the rate of 82 tons per day from the company's Ray SX-EW plant; about 21 tons per day was from sulfide dump leaching, and 61 tons per day was from silicate leaching.

BP Minerals America restarted its refinery in Utah at the end of July. However, full capacity was not expected to be reached until mid-1988, following completion of the mining and milling renovations.

Copper Range had two anode furnaces, one of which was completely rebuilt. From a holding furnace, fire-refined copper was fed through a Hazellett Inc. continuous-casting anode machine. The anode was cut into shape for the refinery from the hot metal sheet, providing a very smooth, uniform anode. Cathode produced by the electrolytic refinery was very pure and was used mainly for magnet wire, according to company officials. Cathode was shipped by truck to Ontonagan from where it went by rail to market. Copper Range was leasing the modern refinery from Echo Bay Mining Ltd. Although there was a specialty casting shop on the premises for making custom cake, rod, and other forms, including high silver-copper alloy, this part of the plant was not being used. It was anticipated that a nickel sulfate line would be put back into operation in the near future. The refinery, which used the Australian Isa process with stainless steel starter sheets, was constructed by Copper Range (Louisiana Land and Exploration Co.) during 1982 and was used for processing scrap during the mine closure from 1982 to 1986.

Near the end of August, Cox Creek Refining Co. of Baltimore, MD, started limited production of copper rod for customer testing and qualification, but full production was not scheduled to begin until 1988. The associated refinery remained idle. Production at the rod mill was from toll cathode and copper scrap, both alloyed and unalloyed. Mitsubishi Metal America joined the venture, providing a supply of raw material for refining and rod production. Halstead Industries Inc. of Zelienople, PA, also joined Mitsubishi and Southwire Co., Georgia, as investors in Cox Creek. Each of these companies owned 20% of Cox Creek, which was purchased from Kennecott. Securing copper supplies in the tight yearend market was a major hurdle for the company before it could begin large-scale production. The Baltimore refinery's capacity was put at about 180,000 tons per year. Kennecott dismantled some tankhouse capacity prior to closing. The original annual capacity had been 254,000 tons.

In 1987, ICC increased proven reserves of low-cost leachable ore at its Arizona-based operations by more than 40% from 1986 levels. It also expected to reduce cash costs of production by about 5 cents per pound after additional SX-EW production of about 11,500 tons starts in the fourth quarter of 1988. Exploratory drilling had proven the availability of sufficient reserves to continue all-leach production at ICC for more than 12 years at current operating rates. In addition, a modernization of ICC's tankhouse was under way and scheduled for completion in 1988. In 1987, the company produced 48,000 tons of copper from leach extraction methods. In 1987, ICC's tankhouse and rod mill produced a record high 78,000 tons of cathode and 120,000 tons of copper rod, respectively.[36]

As part of the tailings reprocessing project at Magma's Pinto Valley Div., capacity at the Miami Unit SX-EW operation was to be doubled from about 15 tons of copper per day to 30 tons per day. In addition, copper starter sheets were to be eliminated at the Pinto Valley tankhouse; instead, a conversion to stainless steel blanks was being made, as was already the case at the company's San Manuel SX-EW plant.

The 100% expansion program of Magma's San Manuel SX-EW plant was about 65% complete at yearend. The new plant was to recover copper from solutions generated by the new in situ, oxide-ore-leaching project and was being built adjacent to the first SX-EW plant, brought on-line last year. The first plant was recovering copper from heap-leaching oxide ore that was being mined by open pit methods from the oxide ore body over a mined-out portion of the sulfide ore zone. Owing to delays occasioned by the need to complete underground mining of the underlying sulfide ore, the scheduled startup for production by the in situ plant may be as late as 1989; eventually, the new plant will double electrowon copper production to 45,500 tons per year. Magma found that the Australian Isa process was a complete success and enabled production of high-quality copper. In its first year of operation, the existing 25,000-ton-per-year plant was producing a little more than its rated capacity. Although production costs for heap leaching were listed by Magma as less than 50 cents per pound, in situ production costs were expected to be substantially lower. The in situ site was at the eastern edge of San Manuel's open pit oxide mine, in the north central portion of the subsidence zone. Injected fluids were to percolate down through 1,000 feet of ore before reaching the collection point at the 2,375-foot level underground. The ore block contained about 161 million tons of recoverable copper and was expected to have a 10-year life.

A third expansion at the Tyrone, NM, SX-EW plant, which was operated by Burro Chief Co., was to increase the plant's annual capacity to 50,000 tons and was nearing completion. A new 41,000-ton-per-year facility was under construction at Chino Mines, with initial production scheduled for the fall of 1988. The 45,000-ton-per-year Morenci electrowinning plant began production in October, and plans were being considered for further expansion.

Phelps Dodge's refinery at El Paso, TX, had a capacity of about 410,000 tons of electrolytic copper per year. Most of Phelps Dodge's refined copper, and additional copper purchased by the company, was cast into rod. Phelps Dodge was the largest domestic producer of copper rod with continuous cast rod facilities in El Paso, TX, and Norwich, CT, that were capable of producing about 386,000 tons of rod per year. Rod sales to outside wire and cable manufacturers constituted about 50% of the company's primary metals sales in 1987.

Copper Powder.—Copper powder production at U.S. manufacturers reached 17.4 million kilograms in 1979 but has declined by about one-half since that time. At the same time, copper powder imports have increased sevenfold. Nonetheless, exports, which were also lower by one-third in 1987 and were lowest in 1983 and 1984 compared with 1979, have continued to be relatively high. U.S. apparent consumption of copper powder decreased from 15.9 million kilograms in 1979 to about 7.3 million kilograms in 1986. Powder metal sales, including copper powder, in North America are heavily dependent upon the automotive industry, which decreased the number of vehicles shipped over the same period. However, U.S. copper powder consumption improved by about 30% in 1987, as U.S. manufacturing of products using powder increased owing to higher demand arising from the decreased value of the dollar. Copper powder consumption was reported from 35 companies in 1987, down from 42 companies reporting copper powder production in 1986. Among those companies reporting to the Bureau of Mines, the largest consumers were General Electric Co., St. Marys Carbon Co., Allied Automotive Co., Chrysler Corp., Stack Pole Corp. and Sintered Metals Inc.

According to Metal Powder Industries Federation shipments data, copper powder usage, including bearings, comprised about 51% of major copper and copper-base powder markets, the total for which amounted to about 16 million kilograms in 1986 and which comprised about 6% of total North American metal powder shipments. Probably the best known use for copper powder was the self-lubricating bearing that was the first major application and still accounted for about 70% of the granular copper powder used. Pure copper powder was also used in the electrical and electronic industries. Copper powder in flake form was used for antifouling paints, decorative and protective coatings, and printing inks. Nonstructural applications included brazing, cold soldering, mechanical plating, metals and medallions, metal-plastic decorative products such as floor tile and epoxy resins, and various chemical and medical applications.

The top three copper and copper alloy powder producers in 1987 were Alcan Metal Powders, Greenback Industries Inc. and SCM Metal Products. The value of U.S. copper powder production comprised only about 2% of the total metal powder sales in the United States, which amounted to nearly $1 billion. Copper powder prices steadily increased in 1987, with commercial-grade copper metal powder reaching $1.55 per pound on December 21, reflecting adjustments for the escalating cost of copper.

Granular copper powder can be produced by a number of methods, including atomization, electrolysis, hydrometallurgy, and solid state reduction. Each method yields a powder having certain inherent characteristics. Atomization was the preferred commercial production technique used because the powder chemistry, cleanliness, size, and shape can be better controlled than with other methods.

Table 2.—Apparent consumption of copper powder in the United States

Year	Production (kilograms)	Imports Quantity (kilograms)	Imports Value (thousands)	Exports[1] Quantity (kilograms)	Exports[1] Value (thousands)	Apparent consumption[2] (kilograms)
1978	16,991,985	220,827	$963	1,712,838	$4,597	15,499,974
1979	17,410,984	241,030	1,048	1,777,112	6,432	15,874,902
1980	13,202,988	185,111	1,144	1,765,621	6,397	11,622,478
1981	13,593,988	292,054	1,309	1,128,977	4,441	12,757,064
1982	9,685,991	374,255	1,198	959,098	3,830	9,101,148
1983	11,454,990	629,988	1,996	785,902	2,799	11,299,076
1984	12,782,989	2,102,952	2,224	881,211	3,379	14,004,730
1985	9,775,991	830,176	1,942	1,111,675	4,020	9,494,492
1986	7,897,993	735,325	1,736	1,367,276	5,353	7,266,042
1987	8,708,992	1,742,450	1,827	1,012,382	11,191	9,439,060

[1]Includes copper flakes.
[2]Production plus imports minus exports.

Source: Bureau of Mines and Bureau of the Census.

Copper Sulfate.—Copper sulfate was produced from copper scrap, blister copper, copper precipitates, electrolytic refinery solutions, and spent electroplating solutions. Imports of copper sulfate, which doubled compared with those of 1986, accounted for an increased share of U.S. consumption. Export data were not available. Tennessee Chemical ceased copper mining and smelting in mid-1987 and by yearend had shifted to using scrap as a basic material in the production of copper sulfate. Kocide Chemical Corp. continued with development of its in situ copper recovery program from the Van Dyke Mine in Miami, AZ. Kocide planned to produce copper precipitate from the leach solutions as a feed material for production of copper sulfate at its Casa Grande, AZ, plant. Data supplied by domestic producers for 1987 indicate that 65% of their shipments were for agricultural end uses, 30% for industrial uses including wood preservatives, and 5% for water treatment.

Table 3.—Copper sulfate producers in the United States in 1987

Company	Plant location
CP Chemicals Inc	Sewaren, NJ, and Sumter, SC.
Kocide Chemical Corp	Casa Grande, AZ.
Madison Industries Inc.	Old Bridge, NJ.
Phelps Dodge Corp	El Paso, TX.
Southern California Chemical Co	Santa Fe Springs, CA, Union, IL, Garland, TX.
Tennessee Chemical Co	Copperhill, TN.

Sulfuric Acid Production.—Sulfuric acid was produced as a byproduct of copper smelting. Three copper smelters in Arizona produced a total of 1.1 million tons, and five smelters in New Mexico, Tennessee, Texas, and Utah produced the remainder of 1.5 million tons in terms of 100% sulfuric acid. Although the Tennessee smelter closed at midyear, increased sulfuric acid production occurred as a result of the reopening of the BP Minerals America plant in Utah and better sulfur capture at all plants. Total byproduct sulfuric acid from copper, lead, and zinc smelting amounted to 3.4 million tons in 1987.

CONSUMPTION

U.S. apparent consumption of primary copper and old copper scrap increased by about 4% from that of 1986 to the highest level since the 1982 recession yet remained almost 7% below the peak consumption year of 1979. Domestic production, primary refined copper plus copper recovered from old scrap, rose by about 6% from that of 1986 and accounted for 75% of apparent consumption; domestic inventories, which declined by 50%, accounted for 5%; and net imports of refined copper, which declined by about 6% from the 1986 peak level, accounted for 20% of apparent consumption. According to Bureau of Mines estimates, the end-use distribution for copper was 70% in electrical applications, 15% in construction, 6% in machinery, 4% in transportation, 2% in ordnance, and 3% in other applications. Electrical and electronic uses in all the end uses, except ordnance, were included under electrical applications. The demand for copper in electrical applications, which increased by about 6%, was reflective of the 5% increase in gross private domestic investment, with which there has been a high degree of historical correlation.

Refined copper and copper-base scrap were consumed directly in the manufacture of semifabricated or fabricated shapes and chemicals at approximately 20 wire-rod mills; 40 brass mills; and more than 1,000 foundries, chemical plants, and miscellaneous manufacturers. Reported consumption of refined copper at wire-rod mills, increased by about 6% and accounted for almost 73% of reported consumption of refined copper. Although refined copper consumption at brass mills declined slightly, overall consumption of copper materials increased owing to increased consumption of purchased scrap.

Based on estimates by the Copper Development Association (CDA) from the gross weight of domestic mill shipments and from net imports of mill products, the end-use distribution of copper and copper-alloy mill products consumed in the domestic market in 1987 was construction, 43%; electrical and electronic products, 22%; industrial machinery and equipment, 14%; transportation equipment, 12%; and consumer and general products, including ordnance, 9%. Total brass mill shipments to the U.S. market increased by almost 7%. The largest increase in demand was in the construction sector where shipments increased by about 12%.[37] The increase in construction demand was reflective of an increased intensity of use as housing starts in 1987 declined and the constant dollar value of new construction, according to the U.S. Department of Commerce, increased only by about 1%. In construction, copper and copper-alloy products are used as building wire (electrical), plumbing and heating tube and fixtures, air conditioning and commercial refrigeration, hardware, and miscellaneous uses including roofing, flashing, and various architectural design uses. Demand in all of these uses increased during 1987. Though only a small percentage of the construction market, the use of copper for roofing and architectural purposes, in both new construction and renovations, continued to gain in popularity, resulting in a 20% increase in the miscellaneous sector.

The increased domestic demand for brass mill products was met by domestic production, with mills operating at or near capacity for much of the year. Net imports of brass mill products, according to the Copper and Brass Fabricators Council Inc., declined by 6% to the lowest level since 1984. The low valuation of the U.S. dollar, plus antidumping and countervailing duties imposed on imports of certain sheet and strip products, served to discourage imports and stimulate exports.

Consumption of copper and copper-base scrap increased by about 6% in 1987 as a result of strong demand by the brass mill industry. Increased consumption of scrap at ingot makers and miscellaneous manufacturers was also attributable in part to the strength of the brass mill industry, which reported a 65% increase in the consumption of purchased brass ingot. The tight supply and resulting price increase for refined copper encouraged the use of lower priced copper scrap. Old scrap accounted for about 43% of the copper recovered from scrap.

Over the past 20 years, there has been a marked decline in the domestic ingot-making industry. In the late 1960's, annual domestic production averaged about 300,000 tons compared with an average in the 1980's of about 190,000 tons. The decline in the ingot-making industry paralleled the decline in the domestic foundry industry: Consumption of brass ingot by foundries declined by about 50% over the same time period. CDA market data indicated that the total foundry product supply to the U.S. market had declined by more than one-third over the past 20 years, principally as a result of substitution by plastics and other materials in the plumbing market. In addition to a fall in demand for their products, domestic ingot makers also have been affected by the transfer of domestic foundry casting capacity overseas, a result of domestic environmental regulations, higher U.S. labor rates, and high material costs. Many of the major domestic suppliers of plumbing fixtures were securing all, or part of, their product line from foreign fabricators.

STOCKS

As a result of a continued world mine production shortfall, stocks of refined copper held by domestic producers and consumers and in COMEX warehouses declined for the fourth consecutive year. By yearend, industry stocks had declined by more than 50% and, at the prevailing rate of consumption, represented less than a 2-week supply. Industry stocks were at the lowest level since the end of the Korean war: At that point, however, the Government stockpile contained about 500,000 tons of copper, compared with 1987 Government stocks of only 20,000 tons.

Most of the decline in domestic stocks was accounted for by a third-quarter drawdown from COMEX warehouses; COMEX stocks by yearend had declined by 80%. During the first 2 months of the year, stocks held in COMEX warehouses actually rose as the new premium for high-grade cathode of 1.5 cents per pound, double the previous premium, attracted more copper into Texas warehouses. At the prevailing producer premiums over COMEX prices, refiners in Texas reportedly found it cheaper to deliver copper to nearby COMEX warehouses than to pay the freight costs to distant consumers. Consequently, a regional disparity developed, with surplus copper available for midwestern consumers and shortages for east coast consumers.

As the copper shortage intensified and merchant and producer premiums increased, copper held at COMEX warehouses declined. COMEX stocks rose only briefly in September as new domestic refinery capacity came on-stream. As competition for spot copper intensified during the fourth quarter, however, exchange stocks plummeted to the lowest level since 1973 and the end of the Vietnam conflict. Similarly, by yearend, consumer stocks, principally at wire-rod mills, had fallen to their lowest level in at least 30 years.

In October, the Commodity Futures Trading Commission intensified its surveillance of the copper commodity market. The small quantity of copper available and the surge in copper price raised concerns of copper price manipulation and insufficient inventories to cover deliveries on expiring contracts. At yearend, no impropriety had been revealed and there was an orderly liquidation of December contracts.

On the London Metal Exchange (LME), there was mounting pressure to eliminate the standard-grade contract owing to its low volume of trade and low liquidity. In April 1986, the LME instituted two new contracts: standard-grade and grade-A. The standard-grade contract appeared to be out of line with the market that was dominated by high-grade copper suitable for wire-rod production.

Interest in the new Mid-America Commodity Exchange copper contract, which had been introduced in June 1986, failed to materialize; by the end of the first quarter, when stocks had been liquidated, the contract became dormant. The new contract, which was comparable to the LME grade-A contract, was intended to be more in line with the physical metal market.

PRICES

The domestic producer price for copper, which had an annual average between 66 and 67 cents per pound over the previous 3 years, and averaged only 65 cents per pound during January 1987, rose throughout the year, peaking at yearend at a record 150.8 cents per pound. The price runup was a result of an increasingly short supply of copper available for purchase on the spot market. The copper shortage was the result of a world mine production shortfall that had persisted over the previous 3 years. Domestic industry stocks of refined copper, which had accumulated to a peak of almost 700,000 tons during the 1982 recession, were drawn down to just over 100,000 tons by yearend. Meanwhile, domestic consumption of copper grew, from a 1983 base, at an annual rate of 1.9%.

At yearend 1986, copper producers and

analysts were still pessimistic about the price of copper, with domestic producers adopting aggressive pricing schemes in an attempt to regain market share. Producer strategies included freight discounts to some delivery points and monthly and quarterly price caps of about 3 cents per pound over the COMEX price. In an effort to remain competitive, foreign producers lowered their premiums; Corporación Nacional del Cobre de Chile (CODELCO-Chile) halved its first quarter COMEX-based premium to 0.75 cents per pound.

Tightness in the copper spot market began to appear early in the year. Producers had secured long-term supply contracts and the new 1.5-cent-per-pound premiums on high-grade copper cathode drew more copper into COMEX warehouses. By May, tightness in the market was clearly evident, with most producers reportedly sold out of spot copper for the remainder of the year; the producer price rose to 80 cents per pound by the second week in July. Factors contributing to the tightness of supply included strong demand during the first quarter, with consumption in March at the highest reported monthly level in almost 8 years; an increase in consumer inventories at wire-rod mills in anticipation of strong demand in the second half of the year; and supply disruptions from Canada and Africa. The price rise was fueled by both a renewed speculative interest in copper markets and a concern that COMEX warehouses could not deliver all the copper held on contract if too many contract holders took delivery rather than liquidate their positions. By May, prices on COMEX had gone into backwardation, with forward sales contracts selling at a slight discount to spot purchases. Prices continued to rise during the second half of the year as domestic inventories declined and demand remained strong.

In November, with industry stocks at a level representing only about a 2-week supply, prices began a dramatic increase as consumers sought to secure copper for the first quarter of 1988. Backwardation of prices on COMEX jumped from 12 cents per pound on 3-month-forward contracts to 24 cents at monthend and to about 50 cents at yearend. Tightness in the domestic market was exacerbated by foreign producers taking advantage of the large spread between the LME price and the COMEX price to ship copper to Europe preferentially and by a declaration of a force majeure for January 1988 shipments by Noranda Copper Co. The LME premium over COMEX, which had averaged only 2.4 cents per pound during the first 10 months of 1987, averaged 10.4 cents in November.

During the first half of the year, domestic dealer buying prices for unalloyed copper scrap generally followed the fortunes of refined copper, with the price spread, or margin, between refined copper and No. 1 scrap remaining constant at about 18 cents per pound. Strong demand by brass mills during the second quarter, as supplies of refined copper became tight, resulted in consumers paying prices for No. 1 scrap at or slightly above the COMEX price for refined copper. As the price of refined copper began its rapid rise at midyear, the margin between scrap and refined copper increased, and by yearend was above 50 cents per pound. The increase in price brought more scrap copper to the market and tended to moderate price increases. The dealer buying prices for alloyed scrap were much slower to respond to the effects of refined price increases and by yearend had only risen by a maximum of about 30%.

WORLD REVIEW

More than one-half of the increase in world mine production of copper was accounted for by North American producers as the United States, Canada, and Mexico added new capacity and/or increased capacity utilization, following rationalization and restructuring of their copper industries. China, Papua New Guinea, and the Republic of South Africa also increased production. In Papua New Guinea, Ok Tedi Mining Co. Ltd. (OTML) started the copper circuit at its gold-copper project. In China, a major concentrator expansion was completed at the Dexing Mine, Jiangxi Province. New world mine capacity added during the year was estimated to be 176,000 tons of copper, to which market economy countries contributed 72%. World mine capacity was estimated to be 9.3 million tons of copper in 1987; market economy countries constituted 83% of the total. Significant production declines were reported by Japan, which resulted mainly from the streamlining of Dowa Mining Co.'s operations that was completed during 1986 and by Spain, which resulted from the closure of Rio Tinto Minera S.A.'s three copper mines. A decision on whether to close permanently the Rio Tinto Mines, which had a combined capacity of about 47,000 tons of copper per year, was not expected until the end of 1988. Rio Tinto's flash smelter and electrolytic refinery continued to operate with imported concentrates.

Development work on several major copper deposits continued. In Australia, the Olympic Dam project was scheduled for a mid-1988 startup. In Chile, negotiations were proceeding to finalize both project financing and concentrate sales contracts for the Escondida project, with final approval of the $1.2 billion project expected in 1988. In Brazil, pilot plant tests on ore from the Salobo deposit reportedly exceeded expectations, and project engineering was under way for development of this deposit by 1992. In Portugal, underground development and construction of the concentrator at the Neves-Corvo project were on schedule and production was scheduled to begin by late 1988 at an annual rate of 1 million tons of ore containing 10% copper.

World smelter production rose by about 2% compared with that of 1986, principally as a result of production from new or expanded smelter capacity in Brazil, China, and Mexico, and from a major smelter in the United States that reopened. Increased concentrate imports allowed production to be increased at Caraiba Metais S.A.'s 150,000-ton-per-year flash smelter in Brazil, which had operated with insufficient feed since being commissioned in 1983. Increased production from the 90,000-ton-of-anode-per-year Guixi smelter in China, which was completed in 1985, was possible owing to increased production at the Dexing Mine. In Japan, although total production from its seven smelters remained at about the same level as that of 1986, production from primary materials rose by about 5%, and stocks of copper concentrates were depleted. Japanese smelters underwent further rationalization during the year as Mitsui Mining and Smelting Co. Ltd. closed its blast furnace as a result of a tolling arrangement made with Nippon Mining Co. Ltd. and Furukawa Co. Ltd. Furukawa halved its production at its Ashio smelter. Belgian smelter production, which was principally from secondary materials, declined by more than 40% owing to tight scrap supplies.

European and Japanese smelters continued to compete for concentrates and to invest in new mining projects in exchange for long-term concentrate supply contracts. In Finland, the state-owned Outokumpu Oy sought to secure concentrates for its Harjavalata smelter. Finland's chronic shortage of copper concentrates was exacerbated by the closure of several Scandinavian mines. In addition, Outokumpu planned to provide loan guarantees for the Escondida project in Chile in exchange for a long-term supply contract (50,000 tons of copper per year in concentrate) and at yearend was negotiating for a large share of Neves-Corvo's concentrates. In Sweden, Boliden AB, whose Ronnskar smelter was threatened with closure owing to environmental constraints and monetary losses, announced plans to invest about $450 million to ensure adequate smelter feed through extending existing mining operations and opening new mines. Boliden operated 17 mines in Sweden, including its Aitik Mine, a 40,000-ton-of-copper-per-year mine that was slated for extension under Boliden's investment plan. Environmental issues remained unresolved because of pending law suits.

Despite the affirmative actions by custom smelters to secure long-term supply contracts, the spot market for custom concentrates was stable throughout the year. Spot Japanese tolling and refining charges averaged about 16 cents per pound of copper. Despite tight supplies, major increases in world smelter consumption of concentrates were generally balanced by increased production at mines.

Even though production from primary materials grew by 3%, world production of refined copper grew by less than 2% as a result of tight scrap supplies. In the United States, primary refined production exceeded the increase in smelter production owing to increased production of electrowon refined copper, which bypassed the smelting process.

Demand for refined copper by market economy countries rose about 3% to a record-high level, according to preliminary data from the World Bureau of Metal Statistics. Consumption increases by North American countries, particularly Mexico and the United States, accounted for about 50% of the world increase in refined copper demand. In South America, refined copper demand in Brazil was reported to have risen by more than 25%. Demand in Western Europe was at about the same level as in 1986, with only small gains or losses reported by most countries. Spain, in particular, showed strong copper demand growth, rising by about 13%. In Asia, significant increases in refined copper consumption were reported in Japan, the Republic of Korea, and Taiwan. In Japan, demand was buoyed by a strong domestic housing market. In the Republic of Korea and Taiwan, demand followed a strong growth trend reflective of the growth in their gross national products.

Table 4.—Estimated production costs at producing copper mines[1]

(January 1987 U.S. dollars per pound of refined copper)

Country	Number of mines	Mine operating cost	Mill operating cost[2]	Smelter-refinery cost[3]	(Less) byproduct credit	Net operating cost[4]	Taxes[5]	Total cash costs[4]	Recovery of capital	Total production cost[4 5]
Australia	3	$0.19	$0.10	$0.32	$0.07	$0.53	$0.01	$0.54	$0.07	$0.60
Canada	14	.28	.24	.33	.32	.53	.02	.55	.11	.65
Chile	7	.15	.19	.09	.06	.37	.01	.38	.04	.42
India	5	.35	.24	.43	.04	.98	.03	1.01	.09	1.10
Peru	5	.20	.24	.34	.05	.73	.02	.75	.12	.87
Philippines	7	.35	.37	.23	.28	.68	.06	.74	.09	.83
United States	15	.19	.28	.14	.10	.51	.02	.53	.05	.58
Zaire	6	.23	.12	.25	.20	.40	.06	.46	.16	.62
Zambia	8	.18	.08	.10	.05	.31	.03	.34	.14	.48
Other	37	.24	.33	.28	.28	.57	.04	.61	.11	.72
Total or average	107	.20	.22	.18	.13	.47	.03	.49	.08	.58

[1]Based on life-of-mine production rates and ore grades. Does not necessarily reflect 1987 operating grade and production.
[2]Includes copper recovery by leaching.
[3]Includes cost of transportation.
[4]Data may not add to totals shown because of independent rounding.
[5]Taxes and production cost are at a zero percent rate of return.

Source: Bureau of Mines, Minerals Availability System (MAS) cost analysis. Prepared by Kenneth Porter.

By yearend, the gap between world demand and refined production increased. Demand for refined copper exceeded production for the fourth consecutive year. As a result, world stocks of refined copper were estimated to have fallen by about 400,000 tons and at yearend, represented only about a 4-week supply at the prevailing rate of consumption. Stocks held in COMEX and LME warehouses alone declined during the year by almost 200,000 tons to a yearend level of only 70,000 tons. The shortfall in production was exacerbated by shipping delays from some of the major copper exporting countries. Rail and port delays were encountered in Africa, as Central African copper exports were shifted from ports in the Republic of South Africa to ports in Mozambique and Tanzania. In Canada, a railroad strike disrupted supply. Consequently, by yearend, the LME price of copper had more than doubled.

The average production cost at the world's producing copper mines, including smelter and refinery charges and recovery of capital, was estimated to be 58 cents per pound, down considerably from the 65 cents estimated for 1986. Net operating costs were estimated to be 47 cents per pound. Some of the lowest costs estimated at the mine and mill level, such as those for Zambia, reflect severe adjustments in exchange rates that effectively lowered the cost. Zambia also had a preponderance of lower cost leach and SX-EW production, which helped to keep its average cost down. The lowest cost producer was Chile, followed by Zambia, the United States, Australia, Zaire, and Canada.

Australia.—Mine production declined for the second consecutive year owing to decreased output from Australia's two largest mines, the Mount Isa Mine (Mount Isa Mines Ltd.) and the Lyell Mine (Renison Goldfields Consolidated Ltd.), as well as to the closure of several mines. The Mount Gunson Mine (EMAC Gunson Partnership) closed in mid-1986, and the small Warego Mine (Peko-Wallsend Ltd.) closed in early 1987. Even so, smelter production increased as Mount Isa increased smelter capacity through incorporation of the Isamelt process. Refinery production increased owing to expanded production at the Townsville refinery.

The joint venture between Cyprus Minerals Australia Co. (37.5%), Arimco NL (37.5%), and Elders Resources Ltd. (25%), announced its intention to develop the Starra copper-gold deposit, which was about 145 kilometers southeast of Mount Isa. The Starra project was slated to begin production in early 1988 and to produce 10,000 tons of copper in concentrate per year. To date, 4.6 million tons of ore, with an average grade of 2.05% copper and 5.2 grams of gold per ton, had been identified.

Barrack Mines Ltd. announced its intention to develop the deeper, polymetallic ore at its Horseshoe gold mine in Western Australia. A plant to produce about 17,000 tons of copper in concentrate was under construction and was scheduled to begin production in early 1988. Ore reserves of at least 930,000 tons, with a grade of 8.4% copper, 22 grams of silver per ton, and 1.4 grams of gold per ton, had been delineated.

Construction of the Olympic Dam copper-gold-silver-uranium project at Roxby Downs Station, South Australia, was progressing toward a mid-1988 startup date. The initial annual production rate was to be 30,000 tons of copper; the smelter and refinery were to begin operation during the fourth quarter of 1988.

Exploration of a number of base metal projects continued during the year, including the Thalanga deposit in Queensland, which reportedly had estimated ore reserves of more than 7 million tons containing 2.2% copper, 11.4% combined lead and zinc, 71 grams of silver per ton, and 0.47 gram of gold per ton. Preliminary studies for a 600,000-ton-of-ore-per-year plant reportedly were completed.

Canada.—Mine production of copper rose by 10% to a record-high level, while smelter and refinery production remained at about the same level as that of 1986. Smelter and refinery production were negatively affected by a strike at Noranda's Horne smelter, which began in November 1986 and continued through the first quarter of 1987, and by a railroad strike that occurred during the fourth quarter of the year and impeded the flow of smelter and refinery feed materials. Consequently, exports of ores and concentrates rose by almost 8% to record levels, while exports of refined copper declined. Domestic demand for refined copper rose by more than 10%, buoyed by strong brass mill demand and exports of brass mill products.

Mine production was regionally divided, principally between the western Province of British Columbia, which accounted for 45%

of Canadian production, and the central and eastern Provinces of Ontario, Manitoba, and Quebec, which accounted for 37%, 9%, and 7% of production, respectively. In British Columbia, Highland Valley Copper Co. (HVC), Canada's largest copper mine producer, which was formed last year through the merger of Cominco Ltd.'s Highland Valley area assets with those of Lornex Mining Corp. Ltd., completed installation of two semimobile, in-pit crushers and an associated 5-kilometer belt conveyor system. The new system, which was completed at yearend at an estimated cost of $44 million, linked Cominco's high-grade Valley Pit with the modern Lornex Concentrator and was expected to substantially reduce costs. HVC reportedly became the most competitive copper operation in Canada. In 1987, HVC processed 42 million tons of ore with an average grade of 0.43% copper to yield 86,000 tons of copper in concentrate; 90% of the ore was processed at the Lornex mill, and the remainder was processed at the Valley mill. Under the new production plan, the Lornex Pit will supply the Lornex Concentrator with only about 15% of its ore, while about 30,000 tons of ore per day from the Valley Mine will be trucked from the conveyor transfer point to Cominco's Bethlehem concentrator. In September, Teck Corp. reached an agreement with the HVC partners to merge its Highmont Mining Corp.'s mill facilities into HVC. Cominco will reportedly relinquish 5% of its 55% share to Teck in exchange for a cash payment from HVC. The acquisition would reportedly allow for the eventual closing of the Bethlehem mill in favor of the Teck mill. Afton Mining Corp. depleted the ore reserves in its main pit, but continued operations from stockpiled ore and from its Pothook Pit, which was to be depleted in 1989.

In Ontario, Falconbridge Ltd. completed the expansion of smelting and refining operations at Kidd Creek to 92,000 tons of copper per year. The smelter was closed for 5 weeks during the fourth quarter for maintenance and modifications related to the expansion.

In Manitoba, Sherritt Gordon Mines Ltd.'s Ruttan Mine was sold to Hudson Bay Mining and Smelting Co. Ltd., effective July 30. Sherritt Gordon, which had reported losses in 1986, had considered closing the mine, which supplied almost 80% of purchased concentrates and 30% of total feed to Hudson Bay's Flin Flon smelter.

In Quebec, Noranda reached an agreement with the Provincial Government to build an acid plant at its Horne smelter to cut sulfur dioxide emissions in half, to 300,000 tons per year. The Federal and Provincial Governments were expected to pay one-third each of the estimated $95 million cost for building the acid plant, which was expected to come on-stream by 1990. In April, a fire at Noranda's underground Gaspé Mine closed the mine indefinitely. The associated smelter, which had an annual capacity of about 65,000 tons of copper, continued operating using stockpiled and tolled concentrates. Minnova Inc., formerly Corporation Falconbridge Copper, was proceeding with its development of the Ansil and Winston Lake properties. Ansil, which had indicated ore reserves of 2 million tons with an average grade of 7.1% copper, 0.5% zinc, and 0.8 ounce of silver per ton, was expected to start production in 1989 at a rate of about 500,000 tons of ore per year. The Winston Lake zinc-copper mine, which had an average ore grade of 16% zinc and 1% copper, was expected on-stream in 1988. It was designed to process 350,000 tons of ore per year. Les Mines Selbaie announced its intention of developing the third ore body at Selbie, Quebec. The development of its A-2 underground zone, which had an average grade of 2.24% copper, 1.04% zinc, 1.23 grams of gold per ton, and 19.4 grams of silver per ton, will extend the mine life by about 4 years.

Chile.—Copper production increased slightly despite a decline in production by state-owned CODELCO-Chile, the world's largest copper-producing company. CODELCO-Chile reported producing 1.09 million tons of copper, 11,500 tons less than its 1986 record-high production. However, even though production of copper declined, production of byproduct molybdenum increased slightly. Copper production at CODELCO-Chile's four producing divisions fell short of projections because of extenuating circumstances relating to severe winter weather conditions, and to the high arsenic content and declining grade encountered in the Chuquicamata ore. Because of the high arsenic content, CODELCO-Chile reportedly exported some of Chuquicamata's concentrates for processing. CODELCO-Chile's sales program had called only for sales of some Andina concentrates. CODELCO-Chile reported record-high pretax revenues of about $730 million, an increase of about 80% over that of 1986. Copper sales increased by about 2% to 1.16 million tons, 40% of which went to Western Europe, 23% to South America, 22% to Asia, 13% to North America, and 2% to other destinations. Electrolytic grade cathode, or wirebar, accounted for 55% of their sales; fire-refined copper, 14%; and unrefined copper, 31%.[38]

In 1987, CODELCO-Chile reported investing $323 million in plant improvements and equipment, in part to expand capacity and in part to compensate for declining ore grades and higher operating costs. At its Tocopilla powerplant, which was spun off from the Chuquicamata Div. to form a fifth operating division, a major investment in a pier and in coal-handling facilities was completed. The new unloading installation can handle up to 1,500 tons of coal per hour. A new power generator, intended to meet the additional power requirements of expansion projects at Chuquicamata, was commissioned in July. At Chuquicamata, milling capacity was being increased by 50% to 153,000 tons of ore per day, work was progressing on a 51,000-wet-ton-per-day concentrator expansion, a new anode casting facility was completed, and a new flash furnace and acid plant were under construction. An expansion of materials-handling facilities, including a waste crushing and conveying system at the mine, was nearly complete, as was a 275,000-ton-per-year expansion of the electrolytic refinery. The expansion plans were geared at not only expanding annual output to about 750,000 tons of copper per year, but also at compensating for a declining ore grade, which was expected to fall from 1.6% copper to 1.0% copper by 2000. The new flash smelter and acid plant, the refinery expansion, and a waste-dump leaching project were all planned for operation in 1988. Excess acid production was expected to be sold at up to a 70% discount from the prevailing market rates as a Government stimulus to the small- and medium-size mining sectors for exploitation of oxide reserves through leaching.

At the El Teniente Div., work on expanding the underground mine into the Mina Sur and Mina Norte sectors progressed for the purpose of increasing ore production by 20% to 110,000 tons per year by 1991. The expansion was necessary to maintain production levels because the more friable, secondary-enriched ore was nearing depletion and ore grades had fallen from 1.8% in 1980 to 1.4% copper. The mine was also shifting to more mechanized block-caving methods in order to cope with the harder ore. The new dam at Caren began receiving tailings through a gravity-fed, 85-kilometer, concrete flume. At the Calcetones smelter, the first of several new and enlarged, El Teniente-type, modified converters was installed as part of an expansion plan that was aimed at keeping pace with increased mine production and lower concentrate grades. At the Andina Div., the tailings dam was augmented to increase disposal capacity as mine capacity was increased. At the El Salvador Div., a new mechanized loading facility was commissioned at the Port of Chanaral, and an oxygen plant was installed at the Porterillos smelter to boost capacity.

Empresa Nacional de Minería (ENAMI), the state-owned custom mineral processor, which served the small- and medium-size private mining sector, operated four concentrators, two smelters, and a refinery. As a custom processor, it was able to handle a wide variety of ores and concentrates. In 1987, it reported a record-high revenue of $662 million and profits of $30.1 million. The rise in copper prices in 1987 allowed for suspension of the price-support system early in the year and for mining companies to begin repayment of debt accrued to ENAMI since 1983. Production of refined copper by ENAMI rose by more than 15% to about 200,000 tons, following completion of an expansion project in 1986 at its Ventanas refinery. At midyear, ENAMI announced approval for the construction of a 290,000-ton-per-year sulfuric acid plant and an oxygen plant at its Ventanas smelter. These plants, expected to be completed in 1989, reportedly will increase smelter capacity by an estimated 180,000 tons of concentrates per year and will allow ENAMI to become an exporter of sulfuric acid. The expansion will eliminate the imbalance between ENAMI's smelting and refining capacity. Previously, excess refinery capacity had allowed ENAMI to toll refine blister copper from CODELCO-Chile and others. Financing for the project, estimated to cost $72 million, was to come from the Federal Republic of Germany.

At yearend, development plans for the Escondida copper project were well under way. Interdependent negotiations were taking place to secure both financing for the project and guaranteed markets for the production. Escondida, which was owned 60% by The Broken Hill Pty. Co. Ltd. of Australia, 30% by the Rio Tinto Zinc Corp.

Ltd., and 10%, by a Japanese consortium headed by Mitsubishi, was expected to produce up to 300,000 tons of copper in concentrates per year and to cost $1.2 billion for development. In addition to the sulfide ore body, feasibility studies were being conducted on the potential for exploitation of the oxide reserves.

Cía. Minera Disputada de las Condes S.A., a subsidiary of Exxon Minerals Corp., completed its $68 million expansion of its mine, mill, and concentrator, which since 1985 had raised production from 5,500 tons of ore per day to more than 11,500 tons per day. Exxon planned to increase total annual production from its El Soldado and Disputada Mines by about an additional 50% to 140,000 tons of contained copper by 1990.

In November, Dallhold Resources Inc., a subsidiary of the Alan Bond group of companies in Australia, purchased Cía. Minera San José Ltda., which was operator of the El Indio and adjacent El Tambo gold-silver-copper mines. Proven reserves at the two mines included 6.7 million tons of ore containing 4.5% copper, 7 grams of gold per ton, and 90 grams of silver per ton. Copper production from the two mines was about 15,000 tons in 1987.

Mexico.—The two major copper mines, La Caridad, owned by Mexicana de Cobre S.A., and Cananea, owned by Cía. Minera de Cananea S.A., accounted for more than 97% of Mexico's copper mine production. Cananea increased production, having completed a major mine expansion program in 1986. Smelter production was also about 35% higher, owing to startup of a new flash smelter at La Caridad in 1986. However, the smelter, which was built to handle all of La Caridad's 1,800 tons of concentrates per day, was experiencing significant startup problems and operated at less than 50% of capacity. A sulfuric acid plant, with a projected capacity of 2,500 tons per day of 93% sulfuric acid, was under construction with commissioning planned for 1988. On January 29, the Governments of Mexico and the United States signed an agreement to limit copper smelter emissions along their common border. The agreement limited sulfur dioxide emissions from the La Caridad smelter to a maximum of 0.065% by volume, as averaged over any 6-hour period, beginning June 1, 1988. A similar limit would apply to the Cananea smelter should it be expanded.

At the Cananea Mine, capacity was being expanded through the new SX-EW plant, which will have a capacity of 20,000 tons of cathode per year and will supplement its existing construction of a 10,000-ton-per-year facility. The mill-head grade at Cananea was improved by segregating the low-grade ore, which contained 0.15% to 0.45% copper, for leaching. To balance mine and smelter production, Cananea purchased the 15,000-ton-per-year Santa Rosalia smelter at Baja. Some of Cananea's concentrates were to be processed at the Santa Rosalia smelter once renovations were complete.

As a result of strong domestic demand for refined copper, which increased by more than 30% in 1987, and a shortfall in domestic smelter production, Mexico was a net importer of refined copper. Mexico's only electrolytic copper refinery, which was owned by Mexicana de Cobre, operated at less than two-thirds of its rated 150,000-ton-of-copper-per-year capacity owing to a shortage of anode copper from its smelters.

Papua New Guinea.—Mine production increased by more than 20% as a result of the commissioning of the copper circuit in June at OTML's gold-copper project. However, startup problems caused copper production to be short of the planned 1,000 tons of concentrates per day, which averaged about 28% copper. OTML had planned to produce 180,000 tons of concentrate in 1987, 400,000 tons in 1988, and following completion of the concentrator expansion, up to 700,000 tons per year in 1992 and 1993. By midyear, Metallgesellschaft AG of the Federal Republic of Germany, which was OTML's sales agent, had negotiated supply contracts for most of the concentrate production. A Japanese consortium was to receive 60,000 tons of concentrate in 1987 followed by 230,000 tons per year over the next 6 years; the Korean Mining and Smelting Co. was to receive 30,000 tons per year over the next 5 years; and West Germany's Norddeutsche Affinerie AG was to receive 25,000 tons in 1987, increasing to 150,000 tons per year in 1988. OTML was reportedly experiencing cash-flow problems during the year and dropped its in-house feasibility study for construction of its own copper smelter.

Because of the mining of a section of lower grade ore, production at Bougainville Copper Ltd. declined slightly to 178,000 tons of copper in concentrates. Ore grade for the year reportedly averaged 0.42% copper. Bougainville completed construction of a preconcentration screening plant during the third quarter, which helped to boost production. Since its Panguna deposit was expected to be exhausted by the year 2000, Bougainville was seeking to have a Government moratorium on exploration rescinded. By yearend, a detailed engineering study for constructing a gravity-flow slurry pipeline, reportedly planned to be the world's largest and longest, had been completed. If constructed, the pipeline, estimated to cost $50 million, would transport tailings 32 kilometers from the concentrator to the Solomon Sea and would replace the existing river transport system.

Peru.—A 23-day strike in November at the Cuajone and Toquapala Mines of Southern Peru Copper Corp. (SPCC) cut production. In addition to SPCC's mines, owned 52% by Asarco, the strike also affected the Government-owned Ilo refinery, which refined all of SPCC's copper. Strikes at Empresa Minera del Perú's (Minero Perú) Cerro Verde Mine and Empresa Minera Especial Tintaya S.A.'s Tintaya Mine also reduced production.

Tintaya was considering several moves to expand its production including the possible treatment of 7.5 million tons of stockpiled oxide ore through the sulfide concentrator. The Government Institute of Geology and Metallurgy reportedly was testing the material for concentrator treatment. Tintaya also installed particle-size monitors and other equipment to enhance recovery and improve concentrate grade. Tintaya was negotiating with Minero Perú for the underground development of the Coroccohuayco deposit, which was near the Tintaya Mine and reportedly had proven ore reserves of at least 15 million tons with a grade of 3% copper. Production from the Coroccohuayco deposit was to start by mid-1990 at a rate of 61,000 tons of concentrate per year.

Minero Perú conducted a feasibility study for a combined leach process using concentration- and bacterial-leaching technologies to solve permeability problems that were encountered in sulfide ore leaching at Cerro Verde. The current leach process had been used to process oxide ores that were nearing depletion. The combined process would require a $35 million investment in new milling and flotation equipment and would involve finer grinding of the ore with segregation of the fines for concentration.

SPCC was increasing efforts to reduce costs, having barely broken even in 1987 despite the improved copper and silver prices, owing to declining ore grades at its Cuajone Mine, high tolling charges by the state-run refinery, and high fuel import tariffs. Improvement plans called for at Cuajone were the installation of column flotation cells for the treatment of about 80 to 100 million tons of sulfide ore dumps with bacterial leaching and SX-EW recovery. Plans also called for reorganization of SPCC management.

Philippines.—Mine production in the Philippines declined slightly in 1987. A 16% increase in production by the Philippine's largest producer, Atlas Consolidated Mining Development Corp., was offset by production declines at the six other copper-producing companies. Despite the rise in copper prices, most Philippine copper producers continued to lose money. Marcopper Mining Corp., with production of 24,000 tons of copper, was threatened with closure unless it could restructure its debt and secure financing for development work. Bond Corp. Holdings Ltd. negotiated throughout the year with Atlas in an effort to obtain a 40% equity in Atlas through assumption of existing loans and for additional loans to be used for exploration and development of the Masbate gold mine. At yearend, loan repayment terms with Atlas's creditors were still unresolved. Lepanto Consolidated Mining Co. Inc. and Galactic Resources Ltd. of Canada announced a joint venture to develop the Far South East deposit, a major copper-gold deposit at Mankayan, Benquet Province. Drilling had thus far delineated more than 290 million tons of ore at the Far South East deposit reportedly containing more than 2 million tons of copper. A feasibility study was scheduled for completion in early 1988.

Philippine Associated Smelting and Refining Corp.'s smelter and refinery at Isabel, South Leyte, which were 40% state-owned through the National Development Corp., announced plans to increase its 138,000-ton-per-year copper capacity by 25%. The cost of the expansion program was estimated at $51 million and was not expected to be completed until at least 1989. In June, the company received Government approval to import, for the first time, 40,000 tons of copper concentrates from Papua New Guinea. The smelter was shut temporarily in March and again in April, first due to power problems and later to allow for repairs.

Zaire.—Copper production in Zaire was from the state-owned company, La Générale des Carrières et des Mines du Zaire (Gécamines), which operated about a dozen mines grouped in three geographic regions along the copperbelt of Central Africa: Kolwesi (western), Likasi (central), and Lumbubashi (southern). At the end of April, the state-owned Société de Développement Industriel et Minière du Zaire (Sodimiza), which operated two underground mines, was incorporated into Gécamines. Sodimiza had been owned by a Japanese consortium until 1983. Gécamines was proceeding with its 5-year, $870 million investment program, which was started in 1985 to rehabilitate its copper industry. Equipment tenders had been submitted for a new 100,000-ton-per-year refinery at Kolwezi. The refinery, which was planned for completion in 1990, was expected to save $20 million per year in foreign exchange from elimination of tolling costs. Rehabilitation of the Kolwezi concentrator was expected to be completed by 1989, and a mobile in-pit crushing and belt-conveying system for the Kolwezi open pits was expected to be completed by 1990.

Zambia.—The 5-year reorganization plan announced in 1986 by Zambia Consolidated Copper Mines Ltd. (ZCCM), the state-controlled company responsible for all of Zambia's output, began to show a positive impact with mine production rising slightly. In August, ZCCM closed its unprofitable Chambishi underground mine and concentrator; open pit mining began at Chambishi in 1965. Output from the Nchanga Div. was not affected as output from the higher grade Konkola Mine was increased to compensate for lower output at Chambishi. Meanwhile, work was progressing on three underground projects at Mufulira, ZCCM's largest underground mine, which had a capacity of about 80,000 tons of recoverable copper per year. The Mufulira projects were geared toward accessing additional ore reserves and included deepening of the access shaft, extension of conveyor and service shaft inclines, and installation of an underground crusher. Ore reserves at Mufulira were estimated to be 81 million tons with an average grade of 3% copper.

In March, in an attempt to restructure its economy, which was largely dependent on copper exports, Zambia announced its intention to break with the austerity measures that had been imposed by the International Monetary Fund, and its intention to cut foreign debt service repayment. Under the new payment plan, the foreign exchange requirements of ZCCM and other state-run industries would be deducted from earnings prior to calculating its debt repayment, which was based on a percentage of earnings. This and other measures, which included cessation of the mineral export tax beginning in 1988, were geared toward ensuring the necessary capital to revitalize Zambia's mineral industry. Zambia also was seeking to halt its dependence on the Republic of South Africa's railroad system. Early in the year it halted all copper shipments through the Republic of South Africa, rerouting all copper shipments through the ports of Dar Es Salaam, Tanzania, and Beira, Mozambique. In April, Angola, Zaire, and Zambia signed a letter of intent to reopen the crippled Benguela Railway leading to the Angolan Port of Lobito. The estimated cost of rehabilitating the Benguela Railroad, which had been shut for 12 years because of destruction during the Angolan civil war, was estimated to be $280 million.

TECHNOLOGY

The first in a planned series of international conferences devoted to technical and economic developments in the copper industry took place in Viña del Mar, Chile, from November 30 to December 3, 1987. The "Copper 87" conference provided a forum for discussing both the outlook for the industry and recent advances in various technical aspects of copper processing. Papers given at the conference were published in four volumes, dealing with subjects in hydrometallurgy, pyrometallurgy, mineral economics, and mineral processing and control.[39] Several authors thought that the copper industry was not spending nearly enough on research and market development.

A comprehensive review of flash smelting was published. The authors found the flash furnace particularly interesting because it oxidizes its raw material (Cu-Fe-S concentrate) to provide part of its energy requirement; it can be operated in many ways (e.g., autogenously with oxygen blast or fossil-fuel assisted with air blast) depending upon the goals of the operator. The book described flash smelting in general, the Outokumpu and Inco flash smelting processes in particular, and included a section in which the flash smelting process was described mathematically. The mathematical section described a set of mass- and heat-balance equations that can be used to describe steady-state smelting under autogenous or near-autogenous smelting conditions. These equations can be used to determine the amounts of blast, flux, and fuel inputs to be employed for achieving a smelting goal and for optimizing and controlling the flash smelting process.[40]

The Bureau of Mines signed a Memorandum of Agreement with the Casa Grande Copper Co. for a cooperative project to help the copper company determine whether in situ mining techniques can be used at its Casa Grande West project and Santa Cruz sites in Arizona. The company was to share hydrological and geological data with the Bureau, and Bureau scientists were to evaluate the information in terms of in situ mining requirements. The Bureau was also working with two other copper companies in the Casa Grande area, evaluating potential sites for future in situ mining projects.

Significant progress has been made in recent years in copper SX-EW plant design. Continuing pressure to reduce costs and increase productivity has promoted the need for a new generation of plants. The Dremco process for electrowinning reportedly was producing a high-quality copper from a solvent extraction electrolyte.[41] The process utilized high-current-density technology, resulting in increased productivity, lower costs, and a high-purity product. Full-scale testing of the Dremco process at a copper producer's plant proved the viability of the process, demonstrating that more copper could be produced for lower cost than through conventional plants. A plant using the Dremco technology would be one-third the size of a conventional plant. The use of rigid permanent cathode blanks, precise electrode alignment, and air agitation resulted in very dense, smooth, and pure cathodes with high tensile strength.

Progress was made in the development of the new ceramic, high-temperature, copper-oxide-base, superconducting materials. In 1986, IBM Corp. researchers in Switzerland made a breakthrough in superconductivity research with copper-oxide-base materials mixed with barium and lanthanum. Prior to their discovery, superconductivity, a state in which electrical current can pass through a solid without resistance, had only been achieved at temperatures approaching absolute zero (-272° C). The highest critical temperature of record was only -250° C, or 23 K. The extreme temperature, which required cooling with expensive liquid helium, limited the application of superconductive materials. Despite the growing use of conventional superconductors in highly specialized applications, there were still many technical barriers to the practical use of superconducting materials.[42]

In 1987, researchers at the University of Houston and University of Alabama discovered that a different ceramic copper oxide, mixed with barium and yttrium, would superconduct at up to 94 K, allowing it to be cooled with significantly less expensive liquid nitrogen. Westinghouse Electric Corp. announced development of a process for producing superconducting powders that could simplify fabrication. The process produced very fine, pure powders, largely composed of single crystals that could be magnetically aligned to give them the orientation necessary to boost current density. The new process was used to make yttrium-barium-copper oxide compounds that superconduct when cooled to about 95 K, or -178° C.[43] In addition, a bismuth-strontium-copper oxide compound was produced with transition temperatures about 95 K. By late 1987, researchers in Arkansas had announced their discovery of a thallium-barium-copper oxide material that achieved zero resistance to electrical current at 81 K, and later, by adding calcium, a new material was produced that retained zero resistance at temperatures up to 106 K.[44]

Most potential applications of superconductors can be divided into two broad categories. The first are those used for large technological systems, either in the form of wire for the transmission of electricity, or in magnets. Examples of these include magnetically levitated trains, high-energy accelerators, energy-storage systems, and nuclear magnetic resonance imaging machines. The second category involves use as "thin films" in small-scale electronic devices similar to semiconductor chips. It was expected that the new ceramic superconductors should have more immediate impact in this application. However, until there is a breakthrough allowing superconductors to operate at room temperature, the transformation of these technologies by superconductor materials was expected to happen slowly.

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[2]All quantities in this chapter are given in metric tons unless otherwise specified.
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[5]ASARCO Incorporated. Operations Data Sheets. Pres. at Sulfur Inst. Annu. Meet., Washington, DC, Jan. 1988; available upon request from J. L. W. Jolly, BuMines, Washington, DC.
[6]Joklik, G. F. Cost Reduction at Bingham Canyon. Pres. at Capital Met. Forum, Washington DC, Nov. 18, 1987; available upon request from J. L. W. Jolly, BuMines, Washington DC.
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[9]Phelps Dodge Corp. 1987 Annual Report. P. 4.
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[11]ASARCO Incorporated. 1987 Annual Report. P. 14.
[12]BP Minerals America. 1987 Annual Report. P. 22.
[13]Cyprus Minerals Co. 1987 Annual Report. P. 1.
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[16]Tribune (Great Falls, MT). Butte Mines May Turn $1.4 Million Profit in '87. May 30, 1987, p. 4.
[17]Montana (Butte) Standard. MRI on $100 Million Profit Report: "We Wish." May 6, 1988, p. 2.
[18]Work cited in footnote 5.
[19]Page 59 of work cited in footnote 12.
[20]Montana (Butte) Standard. The Hill Being Divvied up Again. Feb. 8, 1988, p. 3.
[21]Cyprus Minerals Co. 1987 10K Annual Report. P. 4.
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[23]Page 4 of work cited in footnote 21.
[24]Page 28 of work cited in footnote 14.
[25]Vancas, M. F. Development of the San Manuel Oxide Ore Reserve, Present and Future. Magma Copper Co., SME Annu. Meet., Denver, CO., Feb. 24-27, 1987.
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[27]Magma Copper Co. 1987 Annual Report. P. 1.
[28]Work cited in footnote 27.
[29]Montana (Butte) Standard. Montana Resources Marks First Year of Operation. July 15, 1987, p. 2.
[30]Pay Dirt. Sharon Steel's Continental Copper Mine Awaits a Better Day. Nov. 1987, p. 10A.
[31]Montana (Butte) Standard. Superfund Bill: $20 Million or So and Rising. May 14, 1988, p. 2.
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[33]Pay Dirt. Magma's San Manuel Smelting Furnace To Be World's Largest. June 1987, p. 6B.
[34]Mining Magazine. Flue Dust Processing at Anaconda. Aug. 1987, p. 107.
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[36]Pages 8 and 9 of work cited in footnote 14.
[37]Copper Development Association. Annual Data 1988, Copper Supply & Consumption, 1967-1987. Greenwich, CT, June 1988, 20 pp.
[38]Corporación National del Cobre de Chile. 12th Annual Report. 1987. 50 pp.
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Table 5.—Percentage of copper ore and recoverable copper extracted from open pit and underground mines in the United States

Year	Open pit		Underground	
	Ore	Copper[1]	Ore	Copper[2]
1983	89	85	11	15
1984	92	87	8	13
1985	88	89	12	11
1986	87	86	13	14
1987	88	84	12	16

[1]Includes copper from dump leaching.
[2]Includes copper from in-place leaching and copper recovered from tailings and as a byproduct from other sources.

Table 6.—Mine production of recoverable copper in the United States, by month and by State

(Metric tons)

	1983	1984	1985	1986	1987
Month:					
January	90,025	92,971	92,699	99,029	102,200
February	77,664	87,863	87,089	87,365	93,040
March	89,274	96,124	100,170	96,386	107,134
April	84,646	91,250	93,641	93,838	99,284
May	92,170	95,045	96,834	97,116	105,087
June	89,717	98,000	90,225	96,561	102,487
July	76,323	88,235	90,711	95,151	105,028
August	79,211	89,032	87,446	94,596	108,286
September	86,704	88,074	81,898	97,572	106,364
October	89,608	94,382	94,222	100,185	105,886
November	93,706	92,507	91,870	92,452	109,677
December	89,050	89,130	98,953	97,026	111,441
Total	1,038,098	1,102,613	1,105,758	1,147,277	1,255,914
State:					
Alaska	W	--	--	--	--
Arizona	678,216	746,453	796,556	789,175	764,148
California	W	W	W	W	--
Colorado	W	W	W	W	W
Idaho	3,556	3,701	3,551	W	W
Illinois	--	--	W	W	W
Michigan	--	--	W	W	W
Missouri	7,725	5,818	13,410	W	W
Montana	33,337	W	15,092	W	W
Nevada	W	W	W	W	--
New Mexico	W	W	W	W	W
Oregon	W	--	--	--	--
Tennessee	W	W	W	W	W
Utah	169,751	W	W	W	W
Washington	--	--	--	--	W
Total	1,038,098	1,102,613	1,105,758	1,147,277	1,255,914

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

Table 7.—Twenty-five leading copper-producing mines in the United States in 1987, in order of output

Rank	Mine	County and State	Operator	Source of copper
1	Morenci	Greenlee, AZ	Phelps Dodge Corp	Copper-molybdenum ore, concentrated and leached.
2	Tyrone	Grant, NM	Phelps Dodge Corp. and Burro Chief Copper Co.	Copper ore, concentrated and leached.
3	Bingham Canyon	Salt Lake, UT	Kennecott, Utah Copper Div	Copper-molybdenum ore, concentrated and leached.
4	San Manuel	Pinal, AZ	Magma Copper Co	Copper-molybdenum ore and retreated slag, concentrated and leached.
5	Chino	Grant, NM	Chino Mines Co	Copper-molybdenum ore, concentrated and leached.
6	Ray	Gila, AZ	ASARCO Incorporated	Copper ore, concentrated and leached.
7	Bagdad	Yavapai, AZ	Cyprus Bagdad Copper Co	Copper-molybdenum ore, concentrated and leached.
8	Sierrita	Pima, AZ	Cyprus Sierrita Corp	Do.
9	Pinto Valley	Gila, AZ	Pinto Valley Copper Corp	Do.
10	White Pine	Ontonagon, MI	Copper Range Co	Copper ore, concentrated.
11	Inspiration	Gila, AZ	Inspiration Consolidated Copper Co.	Copper-molybdenum ore, concentrated and leached.
12	Mission Complex[1]	Pima, AZ	ASARCO Incorporated	Copper ore, concentrated.
13	Continental	Silver Bow, MT	Montana Resources Inc	Copper-molybdenum ore, concentrated.
14	Troy	Lincoln, MT	ASARCO Incorporated	Silver-copper ore, concentrated.
15	Casteel	Iron, MO	The Doe Run Co	Lead-copper ore, concentrated.
16	Ox-Hide	Gila, AZ	Inspiration Consolidated Copper Co.	Copper ore, leached.
17	Silver Bell	Pima, AZ	ASARCO Incorporated	Do.
18	Copperhill (1 mine).	Polk, TN	Tennessee Chemical Co	Copper-zinc-iron-sulfide ore, concentrated.
19	San Xavier	Pima, AZ	ASARCO Incorporated	Copper ore, concentrated.
20	Miami	Gila, AZ	Pinto Valley Copper Corp	Copper ore, leached.
21	Viburnum No. 29	Washington, MO	The Doe Run Co	Lead ore, concentrated.
22	Mineral Park	Mohave, AZ	Cyprus Minerals Co	Copper ore, leached.
23	Magmont	Iron, MO	Cominco American Incorporated	Lead-zinc ore, concentrated.
24	Buick	do.	The Doe Run Co	Lead ore, concentrated.
25	Copper Queen	Cochise, AZ	Phelps Dodge Corp	Copper ore, leached.

[1]Includes Eisenhower, Mission, and Pima.

Table 8.—Mine production of copper-bearing ores and recoverable copper content of ores produced in the United States, by source and treatment process

(Metric tons)

Source and treatment process	1983		1984		1985		1986		1987	
	Gross weight	Recoverable copper	Gross weight	Recoverable copper	Gross weight	Recoverable copper	Gross weight	Recoverable copper	Gross weight	Recoverable copper
Mined copper ore:										
Concentrated[1]	171,776,000	810,090	168,226,000	883,338	160,258,000	906,438	166,891,000	909,136	201,434,000	1,005,706
Leached[2]	6,154,000	104,991	3,588,000	106,597	1,952,000	98,453	2,347,000	135,448	1,198,000	161,591
Total	177,930,000	915,081	171,814,000	989,935	162,210,000	1,004,891	169,238,000	1,044,584	202,632,000	1,167,297
Copper precipitates shipped; leached from tailings, dump, and in-place material	130,857	89,274	120,437	80,845	118,096	82,948	111,050	79,031	109,520	69,376
Miscellaneous:										
Silver ore	4,483,000	19,384	4,487,000	22,334	1,041,000	3,745	560,000	2,599	275,000	1,155
Lead ore	7,303,000	7,725	4,748,000	5,818	6,433,000	13,410	3,336,000	7,405	W	4,463
Other copper-bearing ores[3]	9,970,000	6,634	22,821,000	3,681	8,898,000	764	2,447,000	13,658	7,980,000	13,623
Grand total	XX	1,038,098	XX	1,102,613	XX	1,105,758	XX	1,147,277	XX	1,255,914

XX Not applicable. W Withheld to avoid disclosing company proprietary data.

[1]Includes the following methods of concentration: dual process (concentration followed by leaching) and froth flotation.

[2]At least 85% of leached ore processed by electrowinning. Actual figures are as follows: 1983—101,936; 1984—100,180; 1985—90,439; 1986—125,352; and 1987—157,986 tons of electrowon copper (see table 11).

[3]Includes copper-lead ore, gold ore, gold-silver ore, lead-zinc ore, molybdenum ore, tungsten ore, zinc ore, fluorspar, flux ores, cleanup, and tailings.

Table 9.—Recoverable copper, gold, and silver content of concentrated copper ore in 1987

State	Ore concentrated (thousand metric tons)	Recoverable metal content				Value of gold and silver per metric ton of ore
		Copper		Gold (troy ounces)	Silver (troy ounces)	
		Metric tons	Percent			
Arizona	131,756	607,238	0.46	48,430	3,529,883	$0.35
Other[1]	69,678	398,468	.57	212,798	11,800,837	2.56
Total or average	201,434	1,005,706	.50	261,228	15,330,720	1.11

[1]Includes Idaho, Michigan, Montana, New Mexico, Tennessee, and Utah.

Table 10.—Blister and anode copper produced in the United States, by source of material

(Metric tons)

Source	1983	1984	1985	1986	1987
Ores and concentrates:					
Domestic	888,130	989,924	939,257	[1]908,087	[1]972,141
Foreign	39,609	24,200	1,424	W	W
Secondary materials[2]	59,276	169,296	250,138	287,841	276,640
Total	987,015	1,183,420	1,190,819	1,195,928	1,248,781

W Withheld to avoid disclosing company proprietary data; included with "Domestic."
[1]Includes production from foreign ores and concentrates.
[2]Production from secondary sources prior to 1984 excludes data for those plants that were not associated with refineries processing primary materials.

Table 11.—Primary and secondary copper produced by refineries and electrowinning plants in the United States

(Metric tons)

	1983	1984	1985	1986[r]	1987
PRIMARY					
Electrolytic	[r]984,524	[r]1,006,105	[r] [1]966,726	[1]948,623	[1]988,121
Electrowon	[r]101,936	[r]100,180	[r]90,439	125,352	157,986
Fire refined	95,630	58,315	W	W	W
Total	1,182,090	1,164,600	1,057,165	1,073,975	1,146,107
SECONDARY					
Electrolytic	[2]224,761	186,712	264,835	292,686	311,312
Fire refined	[3]176,907	138,237	112,622	113,258	103,426
Total	401,668	324,949	377,457	405,944	414,738
Grand total	1,583,758	1,489,549	1,434,622	1,479,919	1,560,845
Primary domestic materials[4]	1,028,423	1,089,584	1,003,636	[5]1,073,975	[5]1,146,107
Primary foreign materials[4]	153,667	75,016	53,529	W	W
Secondary materials	401,668	324,949	377,457	405,944	414,738
Total	1,583,758	1,489,549	1,434,622	1,479,919	1,560,845

[r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Includes fire-refined copper.
[2]Includes some copper fire refined at plants processing primary materials.
[3]Includes some copper electrolytically refined at plants processing secondary materials only.
[4]The separation of refined copper into metal of domestic and foreign origins can only be approximated at this stage of processing.
[5]Includes primary foreign materials.

Table 12.—Copper production by refinery shape at refineries in the United States

(Thousand metric tons)

	1986	1987
Billets	93	W
Cathodes	r1,334	1,431
Ingots and ingot bars	r27	W
Wirebars	16	W
Other forms	10	130
Total	r1,480	1,561

rRevised. W Withheld to avoid disclosing company proprietary data; included with "Other forms."

Table 13.—Production, shipments, stocks, and imports of copper sulfate in the United States

(Metric tons)

Year	Production		Shipments[1]	Stocks, Dec. 31	Imports
	Quantity	Copper content			
1983	37,500	9,789	36,614	5,029	2,403
1984	34,859	8,862	37,006	3,564	1,884
1985	32,740	8,265	31,952	4,353	2,958
1986r	34,154	8,616	33,540	4,967	2,683
1987	33,340	8,418	35,338	2,969	4,765

rRevised.
[1]Includes consumption by producing companies.

Table 14.—Byproduct sulfuric acid (100% basis) produced in the United States[1]

(Metric tons)

Plant type	1983	1984	1985	1986	1987
Copper[2]	1,837,827	2,251,312	2,230,257	2,308,804	2,542,602
Lead[3]	319,137	248,474	267,159	122,228	116,311
Zinc[4]	384,529	442,517	430,946	379,803	410,460
Total	2,541,493	2,942,303	2,928,362	2,810,835	3,069,373

[1]Includes acid from foreign materials.
[2]Excludes acid made from pyrite concentrates.
[3]Includes acid processed at molybdenum plants to avoid disclosing company proprietary data.
[4]Excludes acid made from native sulfur.

Table 15.—Copper recovered from scrap processed in the United States, by kind of scrap and form of recovery

(Metric tons)

	1983	1984	1985	1986[r]	1987
KIND OF SCRAP					
New scrap:					
Copper-base	611,890	637,201	621,984	635,495	686,703
Aluminum-base	21,926	21,919	13,330	22,891	25,871
Nickel-base	254	68	328	221	187
Zinc-base	31	31	35	27	12
Total	634,101	659,219	635,677	658,634	712,773
Old scrap:					
Copper-base	431,243	443,585	487,199	461,490	482,890
Aluminum-base	18,015	16,929	15,459	15,859	16,401
Nickel-base	158	102	689	84	65
Zinc-base	62	79	60	36	6
Total	449,478	460,695	503,407	477,469	499,362
Grand total	1,083,579	1,119,914	1,139,084	1,136,103	1,212,135
FORM OF RECOVERY					
As unalloyed copper:					
At electrolytic plants	224,761	186,712	264,835	292,686	311,312
At other plants	194,093	151,477	122,834	121,760	112,712
Total	418,854	338,189	387,669	414,446	424,024
In brass and bronze	625,349	735,154	716,833	671,184	732,440
In alloy iron and steel	1,434	1,705	2,498	1,366	1,254
In aluminum alloys	36,704	43,511	29,423	45,781	50,094
In other alloys	162	307	1,803	359	157
In chemical compounds[1]	1,076	1,048	858	2,967	4,166
Total	664,725	781,725	751,415	721,657	788,111
Grand total	1,083,579	1,119,914	1,139,084	1,136,103	1,212,135

[r]Revised.
[1]Data do not include copper sulfate prior to 1986.

Table 16.—Copper recovered as refined copper and in alloys and other forms from copper-base scrap processed in the United States, by type of operation

(Metric tons)

Type of operation	From new scrap		From old scrap		Total	
	1986[r]	1987	1986[r]	1987	1986[r]	1987
Ingot makers and secondary smelters	17,124	24,013	109,467	122,313	126,591	146,326
Refineries[1]	122,795	131,881	283,149	282,857	405,944	414,738
Brass and wire-rod mills	476,654	512,161	33,940	34,853	510,594	547,014
Foundries and manufacturers	18,611	18,271	32,278	39,078	50,889	57,349
Chemical plants	311	377	2,656	3,789	2,967	4,166
Total	635,495	686,703	461,490	482,890	1,096,985	1,169,593

[r]Revised.
[1]Electrolytically refined and fire-refined scrap based on source of material at smelter level.

Table 17.—Production of secondary copper and copper-alloy products in the United States, by item produced from scrap

(Metric tons)

Item produced from scrap	1986[r]	1987
UNALLOYED COPPER PRODUCTS		
Electrolytically refined copper	292,686	311,312
Fire-refined copper	113,258	103,426
Copper powder	7,898	8,709
Copper castings	604	577
Total	414,446	424,024
ALLOYED COPPER PRODUCTS		
Brass and bronze ingots:		
Tin bronzes	23,670	24,221
Leaded red brass and semired brass	99,151	96,615
High-leaded tin bronze	7,223	7,425
Yellow brass	7,641	12,245
Manganese bronze	8,563	7,756
Aluminum bronze	6,818	7,131
Nickel silver	3,215	3,494
Silicon bronze and brass	4,467	4,953
Copper-base hardeners and master alloys	7,067	6,638
Miscellaneous	4,052	9,530
Total	171,867	180,008
Brass mill and wire-rod mill products	628,231	672,987
Brass and bronze castings	34,028	43,957
Brass powder	393	281
Copper in chemical products	2,967	4,166
Grand total	1,251,932	1,325,423

[r]Revised.

Table 18.—Composition of secondary copper-alloy production in the United States

(Metric tons)

	Copper	Tin	Lead	Zinc	Nickel	Aluminum	Total
Brass and bronze ingot production:[1]							
1986[r]	137,761	5,525	9,729	18,532	292	28	171,867
1987	143,984	5,804	10,033	19,508	647	32	180,008
Secondary metal content of brass mill products:							
1986[r]	[2]512,222	225	2,687	111,562	1,535	([3])	[2]628,231
1987	[2]545,895	595	2,500	122,722	1,275	--	[2]672,987
Secondary metal content of brass and bronze castings:							
1986	[r]29,032	872	1,511	[r]2,527	25	61	[r]34,028
1987	38,223	1,092	1,857	2,712	18	55	43,957

[r]Revised.
[1]About 94% from scrap and 6% from other than scrap in 1986, and about 96% from scrap and 4% from other than scrap in 1987.
[2]Includes copper recovered from scrap at wire mills to avoid disclosing company proprietary data.
[3]Revised to zero.

Table 19.—Stocks and consumption of purchased copper scrap in the United States in 1987, by class of consumer and type of scrap

(Metric tons, gross weight)

Class of consumer and type of scrap	Stocks, Jan. 1[1]	Net receipts	Consumption: New scrap	Consumption: Old scrap	Consumption: Total	Stocks, Dec. 31
SECONDARY SMELTERS-REFINERS						
No. 1 wire and heavy	4,783	133,584	74,356	58,510	132,866	5,501
No. 2 wire, mixed heavy and light	15,642	329,817	33,490	289,367	322,857	22,602
Composition or soft red brass	2,733	41,848	6,771	35,615	42,386	2,195
Railroad-car boxes	221	1,037	--	1,116	1,116	142
Yellow brass	2,717	35,130	6,909	28,439	35,348	2,499
Cartridge cases	31	214	--	245	245	--
Automobile radiators (unsweated)	3,587	56,828	--	56,823	56,823	3,592
Bronze	1,696	15,909	2,647	13,442	16,089	1,516
Nickel silver and cupronickel	355	3,317	824	2,567	3,391	281
Low brass	100	2,593	1,943	571	2,514	179
Aluminum bronze	77	211	85	124	209	79
Refinery brass	3,168	116,313	45,391	68,559	113,950	5,531
Low-grade scrap and residues	12,506	92,049	62,236	33,002	95,238	9,317
Total	47,616	828,850	234,652	588,380	823,032	53,434
BRASS AND WIRE-ROD MILLS[2]						
No. 1 wire and heavy	12,402	246,300	225,879	20,421	246,300	18,045
No. 2 wire, mixed heavy and light	2,549	56,247	45,940	10,307	56,247	1,737
Yellow brass	6,579	279,721	273,977	5,744	279,721	11,211
Cartridge cases and brass	11,395	78,140	77,438	702	78,140	14,527
Bronze	1,594	4,304	4,304	--	4,304	1,227
Nickel silver and cupronickel	3,305	6,177	5,980	197	6,177	2,009
Low brass	1,335	12,542	12,291	251	12,542	1,721
Total	39,159	683,431	645,809	37,622	683,431	50,477
FOUNDRIES, CHEMICAL PLANTS, AND OTHER MANUFACTURERS						
No. 1 wire and heavy	2,133	31,677	6,577	24,893	31,470	2,340
No. 2 wire, mixed heavy and light	261	4,748	1,076	3,682	4,758	251
Composition or soft red brass	3,533	15,248	7,466	6,514	13,980	4,801
Railroad-car boxes	317	3,634	--	3,740	3,740	211
Yellow brass	838	8,711	6,591	2,309	8,900	649
Cartridge cases	76	--	--	76	76	--
Automobile radiators (unsweated)	468	5,484	27	5,410	5,437	515
Bronze	818	671	18	639	657	832
Nickel silver and cupronickel	17	33	26	23	49	1
Low brass	80	2,336	1,212	1,110	2,322	94
Aluminum bronze	84	724	66	690	756	52
Low-grade scrap and residues	--	28	28	--	28	--
Total[3]	8,625	73,294	23,087	49,086	72,173	9,746
GRAND TOTAL						
No. 1 wire and heavy	19,318	411,561	306,812	103,824	410,636	25,886
No. 2 wire, mixed heavy and light	18,452	390,812	80,506	303,356	383,862	24,590
Composition or soft red brass	6,266	57,096	14,237	42,129	56,366	6,996
Railroad-car boxes	538	4,671	--	4,856	4,856	353
Yellow brass	10,134	323,562	287,477	36,492	323,969	14,359
Cartridge cases	11,502	78,354	77,438	321	78,461	14,527
Automobile radiators (unsweated)	4,055	62,312	27	62,233	62,260	4,107
Bronze	4,108	20,884	6,969	14,783	21,050	2,348
Nickel silver and cupronickel	3,677	9,527	6,830	2,787	9,617	1,509
Low brass	1,515	17,471	15,446	1,932	17,378	2,282
Aluminum bronze	161	935	151	814	965	1,852
Low-grade scrap and residues[4]	15,674	208,390	107,655	101,561	209,216	14,848
Total	95,400	1,585,575	903,548	675,088	1,578,636	113,657

[1]Revised from 1986 closing stocks.
[2]Brass and wire-rod mill stocks include home scrap; purchased scrap consumption is assumed equal to receipts, so lines in "BRASS AND WIRE-ROD MILLS" and "GRAND TOTAL" sections do not balance.
[3]Of the totals shown, chemical plants reported the following: unalloyed copper scrap, 392 tons new and 3,971 tons old.
[4]Includes refinery brass.

Table 20.—Consumption of copper and brass materials in the United States, by item

(Metric tons)

Item	Brass mills	Wire-rod mills	Foundries, chemical plants, miscellaneous users	Secondary smelters-refiners	Total
1986:[r]					
Copper scrap	[1]635,896	W	63,778	800,019	1,499,693
Refined copper[2]	564,875	1,491,945	44,427	1,378	2,102,625
Brass ingot	15,330	--	141,251	--	156,581
Slab zinc	64,883	--	5,434	3,280	73,597
Miscellaneous	--	--	--	1,532	1,532
1987:					
Copper scrap	[1]683,431	W	72,173	823,032	1,578,636
Refined copper[2]	514,528	1,595,598	40,267	1,436	2,151,829
Brass ingot	28,980	--	136,444	--	165,424
Slab zinc	76,454	--	5,158	2,718	84,330
Miscellaneous	--	--	--	710	710

[r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Includes consumption of copper scrap at wire-rod mills to avoid disclosing company proprietary data.
[2]Detailed information on consumption of refined copper can be found in table 23.

Table 21.—Apparent consumption of copper in the United States

(Metric tons)

Period	Refined copper production	Total old scrap	Net refined imports	Stock change during period	Apparent consumption
1983	1,182,090	449,478	378,171	-3,000	2,012,739
1984	1,164,600	460,695	353,285	-128,000	2,106,580
1985	1,057,165	503,407	339,788	-244,000	2,144,360
1986	[r]1,073,975	[r]477,469	489,532	-95,000	[r]2,135,976
1987:					
January	93,000	37,281	30,500	-10,000	170,781
February	86,847	39,544	34,739	-11,000	172,130
March	86,618	46,918	51,528	-19,000	204,064
April	79,915	51,603	33,664	-2,000	167,182
May	85,110	40,845	56,181	-5,000	187,136
June	93,968	41,794	66,487	-6,000	208,249
July	90,473	36,292	33,954	28,000	132,719
August	90,167	40,584	42,491	-13,000	186,242
September	102,801	41,198	24,690	-9,000	177,689
October	109,799	42,568	30,811	-30,000	213,178
November	111,764	38,134	28,895	-33,000	211,793
December	115,645	42,601	26,022	-2,000	186,268
Total	1,146,107	499,362	459,962	-112,000	2,217,431

[r]Revised.

Table 22.—Foundries and miscellaneous manufacturers consumption of brass ingot and refined copper and copper scrap in the United States, by geographic division and State

(Metric 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
1983	24,448	80,741	11,155	5,423	2,511	1,612	5,675	131,565	30,050	60,366
1984	24,660	89,341	6,143	4,907	2,430	1,457	6,426	135,364	34,424	68,386
1985	22,322	94,239	5,833	6,216	3,923	1,788	7,052	141,371	54,390	65,767
1986[r]	29,894	87,990	6,756	5,743	3,024	2,346	5,496	141,251	43,492	60,687
1987:										
New England:										
Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont	1,618	2,125	404	273	21	438	423	5,301	1,378	483
Middle Atlantic:										
New Jersey, New York, Pennsylvania	6,626	9,562	825	869	77	168	874	19,000	4,481	10,970
East North Central:										
Illinois, Indiana, Michigan, Ohio, Wisconsin	8,061	40,548	1,997	2,858	2,442	837	1,718	58,464	14,191	31,547
West North Central:										
Iowa, Kansas, Minnesota, Missouri, Nebraska, South Dakota	663	4,324	212	1,074	88	6	252	6,619	2,362	1,883
South Atlantic:										
Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia	2,095	10,568	386	308	9	315	216	13,895	7,247	4,598
East and West South Central:										
Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas	3,192	12,783	228	1,043	96	56	684	18,084	8,480	4,293
Mountain and Pacific:										
Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington	1,987	9,824	1,145	785	35	283	1,023	15,081	965	14,036
Total	24,242	89,734	5,197	7,210	2,768	2,103	5,190	136,444	39,104	67,810

[r]Revised.

Table 23.—Refined copper consumed in the United States, by class of consumer

(Metric tons)

Class of consumer	Cathodes	Wirebars	Ingots and ingot bars	Cakes and slabs	Billets	Other	Total
1986:							
Wire-rod mills	r1,449,758	34,249	W	W	--	r7,938	r1,491,945
Brass mills	r254,928	17,737	r85,707	80,033	126,452	18	r564,875
Chemical plants	W	--	--	--	--	935	935
Ingot makers	r1,066	--	W	W	--	r312	r1,378
Foundries	2,855	533	15,209	W	1,495	r530	r20,622
Miscellaneous[1]	9,124	W	4,984	1,616	W	r7,146	r22,870
Total r	1,717,731	52,519	105,900	81,649	127,947	16,879	2,102,625
1987:							
Wire-rod mills	1,584,883	W	W	W	--	10,715	1,595,598
Brass mills	250,157	13,845	96,948	66,920	86,526	132	514,528
Chemical plants	W	--	--	--	--	1,163	1,163
Ingot makers	W	--	W	W	W	1,436	1,436
Foundries	2,822	590	11,355	W	W	1,845	16,612
Miscellaneous[1]	11,296	W	4,988	1,493	W	4,715	22,492
Total	1,849,158	14,435	113,291	68,413	86,526	20,006	2,151,829

rRevised. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Includes iron and steel plants, primary smelters producing alloys other than copper, consumers of copper powder and copper shot, and other manufacturers.

Table 24.—Stocks of copper in the United States, December 31

(Thousand metric tons)

Period	Blister and materials in process of refining[1]	Refined copper: Electrolytic refiners	Wire rod mills	Brass mills	Other[2]	New York Commodity Exchange	Total
1983	174	154	116	26	25	371	692
1984	245	125	134	27	27	251	564
1985	146	66	100	20	25	109	320
1986	135	36	66	14	25	84	225
1987:							
January	121	38	43	17	24	93	215
February	114	28	32	21	24	99	204
March	118	24	32	15	24	90	185
April	95	32	31	16	24	80	183
May	123	38	30	21	24	65	178
June	114	37	33	19	24	59	172
July	127	50	44	19	24	63	200
August	123	40	36	20	24	67	187
September	130	36	21	16	24	81	178
October	133	31	17	16	24	60	148
November	129	27	17	16	24	31	115
December	150	29	28	15	24	17	113

[1]Includes copper in transit from smelters in the United States to refineries therein.
[2]Includes secondary smelters, chemical plants, foundries, and miscellaneous plants; includes 20,000 tons in the National Defense Stockpile.

Table 25.—Dealers' monthly average buying price for copper scrap and consumers' alloy-ingot prices at New York, by type

(Cents per pound)

Year and month	Scrap		Ingot	
	No. 2 heavy copper	No. 1 composition (red brass)	No. 115 brass (85-5-5-5)	Yellow brass (405)
1986:				
January	r38.23	39.50	81.50	70.75
February	39.50	39.50	81.50	70.75
March	39.50	39.50	81.50	70.75
April	39.50	39.50	81.50	70.75
May	39.50	39.50	81.50	70.75
June	39.50	39.50	81.50	70.75
July	39.50	39.50	81.50	70.75
August	r37.79	36.98	81.50	70.75
September	37.50	36.50	81.50	70.75
October	37.50	36.50	81.50	70.75
November	37.50	36.50	81.50	70.75
December	r35.50	36.50	81.50	70.75
Average	r38.42	38.29	81.50	70.75
1987:				
January	37.50	46.50	81.50	70.75
February	37.50	46.50	81.50	70.75
March	37.89	47.08	81.50	70.75
April	39.50	49.50	81.50	70.75
May	41.18	50.34	81.50	70.75
June	42.50	51.50	81.50	70.75
July	44.56	53.56	85.00	73.25
August	49.02	58.02	85.00	73.25
September	49.50	58.50	85.00	73.25
October	55.40	58.82	88.00	76.25
November	56.50	66.50	93.00	79.25
December	65.15	75.15	100.50	84.25
Average	46.35	55.16	85.46	73.67

rRevised.

Source: American Metal Market.

Table 26.—Average monthly prices for refined copper in the United States and on the London Metal Exchange

(Cents per pound)

Month	1986					1987				
	U.S. producers delivered price		COMEX first position	LME cash price[1]		U.S. producers delivered price		COMEX first position	LME cash price[1]	
	Cathode[2]	Wirebar[3]		Cathode	High grade[4]	Cathode[2]	Wirebar[3]		Cathode	High grade[4]
January	69.88	69.88	65.29	63.28	64.31	64.99	64.99	60.76	59.27	61.04
February	68.25	68.25	63.86	62.96	63.73	65.53	65.53	61.73	60.46	62.57
March	70.14	70.14	66.02	65.26	65.52	68.07	68.07	63.57	62.36	66.45
April	68.80	68.80	63.80	64.93	65.05	67.13	67.13	62.37	63.86	68.29
May	67.09	67.09	62.72	63.29	64.24	70.99	70.99	66.47	66.27	68.94
June	67.47	67.47	62.57	63.20	64.07	74.35	74.35	69.89	69.85	71.27
July	63.82	63.82	58.94	58.44	60.96	80.42	80.42	76.19	76.68	76.83
August	62.37	62.37	57.59	57.52	59.08	82.18	82.18	77.63	79.51	79.63
September	64.84	64.84	60.71	59.43	61.08	85.61	85.61	80.99	81.86	82.11
October	63.46	63.46	59.19	58.27	59.71	88.85	88.85	83.04	87.63	89.16
November	62.86	62.86	58.93	57.71	59.10	108.53	108.53	103.92	109.67	114.35
December	63.64	63.64	60.17	58.68	60.56	133.32	133.32	127.49	123.41	129.96
Average	66.05	66.05	61.65	61.08	62.28	82.50	82.50	77.84	78.40	80.88

[1]Based on average monthly rates of exchange.
[2]Listed as "U.S. producer cathode."
[3]Listed as "U.S. producer delivered."
[4]Includes both cathode and wirebar.

Source: Metals Week.

Table 27.—U.S. exports of copper, by country

Country	Ore and concentrate (copper content)		Ashes and residues[1] (copper content)		Refined		Unalloyed copper scrap		Blister and precipitates	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1986	174,348	$187,826	3,826	$10,671	12,452	$18,444	136,422	$123,138	15,963	$17,434
1987:										
Australia	--	--	--	--	--	--	142	89	345	407
Belgium-Luxembourg	--	--	2,397	4,688	--	--	1,955	2,057	--	--
Brazil	--	--	--	--	68	95	3,017	3,621	--	--
Canada	1,826	5,244	1,898	3,314	1,670	2,399	11,134	17,288	836	963
China	2,470	2,094	--	--	--	--	191	79	--	--
Dominican Republic	--	--	--	--	22	41	--	--	10	8
Finland	7,228	7,755	--	--	--	--	88	18	1	2
France	--	--	34	61	440	902	--	--	16	32
Germany, Federal Republic of	886	461	604	3,872	433	826	4,331	4,242	--	--
Hong Kong	--	--	--	--	402	871	3,317	1,919	711	1,484
India	101	89	312	184	--	--	494	375	20	18
Israel	--	--	--	--	--	--	--	--	25	43
Italy	--	--	--	--	194	431	6,141	5,727	3	5
Japan	99,552	122,124	157	440	2,479	6,033	15,550	20,396	4,269	1,709
Korea, Republic of	5,154	9,324	--	--	1,781	4,221	9,662	12,279	4,647	5,440
Kuwait	--	--	7	24	--	--	--	--	--	--
Mexico	3	3	--	--	510	680	12,277	17,961	275	434
Netherlands	--	--	--	--	20	42	369	348	--	--
Philippines	--	--	1	2	--	--	948	252	89	91
Saudi Arabia	--	--	--	--	--	--	--	--	(2)	8
Singapore	--	--	--	--	2	3	1,145	1,059	102	201
Spain	4	7	--	--	--	--	8,053	3,473	4	12
Sweden	--	--	--	--	--	--	2	2	--	--
Switzerland	--	--	2	2	38	66	1	17	--	--
Taiwan	3,776	5,033	530	288	207	297	28,713	12,208	473	991
Trinidad and Tobago	18	18	--	--	11	16	44	5	--	--
United Arab Emirates	--	--	17	29	--	--	--	--	--	--
United Kingdom	--	--	40	250	908	1,987	746	1,245	14	21
Venezuela	--	--	--	--	--	--	196	238	65	85
Yugoslavia	3,731	4,858	--	--	--	--	--	--	--	--
Other	--	--	--	--	12	18	19	3	434	509
Total	124,749	157,010	5,999	13,154	9,197	18,928	108,535	104,901	12,339	12,463

Country	Pipes and tubing		Plates and sheets		Wire and cable, bare		Wire and cable, insulated		Other copper manufactures[3]	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1986	5,343	$15,605	641	$2,151	7,393	$32,482	60,816	$358,677	9,583	$20,799
1987:										
Australia	1	5	(2)	4	31	239	1,044	8,883	1	4
Bahamas	(2)	2	--	--	22	61	279	1,000	--	--
Belgium-Luxembourg	18	57	(2)	3	13	80	135	3,550	1	10
Brazil	295	922	3	17	142	230	378	4,378	(2)	2
Canada	1,631	4,349	216	944	1,352	6,199	35,091	90,231	1,560	4,706
China	203	373	2	11	397	3,149	684	4,739	--	--
Dominican Republic	81	128	(2)	2	652	5,621	423	1,862	4	15
Ecuador	36	96	(2)	3	--	--	115	481	--	--
Egypt	76	204	--	--	3	15	5,437	17,310	5	15
France	16	57	1	15	10	76	1,400	37,933	1	6
Germany, Federal Republic of	1	17	1	5	54	445	3,030	27,785	1	11
Hong Kong	50	155	2	21	39	517	492	3,439	3	10
India	(2)	2	--	--	31	232	95	1,660	9	53
Israel	70	211	5	27	23	210	212	2,914	--	--
Italy	16	41	1	4	65	724	335	5,642	--	--
Jamaica	23	88	--	--	58	189	169	687	1	4
Japan	81	278	19	80	122	638	654	17,339	11	68
Korea, Republic of	1	6	1	8	36	269	1,273	10,226	18	46
Kuwait	147	378	--	--	2	20	58	228	--	--
Mexico	374	1,133	150	688	6,286	19,592	22,256	126,498	1,040	2,683
Netherlands	319	854	--	--	35	252	470	6,659	--	--
Philippines	21	60	40	641	41	136	303	1,369	3	10
Saudi Arabia	515	1,336	--	--	32	132	1,395	5,052	1	10
Singapore	81	425	1	10	31	158	912	8,522	7	32
Spain	254	643	1	10	14	82	171	4,503	(2)	9
Sweden	32	87	44	55	3	20	113	4,213	2	16
Switzerland	7	21	--	--	13	227	281	2,668	2	9
Taiwan	105	297	22	72	56	176	551	6,592	16	78
Trinidad and Tobago	5	13	--	--	39	109	293	728	--	--
United Arab Emirates	184	444	--	--	7	26	179	1,934	--	--
United Kingdom	354	891	6	31	100	836	3,705	48,113	2	6
Venezuela	518	1,876	12	121	30	107	213	1,475	2	8
Yugoslavia	7	20	--	--	--	--	7	125	(2)	2
Other	1,029	2,781	12	55	455	2,102	6,087	31,818	1,033	1,698
Total	6,551	18,250	539	2,827	10,194	42,869	88,240	490,556	3,723	9,511

[1]Includes matte.
[2]Less than 1/2 unit.
[3]Excludes copper wire cloth.

Source: Bureau of the Census.

Table 28.—U.S. exports of copper scrap, by country

Country	Unalloyed copper scrap				Copper-alloy scrap			
	1986		1987		1986		1987	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Belgium-Luxembourg	3,221	$4,027	1,955	$2,057	5,645	$4,453	7,276	$6,674
Brazil	3,967	3,855	3,017	3,621	3,994	4,053	6,384	7,055
Canada	13,746	21,664	11,134	17,288	20,970	33,410	21,156	37,095
China	336	179	191	79	109	131	180	404
France	175	199	--	--	114	153	96	403
Germany, Federal Republic of	8,514	10,560	4,331	4,242	5,050	5,722	7,723	10,127
Hong Kong	5,726	2,242	3,317	1,919	752	445	521	363
India	717	631	494	375	16,566	16,801	11,866	9,364
Italy	12,326	12,421	6,141	5,727	19,606	17,927	6,510	5,287
Japan	12,551	15,732	15,550	20,396	25,712	28,096	24,040	34,346
Korea, Republic of	12,368	13,868	9,662	12,279	14,463	15,842	26,091	31,786
Mexico	5,885	5,919	12,277	17,961	923	1,170	5,723	8,179
Netherlands	1,713	1,691	369	348	1,497	1,363	803	896
Philippines	263	110	948	252	23	87	115	39
Singapore	684	466	1,145	1,059	305	221	232	174
Spain	5,615	3,781	8,053	3,473	7,799	3,507	6,269	2,780
Sweden	33	76	2	2	2,346	3,130	1,599	2,585
Switzerland	104	109	1	17	278	238	163	110
Taiwan	46,898	23,835	28,713	12,208	22,027	19,333	54,657	34,097
Trinidad and Tobago	--	--	44	5	--	--	704	702
United Kingdom	1,485	1,675	746	1,245	4,221	3,503	2,698	3,544
Venezuela	--	--	196	238	--	--	127	611
Other	95	101	249	110	571	1,336	346	317
Total[1]	136,422	123,138	108,535	104,901	152,971	160,921	185,279	196,938

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

Source: Bureau of the Census.

Table 29.—U.S. imports for consumption of unmanufactured copper (copper content), by country

Country	Ore and concentrate		Matte		Blister and anode		Refined		Unalloyed scrap		Total	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1986	4,232	$2,593	702	$573	34,545	$60,236	501,984	$677,010	27,216	$31,646	568,679	$772,058
1987:												
Belgium-Luxembourg	--	--	--	--	--	--	637	240	--	--	637	240
Canada	2,338	2,009	651	372	14	26	208,158	338,324	25,675	35,804	236,836	376,535
Chile	--	--	--	--	7,339	9,987	125,917	196,851	--	--	133,256	206,838
China	--	--	--	--	--	--	150	261	--	--	150	261
Costa Rica	--	--	--	--	--	--	--	--	194	247	194	247
Dominican Republic	--	--	--	--	--	--	--	--	537	722	537	722
Germany, Federal Republic of	--	--	--	--	87	225	23,961	42,434	--	--	24,048	42,659
Guatemala	--	--	--	--	--	--	--	--	85	80	85	80
Japan	--	--	--	--	1,986	3,221	599	819	--	--	2,585	4,040
Korea, Republic of	--	--	--	--	--	--	--	--	112	138	112	138
Mexico	1	4	6,127	8,759	6,762	16,103	553	541	5,344	6,541	18,787	31,948
Netherlands	--	--	--	--	--	--	6,390	12,104	--	--	6,390	12,104
Netherlands Antilles	--	--	--	--	--	--	--	--	86	94	86	94
Norway	--	--	--	--	--	--	186	343	--	--	186	343
Panama	--	--	--	--	--	--	--	--	391	530	391	530
Peru	--	--	91	208	2,650	4,918	34,387	44,875	50	63	37,178	50,064
El Salvador	--	--	--	--	--	--	--	--	151	161	151	161
South Africa, Republic of	--	--	--	--	5,246	7,496	4,580	6,220	--	--	9,826	13,716
Sweden	--	--	--	--	--	--	15,230	21,460	--	--	15,230	21,460
Taiwan	--	--	--	--	--	--	272	344	23	50	295	394
Trinidad and Tobago	--	--	--	--	--	--	--	--	84	99	84	99
Yugoslavia	--	--	--	--	--	--	4,199	5,556	--	--	4,199	5,556
Zaire	--	--	--	--	--	--	23,992	33,579	--	--	23,992	33,579
Zambia	--	--	--	--	--	--	19,805	30,416	--	--	19,805	30,416
Other	--	--	--	--	--	--	143	280	391	592	534	872
Total	2,339	2,013	6,869	9,339	24,084	41,976	469,159	734,647	33,123	45,121	535,574	833,096

Source: Bureau of the Census.

Table 30.—U.S. imports for consumption of copper scrap, by country

Country	Unalloyed copper scrap: Quantity (metric tons)	Unalloyed copper scrap: Value (thousands)	Copper-alloy scrap: Gross weight (metric tons)	Copper-alloy scrap: Copper content (metric tons)	Copper-alloy scrap: Value (thousands)
1986	27,216	$31,646	39,017	28,844	$40,250
1987:					
Bahamas	21	28	34	24	24
Barbados	61	71	37	28	28
Belgium-Luxembourg	--	--	39	21	64
Canada	25,675	35,804	29,630	23,059	35,946
Chile	--	--	105	85	111
Costa Rica	194	247	36	26	28
Dominican Republic	537	722	421	333	402
France	22	121	22	23	64
Germany, Federal Republic of	--	--	275	176	435
Guatemala	85	80	74	55	63
Honduras	37	30	2	2	1
Italy	57	83	148	131	95
Jamaica	56	56	123	111	125
Japan	--	--	52	51	89
Korea, Republic of	112	138	139	136	306
Malaysia	27	33	49	48	111
Mexico	5,344	6,541	10,496	6,791	10,760
Netherlands	--	--	37	21	44
Netherlands Antilles	86	94	233	175	168
Panama	391	530	711	410	490
Peru	50	63	571	459	764
El Salvador	151	161	--	--	--
Singapore	72	76	103	81	112
Sweden	--	--	71	51	100
Switzerland	--	--	46	45	82
Taiwan	23	50	33	46	94
Trinidad and Tobago	84	99	141	109	109
United Kingdom	22	78	291	183	575
Venezuela	--	--	189	131	396
Other	16	16	75	63	110
Total	33,123	45,121	44,183	32,874	51,696

Source: Bureau of the Census; figures adjusted by Bureau of Mines.

Table 31.—Copper: World mine production,[1] by country

(Thousand metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
Albania[e]	14.3	16.1	16.2	17.6	17.8
Algeria	.1	.1	--	--	--
Argentina	.3	.2	.4	.3	.3
Australia	261.5	[r]235.7	259.8	245.4	223.0
Bolivia	2.0	1.6	1.7	.3	([2])
Botswana[3]	[r]20.3	21.5	21.7	19.0	[4]19.0
Brazil	32.1	35.2	41.0	36.2	37.8
Bulgaria[e]	80.0	80.0	80.0	80.0	80.0
Burma	4.2	12.0	16.7	11.4	15.0
Canada[5]	653.0	[r]721.8	738.6	698.5	767.3
Chile[6]	[r]1,255.4	[r]1,307.5	1,359.8	1,399.4	1,417.8
China[e]	175.0	180.0	185.0	185.0	300.0
Colombia	.2	.2	--	--	--
Congo (Brazzaville)	([2])	NA	.5	NA	NA
Cuba	2.7	2.7	3.1	[e]3.3	3.0
Cyprus[7]	2.1	2.3	2.1	1.2	1.0
Czechoslovakia	9.8	10.0	[e]10.3	[e]10.0	10.0
Ecuador	([2])	.2	.1	.1	.1
Finland	39.3	31.3	28.0	25.9	[4]20.4
France	.1	.1	.2	.3	[4].3
German Democratic Republic[e]	12.0	12.0	12.0	10.0	9.0
Germany, Federal Republic of[5]	1.2	1.0	.9	.8	[4]1.5
Guatemala	--	--	4.5	[e]4.2	4.2
Honduras	[e].6	.8	5.1	[e]5.0	5.0
India	37.8	44.1	45.9	48.1	[4]54.8
Indonesia	78.6	82.5	88.7	95.8	102.0
Iran[8]	57.6	43.3	50.0	48.0	48.0

See footnotes at end of table.

Table 31.—Copper: World mine production,[1] by country —Continued

(Thousand metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
Israel	3.5	[e]2.9	--	--	--
Italy	1.5	.9	.1	--	--
Japan	46.0	43.3	43.2	34.9	[4]22.0
Korea, North[e]	15.0	15.0	15.0	15.0	15.0
Korea, Republic of	.4	.3	.3	[e].2	[4].2
Malaysia	29.0	28.9	30.5	28.3	[4]30.1
Mexico	196.0	303.5	276.1	[e]285.0	300.0
Mongolia[e]	104.0	118.0	128.0	[r]136.0	136.0
Morocco	25.4	22.1	22.0	20.2	[4]16.6
Mozambique	.2	.3	.1	.3	.2
Namibia	50.4	47.4	48.0	49.6	50.0
Nepal	([2])	([2])	([2])	([2])	([2])
Norway	22.6	25.0	19.0	21.9	22.0
Oman	11.3	16.2	17.7	18.0	18.0
Papua New Guinea	201.9	[r]164.4	175.0	178.2	[4]217.7
Peru[6]	318.8	353.9	391.3	397.4	392.3
Philippines	271.4	233.4	222.2	222.6	[4]215.0
Poland	402.3	431.0	431.3	434.0	437.0
Portugal[6]	.3	.4	.3	.2	[4].1
Romania[e 5]	27.0	25.0	26.0	27.0	26.0
South Africa, Republic of[5]	205.0	198.2	195.4	184.2	[4]213.0
Spain	50.0	63.1	55.5	46.9	[4]15.0
Sweden	74.6	87.0	91.8	87.4	[4]90.3
Turkey[9]	24.9	27.1	33.0	[e]33.0	35.0
U.S.S.R.[e 5]	570.0	590.0	[r]600.0	620.0	630.0
United Kingdom	.7	.7	.6	.6	[4].8
United States:[5]					
By concentration or leaching	[r]936.1	[r]1,002.4	1,015.4	1,021.9	[4]1,097.9
Leaching (electrowon)	[r]102.0	[r]100.2	90.4	125.4	[4]158.0
Yugoslavia[9]	[r]129.5	137.6	[r e]141.3	[r e]144.9	144.3
Zaire	536.5	562.0	557.9	[e]563.0	564.0
Zambia:[10]					
By concentration or leaching	406.6	406.8	354.7	322.6	330.0
Leaching (electrowon)	134.4	125.9	103.9	139.3	140.0
Zimbabwe	21.6	24.0	21.6	21.4	21.0
Total	[r]7,659.1	[r]7,999.1	8,079.9	8,125.2	8,474.8

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.

[1]Data represent copper content by analysis of concentrates produced except where otherwise specified. Table includes data available through July 8, 1988.

[2]Less than 50 tons.

[3]Copper content of matte produced.

[4]Reported figure.

[5]Recoverable content.

[6]Recoverable copper content by analysis of concentrates for export plus nonduplicative total of copper content of all metal and metal products produced indigenously from domestic ores and concentrates. Includes leach production for electrowinning.

[7]Includes copper content of cupriferous pyrite.

[8]Data are for fiscal year beginning Mar. 21 of that stated.

[9]Copper content by analysis of ore mined.

[10]Data are for fiscal year beginning Apr. 1 of that stated.

Table 32.—Copper: World smelter production,[1] by country

(Thousand metric tons)

Country[2] and metal origin	1983	1984	1985	1986[p]	1987[e]
Albania, primary	11.0	12.6	[e]12.6	[e]13.7	14.0
Australia:					
Primary	173.6	179.8	167.7	169.6	177.0
Secondary	8.2	[r]8.1	[e]8.0	[e]8.0	8.5
Total	181.8	[r]187.9	[e]175.7	[r] [e]177.6	185.5
Austria, secondary	[r]24.3	[r]24.6	25.9	25.5	26.0
Belgium:[e]					
Primary	2.8	.5	.9	2.0	1.5
Secondary	70.5	75.5	114.2	106.0	60.7
Total	73.3	76.0	115.1	108.0	62.2
Brazil, primary	63.1	61.3	93.9	116.0	139.9
Bulgaria:[e]					
Primary	57.0	57.0	87.0	87.0	87.0
Secondary	3.0	3.0	3.0	3.0	4.0
Total	60.0	60.0	90.0	90.0	91.0
Canada:					
Primary	499.7	504.3	493.3	472.7	474.0
Secondary[e]	11.0	11.0	17.0	12.0	14.0
Total[e]	510.7	515.3	510.3	[r]484.7	488.0
Chile, primary[3]	1,058.9	1,098.3	1,088.5	1,124.1	1,103.7
China, primary[e]	195.0	210.0	225.0	225.0	300.0
Czechoslovakia:					
Primary	10.0	10.0	10.2	[e]10.0	10.0
Secondary	2.4	2.4	[e]2.4	[e]2.4	2.4
Total[e]	12.4	12.4	12.6	12.4	12.4
Finland:					
Primary	74.5	71.2	[e]71.0	[e]70.0	68.9
Secondary	12.6	12.1	[e]12.0	[e]12.0	12.0
Total	87.1	83.3	[e]83.0	[e]82.0	80.9
France, secondary	7.2	6.8	7.0	6.1	6.0
German Democratic Republic, primary[e]	17.0	14.0	14.0	12.0	12.0
Germany, Federal Republic of:					
Primary	159.1	148.8	152.4	161.9	161.0
Secondary	94.5	76.7	94.6	76.7	76.5
Total	253.6	225.5	247.0	238.6	237.5
Hungary, secondary[e]	.1	.1	.1	.1	.1
India, primary	35.5	40.5	32.5	39.1	37.1
Iran, primary[e]	[r]8.5	[r]47.9	[r]60.0	60.0	60.0
Japan:					
Primary	944.6	821.1	802.3	827.7	[4]871.0
Secondary	117.3	107.9	130.3	134.4	[4]97.7
Total	1,061.9	929.0	932.6	962.1	[4]968.7
Korea, North:[e]					
Primary	15.0	15.0	15.0	15.0	15.0
Secondary	3.0	3.0	3.0	3.0	3.0
Total	18.0	18.0	18.0	18.0	18.0
Korea, Republic of, primary and secondary	124.0	100.2	106.9	165.0	[4]157.9
Mexico, primary	[r]59.5	[r]70.3	68.2	74.7	[4]101.4
Namibia, primary	54.2	46.4	43.3	45.7	45.7
Norway, primary	25.7	36.8	38.2	35.2	[4]29.7
Oman, primary	7.6	21.3	18.8	19.6	19.6
Peru, primary	258.3	298.8	326.6	286.2	[4]286.6
Philippines, primary	57.6	109.2	133.8	124.3	[4]124.7
Poland:[e]					
Primary	349.0	360.0	370.0	375.0	375.0
Secondary	13.0	15.0	20.0	25.0	25.0
Total	362.0	375.0	390.0	400.0	400.0

See footnotes at end of table.

Table 32.—Copper: World smelter production,[1] by country —Continued

(Thousand metric tons)

Country[2] and metal origin	1983	1984	1985	1986[p]	1987[e]
Portugal:[e]					
Primary	3.2	2.5	2.6	3.0	2.0
Secondary	3.0	1.0	2.0	3.0	2.0
Total	6.2	3.5	4.6	6.0	4.0
Romania:[e]					
Primary	34.0	32.0	32.0	32.0	30.0
Secondary	6.0	6.0	6.0	7.0	8.0
Total	40.0	38.0	38.0	39.0	38.0
South Africa, Republic of, primary	192.3	178.7	191.7	[r e]192.0	192.0
Spain:					
Primary	100.0	97.0	88.0	[r e]95.0	96.7
Secondary	18.0	30.0	40.0	[e]40.0	42.0
Total	118.0	127.0	128.0	[r e]135.0	138.7
Sweden:					
Primary	78.8	79.8	74.7	[r e]82.5	84.0
Secondary	23.1	22.9	26.0	[e]20.0	21.6
Total	101.9	102.7	100.7	[r e]102.5	105.6
Taiwan, primary	[r]38.0	48.4	46.7	50.4	47.0
Turkey:					
Primary	18.8	31.8	33.5	35.2	34.8
Secondary	.3	.2	.4	.3	.2
Total	19.1	32.0	33.9	35.5	35.0
U.S.S.R.:[e]					
Primary	700.0	735.0	750.0	770.0	780.0
Secondary	139.0	141.0	143.0	145.0	147.0
Total	839.0	876.0	893.0	915.0	927.0
United States:					
Primary[5]	927.7	1,014.1	940.7	908.1	[4]972.1
Secondary	59.3	169.3	250.1	287.8	[4]276.6
Total	987.0	1,183.4	1,190.8	1,195.9	[4]1,248.7
Yugoslavia, primary	86.8	84.7	[r e]137.1	[r e]127.2	126.0
Zaire, primary:					
Electrowon	304.1	309.1	313.9	319.2	320.0
Other	175.0	171.5	172.9	178.9	180.0
Total	479.1	480.6	486.8	498.1	500.0
Zambia, primary	562.7	531.8	522.6	452.0	474.0
Zimbabwe, primary	21.6	22.7	20.4	20.4	20.4
Grand total	[r]8,120.0	[r]8,391.0	8,663.9	8,714.7	8,865.0
Of which:					
Primary:					
Electrowon	304.1	309.1	313.9	319.2	320.0
Other	[r]7,076.1	[r]7,265.1	7,338.1	7,313.2	7,553.8
Secondary	[r]615.8	[r]716.6	905.0	917.3	833.3
Undifferentiated	124.0	100.0	106.9	165.0	157.9

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

[1]This table includes total production of copper metal at the unrefined stage, including low-grade cathode produced by electrowinning methods. The smelter feed may be derived from ore, concentrates, copper precipitate or matte (primary), and/or scrap (secondary). To the extent possible, primary and secondary output of each country is shown separately. In some cases, total smelter production is officially reported, but the distribution between primary and secondary has been estimated. Table includes data available through July 8, 1988.

[2]Argentina presumably produces some smelter copper utilizing its own small mine output together with domestically produced cement copper and possibly using other raw materials including scrap, but the levels of such output cannot be reliably estimated.

[3]Data include electrowon production; estimated to be 35,000 to 45,000 tons per year that is fire refined and cast into wirebars; detailed data are not available.

[4]Reported figure.

[5]Figures for U.S. primary smelter production may include a small amount of copper derived from precipitates shipped directly to the smelter for further processing; production derived from electrowinning and fire refining is not included. Copper content of precipitates shipped directly to smelter are as follows, in metric tons: 1983—89,274; 1984—80,845; 1985—82,948; 1986—79,031; and 1987—69,376. Production from scrap prior to 1984 excludes data from secondary smelters processing only scrap.

Table 33.—Copper: World refinery production,[1] by country

(Thousand metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
Albania, primary[e]	10.5	11.5	11.5	11.7	12.0
Australia:					
Primary	168.5	171.2	163.8	164.0	185.0
Secondary	34.1	26.0	30.5	20.4	25.8
Total[2]	202.6	197.2	194.3	184.3	210.8
Austria:					
Primary	8.8	9.6	8.2	7.1	7.0
Secondary	33.1	34.3	35.0	32.6	42.0
Total[2]	41.9	43.9	43.2	39.6	49.0
Belgium:					
Primary	360.3	351.7	340.5	[r,e]311.7	307.5
Secondary	71.0	76.0	115.0	[r,e]100.9	100.0
Total	431.3	427.7	455.5	[r,e]412.6	407.5
Brazil:					
Primary	63.1	61.3	93.9	116.0	139.9
Secondary	39.3	36.0	49.0	50.0	50.0
Total	102.4	97.3	142.9	166.0	189.9
Bulgaria, primary and secondary[e]	62.0	62.0	93.0	95.0	95.0
Canada:					
Primary	464.3	504.3	499.6	493.4	491.2
Secondary[e]	33.0	35.0	34.0	33.0	34.0
Total[e]	497.3	539.3	533.6	[r]526.4	525.2
Chile, primary	834.2	879.7	884.3	942.5	945.0
China, primary and secondary[e]	310.0	310.0	400.0	400.0	400.0
Czechoslovakia, primary and secondary	25.7	26.1	[e]26.5	[e]26.5	26.5
Egypt, secondary	2.4	2.6	[e]2.6	[e]2.7	3.0
Finland:					
Primary	45.4	47.3	[e]46.5	[r,e]52.2	47.5
Secondary[e]	10.0	10.0	12.0	12.0	12.0
Total	55.4	57.3	[e]58.5	[r,e]64.2	59.5
France:					
Primary[e]	7.8	15.0	13.7	[r]15.1	13.3
Secondary	37.3	25.9	30.0	26.8	26.0
Total	45.1	40.9	43.7	[r,e]41.9	39.3
German Democratic Republic, primary and secondary[e]	68.0	65.0	63.0	63.0	58.0
Germany, Federal Republic of:					
Primary	[r]212.5	[r]207.1	210.1	238.0	[3]232.8
Secondary	[r]207.8	[r]171.7	204.3	183.9	[3]167.0
Total[2]	[r]420.3	[r]378.8	414.4	421.9	[3]399.8
Hungary, primary and secondary[e]	12.5	12.8	12.8	12.8	12.5
India, primary:					
Electrolytic	28.4	32.6	28.0	37.9	32.2
Fire refined[e]	1.0	1.0	1.0	1.0	1.0
Total[e]	29.4	33.6	29.0	[r]38.9	33.2
Iran, primary[4]	10.0	5.0	12.0	12.0	12.0
Italy, secondary	31.2	50.3	64.3	65.4	65.1
Japan:					
Primary	944.6	821.1	802.3	827.7	[3]871.0
Secondary	147.4	114.1	133.6	115.4	[3]109.4
Total[2]	1,091.9	935.2	936.0	943.0	[3]980.3

See footnotes at end of table.

Table 33.—Copper: World refinery production,[1] by country —Continued

(Thousand metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
Korea, North, primary and secondary[e]	22.0	22.0	22.0	22.0	22.0
Korea, Republic of:					
Primary	123.3	129.1	140.1	157.8	[3]156.3
Secondary[e]	11.5	7.9	11.5	[r]7.2	8.7
Total[e]	134.8	137.0	151.6	[r]165.0	165.0
Mexico:					
Primary:					
Electrowon	7.5	9.3	8.0	8.0	10.0
Other	61.0	69.0	101.5	66.5	95.4
Secondary[e]	15.0	[r] [3]13.9	14.0	15.0	15.0
Total[e] [2]	[r]83.5	[r]92.2	[r]123.6	[r]89.5	120.4
Norway, primary[5]	22.7	30.3	31.1	30.5	29.4
Oman, primary	3.8	[r]15.2	14.3	18.0	18.0
Peru, primary:					
Electrowon	33.0	31.5	27.4	27.5	27.5
Other	161.4	188.6	203.0	197.7	190.9
Total[2]	194.4	220.0	230.5	225.3	218.4
Philippines, primary	38.8	99.2	130.2	134.5	[3]132.1
Poland, primary[5]	360.0	372.3	387.0	388.0	[3]390.0
Portugal, primary	[e]4.6	5.3	4.5	5.3	4.8
Romania:[e]					
Primary	35.0	33.0	33.0	32.0	30.0
Secondary	12.0	12.0	12.0	11.0	12.0
Total	47.0	45.0	45.0	43.0	42.0
South Africa, Republic of, primary[6]	157.7	155.7	164.3	158.6	155.0
Spain:					
Primary	137.6	117.4	101.7	[e]113.2	100.8
Secondary	21.0	39.0	50.0	[e]45.0	50.0
Total	158.6	156.4	151.7	[e]158.2	150.8
Sweden:					
Primary	50.1	53.5	[e]52.0	[e]60.0	55.0
Secondary	13.2	10.4	12.7	[e]20.0	15.0
Total[2]	63.4	63.9	64.7	[e]80.0	70.0
Taiwan:					
Primary[e]	30.0	40.4	46.7	[r]50.4	[3]47.0
Secondary[e]	8.0	8.0	8.0	8.0	10.0
Total	38.0	48.4	54.7	58.4	57.0
Turkey, primary	31.8	39.0	[e]30.0	[e]35.0	35.0
U.S.S.R.:[e]					
Primary	776.0	[r]790.0	810.0	[r]830.0	840.0
Secondary	139.0	141.0	143.0	145.0	147.0
Total	915.0	[r]931.0	953.0	[r]975.0	987.0
United Kingdom:					
Primary	67.5	69.5	63.9	62.4	62.0
Secondary	76.8	67.4	61.6	63.2	63.0
Total[2]	144.4	136.8	125.4	125.6	125.0

See footnotes at end of table.

Table 33.—Copper: World refinery production,[1] by country —Continued

(Thousand metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
United States:					
Primary:					
Electrowon	[r]101.9	[r]100.2	90.4	125.4	[3]158.0
Other	[r]1,080.2	[r]1,064.4	966.7	948.6	[3]988.1
Secondary	401.7	324.9	377.5	405.9	[3]414.7
Total	[r]1,583.8	[r]1,489.5	1,434.6	1,479.9	[3]1,560.8
Yugoslavia:					
Primary	82.9	80.3	[r] [e]80.0	[r] [e]81.0	80.5
Secondary	40.8	[r]47.4	[r] [e]55.4	[r] [e]59.4	58.4
Total[2]	123.7	127.6	135.4	140.4	[3]138.9
Zaire, primary	227.2	224.8	221.4	218.0	220.0
Zambia, primary:[7]					
Electrowon	[r]134.4	[r]125.9	103.9	139.3	[3]140.0
Other	[r]406.6	[r]406.8	354.7	322.6	[3]323.0
Total	[r]541.0	[r]532.7	458.6	461.9	[3]463.0
Zimbabwe, primary	21.6	22.7	20.4	20.4	20.0
Grand total[2]	[r]9,201.7	[r]9,116.1	9,375.1	9,503.1	9,647.1
Of which:					
Primary[2]	[r]7,315.9	[r]7,364.5	7,302.0	7,461.0	7,605.2
Secondary[2]	[r]1,385.6	[r]1,253.8	1,455.9	1,422.8	1,427.9
Primary and secondary, undifferentiated	500.2	497.9	617.3	619.3	614.0

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

[1]This table includes total production of refined copper, whether produced by pyrometallurgical or electrolytic refining methods and whether derived from primary unrefined copper or from scrap. Copper cathode derived from electrowinning processing is also included. To the extent possible, primary and secondary output of each country is shown separately. In most cases, total refinery production is officially reported, and in some, the distribution between primary and secondary has been estimated. Table includes data available through July 8, 1988.

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

[3]Reported figure.

[4]Data are for fiscal year beginning Mar. 21 of that stated.

[5]May include small quantities of secondary.

[6]Although only primary production is reported, an unknown but small additional output of secondary refined copper may have been produced.

[7]Data are for fiscal year beginning Apr. 1 of that stated.

Diatomite

By Arthur C. Meisinger[1]

U.S. sales of processed diatomite increased compared with that of 1986 by 30,000 short tons to 658,000 tons valued at $134 million. Domestic consumption increased slightly, spurred by an 8% increase in filter-grade sales. Diatomite exports increased for the second straight year and continued to account for 21% of domestic production. California continued to be the leading producing State.

The United States accounted for about 32% of estimated world production of 2 million tons.

Domestic Data Coverage.—Domestic production data for diatomite are developed by the Bureau of Mines from one voluntary survey of U.S. plant operations. Of the 11 operations to which a survey request was sent, all responded, representing 100% of the total production shown in tables 1 and 5.

DOMESTIC PRODUCTION

Domestic production (sales) of diatomite, compared with that of 1986, increased nearly 5% to 658,000 tons valued at $134 million. Diatomite was processed by 6 companies in 10 plants in 4 States. California continued to be the leading producing State, followed by Nevada, Washington, and Oregon.

As in previous years, the major domestic producers were Manville Products Corp., with operations at Lompoc, CA; Grefco Inc., Dicalite Div., at Lompoc and Burney, CA, and Mina, NV; Eagle-Picher Minerals Inc., a subsidiary of Eagle-Picher Industries Inc., at Sparks and Lovelock, NV, and Vale, OR; and Witco Corp., Inorganic Specialties Div., at Quincy, WA. Other producers were Oil-Dri Production Co., a subsidiary of Oil-Dri Corp. of America, Christmas Valley, OR, and CR Minerals Corp., Fernley, NV.

CR Minerals, a subsidiary of Canyon Resources Corp., Golden, CO, purchased the Nevada diatomite operation of Cyprus Minerals Co. in November 1987. Lassenite Industries Inc., Yuba City, CA, closed its California diatomite operation at yearend 1986.

Table 1.—Diatomite sold or used by producers in the United States

(Thousand short tons and thousand dollars)

	1983	1984	1985	1986	1987
Domestic production (sales)	619	627	635	628	658
Total value of sales	$114,279	$120,926	$127,030	$128,362	$134,239

CONSUMPTION AND USES

Apparent domestic consumption of processed diatomite increased 6% to 526,000 tons compared with that of 1986. Domestic and export sales of filter-grade diatomite increased 8% from 422,000 tons in 1986 to 454,000 tons. Sales of filler-grade diatomite decreased slightly from 109,000 tons in 1986 to 105,000 tons in 1987. Sales of diatomite used for absorbents, additives, and insulation totaled 99,000 tons, a slight increase over that of 1986.

Table 2.—Diatomite sold or used,[1] by major use

(Percent of U.S. production)

Use	1983	1984	1985	1986	1987
Fillers	21	22	21	17	16
Filtration	66	67	66	67	69
Insulation	3	1	1	3	2
Other[2]	10	10	12	13	13

[1]Includes exports.
[2]Includes absorbents, additives, and silicate admixtures.

PRICES

The average unit value of sales for processed diatomite was $204 per ton—unchanged from that of 1986.

Table 3.—Average annual value per ton[1] of diatomite, by major use

Use	1985	1986	1987
Fillers	$184.49	$220.53	$226.54
Filtration	220.80	219.69	217.60
Insulation	110.95	129.96	109.72
Other[2]	118.39	116.72	120.54
Weighted average	199.93	204.28	204.17

[1]Based on unrounded data.
[2]Includes absorbents, additives, and silicate admixtures.

FOREIGN TRADE

U.S. exports of processed diatomite increased 8,000 tons from 131,000 tons in 1986. Average unit value decreased from $245 per ton to $238 per ton. Diatomite was exported to 70 countries, and the quantity represented 21% of domestic production. The following five countries received 49% of the total: Canada, 24,100 tons; Japan, 14,950 tons; Australia, 11,200 tons; the Federal Republic of Germany, 10,600 tons; and the United Kingdom, 7,500 tons.

Imports of diatomite totaled 6,646 tons, of which 95% was supplied by the Federal Republic of Germany.

Table 4.—U.S. exports of diatomite

(Thousand short tons and thousand dollars)

Year	Quantity	Value[1]
1984	127	29,461
1985	120	28,519
1986	131	32,180
1987	139	33,075

[1]U.S. Customs.

WORLD REVIEW

World production of diatomite was estimated to be 2 million tons. The United States, Romania, the U.S.S.R., and France continued to account for 1.5 million tons or 75% of that total.

[1]Industry economist, Branch of Industrial Minerals.

Table 5.—Diatomite: World production, by country[1]

(Thousand short tons)

Country	1983	1984	1985	1986[p]	1987[e]
Algeria	[e]5	2	3	4	4
Argentina	12	6	9	[e]11	9
Australia	9	7	8	9	9
Brazil (marketable)	16	18	14	[r e]16	20
Canada[e]	2	[r]4	[r]4	[r]5	5
Chile	1	2	3	3	3
Colombia[e]	1	1	1	1	1
Costa Rica	[e]1	[e]1	--	--	--
Denmark:[2]					
Diatomite[e]	7	11	7	[r]7	7
Moler	[e]72	70	79	80	73
Egypt	([3])	([4])	([4])	([4])	--
France	244	273	298	[r e]287	276
Germany, Federal Republic of	49	54	53	54	54
Iceland	28	30	32	25	28
Italy[e]	28	31	33	30	31
Kenya	2	2	2	2	2
Korea, Republic of	62	53	59	60	55
Mexico	48	49	50	48	50
Peru	15	8	16	[e]17	16
Portugal	2	2	2	2	2
Romania[e]	320	331	331	331	309
South Africa, Republic of	1	([3])	1	2	2
Spain	61	80	106	141	110
Thailand	([3])	1	([3])	([3])	([3])
Turkey	11	3	[e]3	[e]3	3
U.S.S.R.[e]	260	265	270	276	281
United Kingdom[e]	([3])	([3])	([3])	([3])	([3])
United States	619	627	635	628	[5]658
Total	1,876	[r]1,931	2,020	2,042	2,008

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through Apr. 22, 1988.
[2]Data represent sales.
[3]Less than 1/2 unit.
[4]Revised to zero.
[5]Reported figure.

Feldspar, Nepheline Syenite, and Aplite

By Michael J. Potter[1]

Total U.S. feldspar production in 1987, including soda, potash, mixed feldspar, and feldspar-silica mixtures, was 720,000 short tons with a value of $26.1 million. A lower level of housing construction, compared with that of 1986, resulted in a reduced demand for the related markets of plumbing fixtures, tile, and glass fiber insulation in which feldspar is used. Imports for consumption of crude and ground nepheline syenite were about 309,000 tons with a total value of $11.4 million.

Domestic Data Coverage.—Domestic production data for feldspar are developed by the Bureau of Mines by means of a voluntary survey. Of the 13 active operations, 10, or 77%, responded, representing an estimated 79% of the total production data for feldspar shown in table 1. The remaining 21% was estimated from prior years' data adjusted to current industry levels.

Legislation and Government Programs.—According to provisions of the Tax Reform Act of 1969, which continued in force throughout 1987, the depletion rate allowed on domestic and foreign feldspar production was 14%.

Table 1.—Salient feldspar and nepheline syenite statistics

	1983	1984	1985	1986	1987
United States:					
Feldspar:					
Produced[1] short tons	710,000	710,000	700,000	735,000	720,000
Value thousands	$22,500	$23,500	$22,800	$26,100	$26,100
Exports short tons	9,360	10,080	9,280	12,000	9,634
Value thousands	$856	$920	$680	$1,024	$691
Imports for consumption short tons	64	25	952	1,251	4,833
Value thousands	$31	$15	$1,150	$542	$477
Nepheline syenite:					
Imports for consumption short tons	407,351	377,945	332,604	298,806	308,685
Value thousands	$13,997	$14,218	$11,435	$11,280	$11,401
Consumption, apparent[2] (feldspar plus nepheline syenite) thousand short tons	1,108	1,078	1,024	1,023	1,024
World: Production (feldspar) do	[r]3,954	[r]4,238	4,453	[p]4,610	[e]4,531

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Includes hand-cobbed feldspar, flotation-concentrate feldspar, and feldspar in feldspar-silica mixtures; includes potash feldspar (8% K_2O or higher).
[2]Production plus imports minus exports.

FELDSPAR

DOMESTIC PRODUCTION

Soda feldspar is defined commercially as containing 7% soda (Na_2O) or higher; potash feldspar contains 10% potash (K_2O) or higher. However, to publish information on potash feldspar without revealing company proprietary data in this report, feldspars containing 8% K_2O or more are defined as potash feldspars. Hand-cobbed or hand-sorted feldspar is usually obtained from pegmatites and is relatively high in K_2O

compared with Na_2O. Hand cobbing continued to be a minor fraction of total production in 1987. Feldspar flotation concentrates, most of the U.S. output, are classified as either soda, potash, or mixed feldspar, depending on the relative amounts of Na_2O and K_2O present. Feldspar-silica mixtures, feldspathic sand, can either be naturally occurring or a flotation product. Total feldspar content of this mixture was 30% of total feldspar output during 1987.

Feldspar was mined in six States, led by North Carolina and followed in descending order by Connecticut, California (estimated), Georgia, Oklahoma, and South Dakota. North Carolina accounted for 71% of the total. Twelve U.S. companies operating thirteen beneficiating plants and one grinding plant produced feldspar or feldspar-silica mixtures for shipment to more than 31 States and foreign countries, including Canada and Mexico. Of the 12 companies, 3 produced potash feldspar, and 9 produced soda or mixed feldspar or feldspathic sand mixtures. North Carolina had six plants, California had three, and Connecticut, Georgia, Oklahoma, and South Dakota each had one. The grinding plant was in South Carolina.

The data for potash feldspar were collected from the three U.S. producers of this material; some of this feldspar contained less than 10% K_2O (8% to 10% K_2O).

Table 2.—Feldspar[1] produced in the United States

(Thousand short tons and thousand dollars)

Year	Hand-cobbed		Flotation concentrate		Feldspar-silica mixtures[2]		Total[3]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1983	7	107	525	17,128	178	5,265	710	22,500
1984	7	124	502	17,874	201	5,503	710	23,500
1985	14	W	487	16,781	197	W	700	22,800
1986	13	W	522	19,855	200	W	735	26,100
1987	10	W	492	17,800	219	W	720	26,100

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1]Includes potash feldspar (8% K_2O or higher).
[2]Feldspar content.
[3]Data may not add to totals shown because of independent rounding.

Table 3.—Producers of feldspar and feldspathic materials in 1987

Company	Plant location	Product
APAC Arkansas Inc	Muskogee, OK	Feldspar-silica mixture.
California Silica Products Co	San Juan Capistrano, CA.	Do.
Calspar Div. of Steelhead Resources Inc	Santa Fe Springs, CA	Soda feldspar.
The Feldspar Corp	Middletown, CT	Do.
Do	Monticello, GA	Potash feldspar.
Do	Spruce Pine, NC	Soda feldspar.
Do	Montpelier, VA	Aplite.
Foote Mineral Co	Kings Mountain, NC	Feldspar-silica mixture.
Indusmin Ltd	Spruce Pine, NC	Soda feldspar.
KMG Minerals Inc	Kings Mountain, NC	Potash feldspar.
Lithium Corp. of America	Bessemer City, NC	Feldspar-silica mixture.
Pacer Corp	Custer, SD	Potash feldspar.
Spartan Minerals Corp	Pacolet, SC	Feldspar-silica mixture.
Unimin Corp	Spruce Pine, NC	Soda feldspar.
U.S. Silica Co	Oceanside, CA	Feldspar-silica mixture.

CONSUMPTION AND USES

Of the total feldspar consumed in the United States, 55% was used in glassmaking, including container glass and glass fiber, and 44% was used in pottery.

Fewer housing starts, compared with those of 1986, resulted in reduced feldspar usage in plumbing fixtures, tile, and glass fiber for insulation.

The value of potash feldspar sold or used in 1987 was $5.3 million. Tonnage data are withheld to avoid disclosing company proprietary data.

Table 4.—Feldspar[1] sold or used by producers in the United States, by use

(Thousand short tons and thousand dollars)

Use	1986 Quantity	1986 Value	1987 Quantity	1987 Value
Hand-cobbed:				
Pottery	11	W	4	W
Other	1	W	3	W
Total	12	W	7	W
Flotation concentrate:				
Glass	221	7,304	218	7,845
Pottery	300	14,892	277	14,460
Total	521	22,196	495	22,305
Feldspar-silica mixtures:[2]				
Glass	176	8,866	179	8,417
Pottery	25	W	34	W
Total	201	W	213	W
Total:[3]				
Glass[4]	394	16,170	398	16,262
Pottery	339	W	316	W
Other[5]	2	W	3	W
Total	735	32,900	720	32,900

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1]Includes potash feldspar (8% K_2O or higher).
[2]Feldspar content.
[3]Data may not add to totals shown because of independent rounding.
[4]Includes container glass and glass fiber.
[5]Includes enamel, filler, etc., and unknown.

Table 5.—Destination of shipments of feldspar[1] sold or used by producers in the United States, by State

(Short tons)

State	1983	1984	1985	1986	1987
Alabama	14,600	15,100	W	20,100	W
California[e] [2]	45,000	45,000	50,000	50,000	50,000
Florida	22,700	20,300	16,900	20,000	14,200
Georgia	96,900	96,000	95,300	91,600	86,500
Illinois	46,600	38,000	37,000	27,900	28,700
Indiana	37,200	35,700	W	W	W
Kentucky	11,400	13,300	16,200	16,900	W
Louisiana	17,400	21,300	12,200	14,100	14,900
Maryland	4,500	7,400	7,400	7,000	6,400
Massachusetts	1,200	10,800	W	W	W
Mississippi	15,900	12,000	W	W	W
Missouri	5,000	4,400	4,700	6,100	5,200
New Jersey	56,600	53,200	W	W	W
New York	18,300	10,800	W	W	W
North Carolina	20,100	16,400	17,000	20,700	40,500
Ohio	53,600	64,900	65,800	68,200	64,400
Pennsylvania	33,200	37,200	31,100	33,600	36,400
South Carolina	18,400	17,400	W	W	W
Texas	41,900	41,400	42,000	45,000	44,000
West Virginia	38,100	28,500	27,000	24,400	19,800
Wisconsin	9,400	11,100	W	W	W
Other [3]	102,000	99,800	277,400	289,400	306,000
Total	710,000	700,000	700,000	735,000	[4]720,000

[e]Estimated. W Withheld to avoid disclosing company proprietary data; included with "Other destinations."
[1]Includes potash feldspar (8% K_2O or higher).
[2]Data are incomplete, and estimates are very rough.
[3]Includes Arkansas, Colorado, Connecticut, Kansas, Michigan, Minnesota, Oklahoma, Rhode Island, Tennessee, Virginia, States indicated by symbol W, and other unspecified States. Tennessee, Virginia, States indicated by symbol W, and other unspecified States. Also includes exports to Canada, Mexico, and other foreign countries.
[4]Data do not add to total shown because of independent rounding.

Table 6.—Destination of shipments of potash feldspar[1] sold or used by producers in the United States

(Short tons)

Destination	1983	1984	1985	1986	1987
Illinois, Indiana, Wisconsin	6,000	5,800	5,800	5,500	W
Maryland, New York, West Virginia	25,300	21,800	28,000	25,600	W
Ohio	8,100	9,000	8,200	(2)	W
Pennsylvania	7,100	13,500	8,200	(2)	W
Texas	300	200	200	300	W
Canada	4,300	4,600	5,200	3,500	W
Other[3]	14,100	16,400	21,400	39,200	W
Total	65,200	71,300	77,000	74,100	W

W Withheld to avoid disclosing company proprietary data.
[1]K_2O content of 8% or higher.
[2]Included with "Other."
[3]Includes Alabama, Arkansas, California, Colorado, Connecticut, Florida, Georgia, Kansas, Kentucky, Massachusetts, Michigan, Minnesota, Missouri, New Jersey, North Carolina, South Carolina, Tennessee, Virginia, States indicated by symbol W, and other unspecified States.

PRICES

Published feldspar prices were the same as those of 1986. Engineering and Mining Journal, December 1987, listed the following prices for feldspar, per short ton, f.o.b. mine or mill, carload lots, bulk, depending on grade:

Producing States	1986	1987
Connecticut:		
20 mesh, granular	$43.00	$43.00
200 mesh	58.75	58.75
Georgia:		
40 mesh, granular	57.25	57.25
200 mesh	76.50	76.50
North Carolina:		
20 mesh, flotation	29.25	29.25
40 mesh, flotation	57.25	57.25
200 mesh, flotation	77.80	77.80

Source: Engineering and Mining Journal, v. 188, No. 12, Dec. 1987, p. 27.

FOREIGN TRADE

U.S. exports classified as feldspar, leucite, and nepheline syenite decreased 20%. Feldspar imports for consumption increased 286%.

In addition to feldspar and nepheline syenite, the United States imported 44,386 tons of "Other crude natural mineral fluxes" with a value of $466,285. This represented a 37% decrease in tonnage compared with that of 1986. Also, 8,517 tons of "Other mineral fluxes, crushed" was imported with a value of $1,860,000. This was a 416% increase in tonnage compared with that of 1986.

The tariff schedule in force throughout 1987 for most favored nations provided for a 2.9% ad valorem duty on ground feldspar; imports of unground feldspar were admitted duty free.

Table 7.—U.S. exports of feldspar, by country

Country	1986 Short tons	1986 Value	1987 Short tons	1987 Value
Canada	3,850	$227,600	1,864	$100,403
Dominican Republic	1,100	85,900	1,661	91,147
Italy	600	26,000	623	32,960
Mexico	1,090	80,400	1,309	122,760
Panama	3,200	262,000	--	--
Taiwan	1,100	202,900	1,002	101,291
Venezuela	500	32,000	2,272	143,717
Other	560	107,400	903	99,010
Total	12,000	1,024,200	9,634	691,288

Source: Bureau of the Census.

Table 8.—U.S. imports for consumption of feldspar, by type and country

Type and country	1986		1987	
	Short tons	Value[1]	Short tons	Value[1]
Crude:				
Canada	22	$8,000	194	$1,982
Mexico	256	29,017	150	2,341
Venezuela	290	436,584	--	--
Ground, crushed, or pulverized:				
Korea, Republic of	--	--	39	6,577
Mexico	683	68,440	4,377	418,170
Switzerland	--	--	30	30,834
United Kingdom	--	--	43	16,916
Total	1,251	542,041	4,833	476,820

[1]Customs value.

Source: Bureau of the Census.

WORLD REVIEW

Australia.—Production of feldspar increased from 5,000 tons in 1983 to an estimated 12,000 tons in 1987. ACI Resources Ltd.'s Industrial Minerals Div. was investigating the extraction of feldspar by flotation from granite.[2]

Pakistan.—Several companies produced an estimated total of 13,000 tons of soda and potash feldspar per year for domestic glass and ceramics production.[3]

Spain.—A new company, Rio Piron, was established to develop a feldspathic sand deposit.[4]

Turkey.—Known feldspar deposits occur in the western and northeastern parts of the country. A plant to treat 4,000 tons of ground feldspar per year and 19,000 tons of flotation feldspar per year was under construction in southwestern Turkey by Esan Eczacibasi Industrial Minerals Co. The company planned to export one-half of the production.[5]

Table 9.—Feldspar: World production, by country[1]

(Thousand short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Argentina	22	20	9	r e11	11
Australia	5	4	7	12	12
Austria	1	3	15	3	3
Brazil[3]	136	116	e132	e132	138
Burma	3	7	3	3	3
Chile	3	3	3	3	2
Colombia	35	36	38	39	39
Egypt	7	8	21	21	22
Finland	57	62	58	52	55
France	193	230	190	238	231
Germany, Federal Republic of	364	328	355	336	330
Guatemala[e]	7	6	[4]6	7	7
Hong Kong	62	127	120	39	28
India	46	44	51	51	46
Iran	26	36	35	r e35	35
Italy	911	1,086	1,230	1,364	1,320
Japan[5]	34	39	34	35	36
Kenya	1	1	1	(6)	1
Korea, Republic of	121	140	160	144	143
Mexico	130	93	e110	e110	110
Morocco[e]	1	1	1	1	1
Mozambique	1	e1	(7)	(7)	(7)
Nigeria[e]	6	(6)	r2	[4]3	3
Norway[8]	64	75	88	r e88	88
Pakistan	6	6	6	13	3
Peru	3	4	--	--	--
Philippines	7	13	6	e7	7
Poland[e]	88	88	88	88	88
Portugal	39	32	32	37	35
Romania[e]	94	94	95	95	90
South Africa, Republic of	50	43	36	58	[4]73
Spain[9]	128	151	150	149	151
Sri Lanka	3	6	11	8	9
Sweden	58	55	46	r e44	44
Taiwan	13	17	12	29	28

See footnotes at end of table.

Table 9.—Feldspar: World production, by country[1] —Continued

(Thousand short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Thailand	53	82	115	127	127
Turkey[e]	[4]10	11	22	22	22
U.S.S.R.[e]	360	360	370	370	370
United Kingdom (china stone)	6	7	7	8	8
United States	710	710	700	735	[4]720
Uruguay	1	2	1	[e]1	1
Venezuela	41	[r]43	34	38	39
Yugoslavia[e]	[4]46	46	50	[r]52	50
Zambia	(7)	(7)	(7)	(7)	(7)
Zimbabwe	2	2	3	2	2
Total	[r]3,954	[r]4,238	4,453	4,610	4,531

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through May 6, 1988.
[2]In addition to the countries listed, Czechoslovakia, Madagascar, and Namibia produce feldspar, but output is not officially reported, and available general information is inadequate for the formulation of reliable estimates of output levels.
[3]Series excludes production of leucite and sodalite; data consist only of that material reported by Brazil under the heading of "Feldspar." Data represent the sum of (1) run-of-mine production for direct sale and (2) salable beneficiated product; total run-of-mine feldspar production was as follows, in thousand short tons: 1983—71; 1984—93; 1985—91; 1986—91 (revised, estimated); and 1987—93 (estimated).
[4]Reported figure.
[5]In addition, the following quantities of aplite were produced, in thousand short tons: 1983—442; 1984—486; 1985—517; 1986—493; and 1987—474 (estimated).
[6]Revised to zero.
[7]Less than 1/2 unit.
[8]Excludes nepheline syenite.
[9]Includes pegmatite.

NEPHELINE SYENITE

Output from the two operations of Indusmin Ltd., a division of Falconbridge Ltd., at Blue Mountain, Ontario, Canada, was 534,600 tons in 1986, the latest year data were available. Of this total, an estimated 75% was glass grade and 25% was fine-grind grades for ceramic, paint, and other applications. In Norway, nepheline syenite was produced at the Norsk Nefelin underground mining operation on the Arctic island of Stjernoy. Sales were mostly to markets in Western Europe.

Prices for nepheline syenite have been depressed since 1981, especially for glass grades.[6] This was due to closing of a number of glass container plants in recent years and competition from other feldspathic materials.

Prices for Canadian nepheline syenite listed in Industrial Minerals (London), December 1987, were $21.50 to $30.50 per ton for glass grade, 30 mesh, bulk, carlots-trucklots, depending on iron content; $64 to $66 per ton for ceramic grade, 200 mesh, bagged 10-ton lots; and $85 to $99 per ton for filler-extender grade, bagged.

Alkane Exploration NL was evaluating a deposit of nepheline syenite and rare-earth elements near Dubbo in west-central New South Wales, Australia.[7]

In Pakistan, deposits of nepheline syenite occur in the Province of Swat. Some sample material has been used in glass and ceramics. Larger scale laboratory test work was anticipated.[8]

Table 10.—U.S. imports for consumption of nepheline syenite

Year	Crude		Ground	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1985	920	$62	331,684	$11,373
1986	2,970	205	295,836	11,075
1987	3,720	142	304,965	11,259

Source: Bureau of the Census.

APLITE

Aplite is a feldspar mineral that has more than one geological definition. However, aplite from the only active U.S. operation contains primarily lime-soda feldspar. Aplite, usually unsuitable for use in ceramics, has been used in the manufacture of glass, when it is sufficiently low in iron. Japan, with an annual production of approximately 490,000 tons, has been the world's largest producer of aplite.

Aplite of glassmaking quality was produced in the United States by The Feldspar Corp. near Montpelier, Hanover County, VA.

Domestic output decreased compared with that of 1986. The data are company proprietary and cannot be released for publication. Aplite traditionally has a somewhat lower price than feldspar. Industrial Minerals (London), December 1987, gave a value of $25.75 per ton for glass grade, bulk, 100% plus 200 mesh, f.o.b. Montpelier, VA.

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[1]Physical scientist, Branch of Industrial Minerals.
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[6]Midgette, W. B. Nepheline Syenite. Am. Ceram. Soc. Bull., v. 66, No. 5, May 1987, p. 771.
[7]Industrial Minerals (London). Mineral Notes. No. 238, July 1987, p. 93.
[8]Pages 36 and 39 of work cited in footnote 3.

Ferroalloys

By Clark R. Neuharth[1]

Demand for ferroalloys increased in many countries compared with that of 1986, owing to increased consumption by the iron and steel and aluminum industries. Prices for ferroalloys rose steadily as supplies tightened, and a continuing production shift from traditional suppliers to developing countries was observed as plant closings occurred in some industrialized countries. Overall world production was little changed.

Domestic Data Coverage.—Domestic production data for ferroalloys are developed by the Bureau of Mines by means of monthly and annual voluntary domestic surveys. Typical of these surveys are the three separate monthly surveys for chromium alloys and metal, manganese alloys and metal, and silicon alloys and metal, and the annual survey for ferroalloys. Of the 41 operations to which a survey was sent, 31 responded, representing an estimated 76% of the total production and/or shipments shown in table 2. Production and shipments for the remaining 10 nonrespondents were estimated using reported prior year production and shipment levels adjusted by trends in employment and other guidelines.

Legislation and Government Programs.—House bill (H.R.) 3, entitled "The Omnibus Trade Act of 1987" in the House of Representatives and its companion Senate version, Senate bill (S.) 490, were introduced early in the year. The purpose of S. 490, which was subsequently passed by the Senate and incorporated into H.R. 3, was to revise trade remedy statutes, such as dumping and subsidy laws. H.R. 3 would create sweeping changes in existing trade laws covering import relief and other aspects of international competitiveness.

S. 556 and its counterpart, H.R. 1580, were subsequently introduced for the purpose of prohibiting U.S. investment in and trade with the Republic of South Africa. However, both bills included clauses exempting any minerals or materials considered by the President and Congress to be strategic to defense needs. This exemption probably would include ferroalloys and related ores. As required by section 303(a)(2) of the Comprehensive Anti-Apartheid Act of 1986, the U.S. Department of State certified 10 strategic minerals as essential for the economy or defense of the United States and unavailable in adequate quantities from reliable and secure suppliers. The list included chromium, manganese, vanadium, and their respective ferroalloys. Section 501 of the act required the Department of State to submit a report to the President assessing the yearlong effects of selected sanctions on the Republic of South Africa and what effect they had on dismantling apartheid. Also, section 504 required that the Administration study alternative sources for ferroalloys to cut the Country's dependency on the Republic of South Africa for ferroalloys and other metals.

The General Services Administration awarded 2-year contracts to Macalloy Corp. and Elkem Metals Co. for upgrading National Defense Stockpile chromite ore and manganese ore, respectively, into high-carbon ferrochromium (H-C-FeCr) and high-carbon ferromanganese (H-C-FeMn). Continuance of the upgrading program, which began in 1984, was authorized for fiscal years 1987-93 under Title II—National Defense Stockpile of the Defense Authorization Act of 1987. The defense authorization legislation also transferred the power to set National Defense Stockpile goals from the President to the Congress and shifted management of the stockpile from the Federal Emergency Management Agency to the Secretary of Defense. The Senate rejected an amendment to the authorization legislation that would have allowed the President to reduce stockpile reserves to $7.2 billion and the level of each material by 15%.

As a result of a general review of the Generalized System of Preferences (GSP) program, mandated by the Trade and Tariff Act of 1984, the United States removed imports of Brazilian silicon metal from the GSP's exemption list, placing a 5.3% duty on imports of silicon metal in the 99.0% to 99.7% purity category, effective July 1, 1987.

West Virginia gave a tax break to power companies that supply ferroalloy producers in that State. Under the new law, power companies were not subject to gross sales tax on power distributed to produce ferroalloys. The power companies were required to pass along the savings to the ferroalloy producers through rate reductions.

The Environmental Protection Agency (EPA) published revised particulate-emissions controls. The particulate-matter rules superseded earlier standards and required that smaller particles be captured by emission control equipment. EPA also published land disposal restrictions on a second group of chemicals mentioned in the 1984 amendments to the Resource Conservation and Recovery Act (RCRA). The group included eight metals, among which were chromium and nickel. RCRA requires that liquid wastes, including free liquids associated with any solid or sludge, be restricted from land disposal if they contain certain concentrations of the listed metals or their compounds. The EPA also set limits for hazardous materials in electric arc furnace dust that would be disposed of in landfills.

Table 1.—Government inventory of ferroalloys, December 31, 1987

(Thousand short tons)

Alloy	Stockpile grade	Nonstockpile grade	Total
Ferrochromium:			
High-carbon	537	1	538
Low-carbon	300	19	319
Ferrochromium-silicon	57	1	58
Ferrocolumbium (contained columbium)	.3	.2	.5
Ferromanganese:			
High-carbon	705	--	705
Medium-carbon	29	--	29
Ferrotungsten (contained tungsten)	.4	.6	1
Silicomanganese	24	--	24

DOMESTIC PRODUCTION

Production and shipments of bulk ferroalloys (i.e., those containing chromium, manganese, and silicon) and metals overall increased 7% and 8%, respectively, compared with those of 1986. Producer stocks of most ferroalloy materials were down at yearend, owing to high demand from consuming industries.

Applied Industrial Minerals Corp. shut down its Kimball, TN, ferrosilicon plant early in the year, owing to competition from low-priced imports. SKW Alloys Inc. started silicon metal production in January, after completing the conversion of one of its ferrosilicon furnaces in Niagara Falls, NY. Universal Consolidated Co. purchased M. A. Hanna Co.'s previously closed ferronickel smelter in Riddle, OR, and announced plans to reactivate the facility to produce ferrosilicon in 1988.

Moore McCormack Resources Inc. completed the sale of Globe Metallurgical Inc., a silicon and ferrosilicon producer, to a management group backed by Lee Capital Corp., an investment banking firm based in Boston, MA. Globe planned to continue producing silicon metal, magnesium ferrosilicon, and 50% ferrosilicon at its facilities in Beverly, OH, and Selma, AL.

Foote Mineral Co. sold both of its ferrosilicon production facilities at the end of the year. The Graham, WV, plant, which had been closed since 1985, was purchased by an employee group under the name American Alloys Inc. The new company planned to start production of 50% ferrosilicon by March 1988 and possibly convert some of its capacity to silicon metal production later in the year. Keokuk Ferro-Sil Inc., a group formed by former Foote employees, purchased the Keokuk, IA, facility and planned to continue production of silvery pig iron and 50% ferrosilicon. Foote had sold its ferrovanadium production facility in Cambridge, OH, to Shieldalloy Corp. earlier in the year.

Estimated ferrous scrap consumption by the domestic ferroalloys industry was 280,000 tons in 1987 compared with 250,000 tons in 1986.

The Ferroalloys Association reported that its member companies consumed 4.5 billion kilowatt hours of electricity in 1987 compared with 4.2 billion kilowatt hours in 1986.

Table 2.—Ferroalloys[1] produced and shipped from furnaces in the United States

	1986				1987			
	Net production		Net shipments		Net production		Net 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)
Chromium alloys[2]	105,407	62	115,659	$87,624	117,634	61	126,423	$107,078
Chromium metal	(3)	100	(3)	(3)	(3)	100	(3)	(3)
Manganese alloys[4]	117,368	81	111,592	90,941	112,945	78	128,638	101,768
Manganese metal	(5)	100	(5)	(5)	(5)	100	(5)	(5)
Silicon alloys[6]	339,441	53	371,310	218,382	357,255	52	374,865	193,227
Silicon metal	123,893	99	126,077	148,797	149,428	99	149,713	186,713
Total[7]	686,109	XX	724,638	545,744	737,262	XX	779,639	588,651
Ferrocolumbium	W	65	W	W	(8)	65	(8)	(8)
Ferrophosphorus	58,147	24	53,758	7,161	40,188	23	40,642	6,171
Other[9]	72,109	XX	76,231	111,848	34,676	XX	51,686	123,669
Total[7]	130,256	XX	129,989	119,009	75,864	XX	92,328	129,840
Grand Total[7]	816,365	XX	854,627	664,753	813,126	XX	871,967	718,491

W Withheld to avoid disclosing company proprietary data; included with "Other." XX Not applicable.
[1]Does not include alloys consumed in the making of other ferroalloys.
[2]Includes ferrochromium, ferrochromium-silicon, chromium briquets, exothermic additives, and miscellaneous chromium alloys.
[3]Included with chromium alloys.
[4]Includes ferromanganese, fused-salt electrolytic low- and medium-carbon ferromanganese (massive manganese), and silicomanganese.
[5]Included with manganese alloys.
[6]Included with ferrosilicon and other miscellaneous silicon alloys.
[7]Data may not add to totals shown because of independent rounding.
[8]Included with "Other."
[9]Includes ferroaluminum, ferroboron and other complex boron additive alloys, ferromolybdenum, ferronickel, ferrotitanium, ferrotungsten, ferrovanadium, ferrozirconium, silvery pig iron, and other miscellaneous alloys.

Table 3.—Producers of ferroalloys in the United States in 1987

Producer	Plant location	Products[1]	Type of furnace
FERROALLOYS (EXCEPT FERROPHOSPHORUS)			
Affiliated Metals and Minerals Inc	New Castle, PA	FeMo, FeV	Metallothermic.
Aluminum Co. of America, Northwest Alloys Inc.	Addy, WA	FeSi, Si	Electric.
AMAX Inc., Climax Molybdenum Co. Div	Langeloth, PA	FeMo	Metallothermic.
Applied Industrial Minerals Corp. (AIMCOR)	Bridgeport, AL	FeSi	Electric.
Do	Kimball, TN	FeSi, other[2]	Do.
Ashland Chemical Co	Columbus, OH	FeB, FeCb, FeMo, FeTi, FeW, NiCb.	Electric and metallothermic.
Cabot Corp.	Revere, PA	FeCb	Metallothermic.
Cyprus Minerals Co., Duval Corp	Sahuarita, AZ	FeMo	Do.
Dow Corning Corp	Springfield, OR	Si	Electric.
Elkem A/S, Elkem Metals Co	Alloy, WV Ashtabula, OH Marietta, OH Niagara Falls, NY	Cr, FeB, FeCr, FeMn, FeSi, Mn, Si, SiMn, other.[2]	Electric and electrolytic.
Foote Mineral Co., Ferroalloys Div	Graham, WV[3] Keokuk, IA[4]	FeSi, silvery pig iron, other.[2]	Electric.
Hanna Mining Co., Silicon Div	Wenatchee, WA	FeSi, Si	Do.
Kerr-McGee Chemical Corp	Hamilton (Aberdeen), MS.	Mn	Electrolytic.
Macalloy Corp	Charleston, SC	FeCr	Electric.
Metallurg Inc., Shieldalloy Corp	Cambridge, OH Newfield, NJ	Cr, FeAl, FeB, FeCb, FeTi, FeV, other.[2]	Electric and Metallothermic.
Moore McCormack Resources Inc., Globe Metallurgical Inc.	Beverly, OH Selma, AL	FeCr, FeSi, Si	Electric.
Ohio Ferro-Alloys Corp	Montgomery, AL	FeSi, Si	Do.
Reactive Metals and Alloys Corp	West Pittsburg, PA	FeAl, FeB, FeTi, other[2]	Do.
Reading Alloys Inc	Robesonia, PA	FeCb, FeV	Metallothermic.

See footnotes at end of table.

Table 3.—Producers of ferroalloys in the United States in 1987 —Continued

Producer	Plant location	Products[1]	Type of furnace
FERROALLOYS (EXCEPT FERROPHOSPHORUS) — Continued			
Reynolds Metals Co	Sheffield, AL	Si	Electric.
SEDEMA S.A., Chemetals Inc	Baltimore, MD	FeMn	Electric and electrolytic.
SKW Alloys Inc	Calvert City, KY	FeCr, FeCrSi	Electric.
	Niagara Falls, NY	FeSi	Do.
Strategic Minerals Corp. (STRATCOR):			
U.S. Vanadium Corp	do	FeV, FeW	Do.
U.S. Tungsten Corp			
Teledyne Inc., Teledyne Wah Chang, Albany Div.	Albany, OR	FeCb	Metallothermic.
Union Oil Co. of California, Molycorp Inc	Washington, PA	FeB, FeMo	Electric and metallothermic.
Universal Consolidated Co., Nickel Mountain Resources.	Riddle, OR	FeNi, FeSi	Electric.
FERROPHOSPHORUS			
FMC Corp., Industrial Chemical Div	Pocatello, ID	FeP	Do.
Monsanto Co., Monsanto Industrial Chemicals Co.	Soda Springs, ID	do	Do.
Occidental Petroleum Corp., Hooker Chemical Co., Industrial Chemicals Group.	Columbia, TN	do	Do.
Stauffer Chemical Co., Industrial Chemical Div.	Mount Pleasant, TN Silver Bow, MT	do	Do.

[1]Cr, chromium metal; 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; FeZr, ferrozirconium; Mn, manganese metal; Si, silicon metal; SiMn, silicomanganese.
[2]Includes specialty silicon alloys, zirconium alloys, and miscellaneous ferroalloys.
[3]Sold to American Alloys Inc. at yearend.
[4]Sold to Keokuk Ferro-Sil Inc. at yearend.

CONSUMPTION AND USES

Overall demand for ferroalloys as additives and alloying elements increased in 1987, owing partly to an 8% increase in raw steel production. Other major consuming markets, such as the stainless steel and ferrous castings industries, also demanded more ferroalloys than in 1986.

USX Corp., a major consumer of ferroalloys, reopened steelmaking operations that had been shut down for about half of 1986 because of a labor dispute.

Table 4.—Reported U.S. consumption of ferroalloys as additives in 1987, by end use[1]

(Short tons of alloys unless otherwise specified)

End use	FeMn	SiMn	FeSi	FeTi	FeP	FeB
Steel:						
Carbon	313,009	81,812	[2]57,750	784	8,401	319
Stainless and heat-resisting	[2]17,784	3,770	[2]74,769	2,457	W	32
Other alloy	[2]69,541	[2]22,815	[2]52,522	358	960	323
Tool	[2]369	([3])	2,001	([3])	--	--
Unspecified	1,610	416	10,753	5	--	--
Total	402,313	108,813	197,795	3,604	9,361	674
Cast irons	[4]8,839	2,555	202,914	W	2,207	W
Superalloys	154	W	[4]271	689	--	W
Alloys (excluding alloy steels and superalloys)	18,373	W	[4]47,063	320	109	71
Miscellaneous and unspecified	5,269	3,177	73,792	40	7	88
Total consumption	434,948	114,545	521,835	4,653	11,684	833
Percent of 1986	109	111	104	109	107	111

W Withheld to avoid disclosing company proprietary data; included with "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; FeB, ferroboron including other boron materials.
[2]Part included with "Steel: Unspecified."
[3]Included with "Steel: Unspecified."
[4]Part included with "Miscellaneous and unspecified."

Table 5.—Reported U.S. consumption of ferroalloys as alloying elements in 1987, by end use[1]

(Short tons of contained elements unless otherwise specified)

End use	FeCr	FeMo	FeW	FeV	FeCb	FeNi
Steel:						
Carbon	[2]4,333	132	--	1,197	807	--
Stainless and heat-resisting	205,278	252	71	65	460	16,677
Other alloy	[2]23,778	980	31	2,152	827	346
Tool	[2]2,406	W	168	465	([2])	--
Unspecified	([3])	([3])	--	--	6	--
Total[4]	235,795	1,364	270	3,880	2,100	17,023
Cast irons	[5]3,578	637	([3])	25	--	314
Superalloys	[5]9,362	50	W	10	442	--
Alloys (excluding alloy steels and superalloys)	[5]1,892	168	W	[5]691	8	61
Miscellaneous and unspecified	3,995	310	10	48	40	20
Total consumption[4]	254,622	2,530	279	4,653	2,589	17,418
Percent of 1986	121	124	135	108	104	131

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."
[1]FeCr, ferrochromium including other chromium ferroalloys and chromium metal; FeMo, ferromolybdenum including calcium molybdate; FeW, ferrotungsten; FeV, ferrovanadium including other vanadium-carbon-iron ferroalloys; FeCb, ferrocolumbium including nickel columbium; FeNi, ferronickel.
[2]Included with "Steel: Unspecified."
[3]Included with "Miscellaneous and unspecified."
[4]Data may not add to totals shown because of independent rounding.
[5]Part included with "Miscellaneous and unspecified."

Table 6.—Reported stocks of ferroalloys held by producers and consumers in the United States, December 31

(Short tons)

	Producer		Consumer		Total	
	1986 (gross weight)	1987 (gross weight)	1986 (gross weight)	1987 (gross weight)	1986 (gross weight)	1987 (gross weight)
Chromium alloys[1]	14,105	5,687	31,790	24,900	45,895	30,587
Manganese alloys[2]	W	W	W	W	[r]109,032	64,803
Silicon alloys[3]	140,788	81,400	21,264	20,375	162,052	101,775
Ferroboron[4]	137	127	217	252	354	379
Ferrophosphorus	63,530	25,326	1,380	1,307	64,910	26,663
Ferrotitanium	W	W	609	773	609	773
Total	218,560	112,540	55,260	47,607	382,852	224,980
	1986 (contained element)	1987 (contained element)	1986 (contained element)	1987 (contained element)	1986 (contained element)	1987 (contained element)
Ferrocolumbium[5]	W	W	W	W	W	W
Ferromolybdenum[6]	909	742	309	277	1,218	1,019
Ferronickel	--	--	1,028	NA	1,028	NA
Ferrotungsten	W	W	29	68	29	68
Ferrovanadium[7]	W	W	314	372	314	372
Total	909	742	1,680	717	2,589	1,459

[r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.
[1]Includes ferrochromium, ferrochromium-silicon, other chromium alloys, and chromium metal.
[2]Includes ferromanganese, silicomanganese, and manganese metal.
[3]Includes ferrosilicon, miscellaneous silicon alloys, and silicon metal.
[4]Consumer totals include other boron materials.
[5]Consumer totals include nickel columbium.
[6]Consumer totals include calcium molybdate.
[7]Includes other vanadium-iron-carbon ferroalloys.

PRICES

Published prices for most ferroalloys rose in 1987 owing to increasing demand by major consuming industries and tightening supplies. The average posted price for most imported bulk ferroalloys was higher in 1987 compared with that of 1986; for example, by 10% to 43.5 cents per pound of chromium for charge chrome containing 50% to 55% chromium, by 4% to 85.92 cents per pound of chromium for low-carbon ferrochromium (L-C-FeCr), by 7% to $336.95 per long ton of alloy for standard 78% ferromanganese, by 7% to 33.76 cents per pound of manganese for medium-carbon ferromanganese, by 8% to 18.7 cents per pound of alloy for silicomanganese, by 9% to 37.76 cents per pound of silicon for 50% ferrosilicon, and by 10% to 36.15 cents per pound of silicon for 75% ferrosilicon. The average annual price for imported charge chrome containing 60% to 65% chromium fell slightly to 42.38 cents per pound of chromium. Posted average annual prices for comparable domestically produced alloys in 1987 were mixed compared with those of 1986. The average prices for 50% and 75% ferrosilicon rose 3% and 1%, respectively, while those for medium-carbon ferromanganese and charge chrome containing 66% to 70% chromium fell slightly. Most other average prices remained unchanged.

Alloy	Yearend price[1]	
	1986	1987
Charge chromium (66% to 70%)	$0.54	$0.52
Low-carbon ferrochromium, 0.02% maximum carbon (Simplex)	1.00	1.10
Standard 78% ferromanganese, per long ton of alloy[2]	305.00	380.00
Ferromolybdenum, dealer export	3.65	3.93
Ferrosilicon, 50%	.40	.47
Ferrosilicon, 75%	.40	.47

[1]Per pound contained, except as noted otherwise. If range of prices was quoted, the lowest price is shown.
[2]Prices for imported material. List price for domestic material suspended on June 28, 1984.

Source: Metals Week.

FOREIGN TRADE

The trade deficit for ferroalloys decreased from $505 million in 1986 to $490 million in 1987. A trade surplus of $13 million was recorded for ferroalloy metals in 1987 compared with a deficit of $21 million in 1986.

Imports for consumption of ferroalloys and ferroalloy metals were supplied by 37 countries and decreased nearly 7% compared with those of 1986. Geographic sources and their respective share of total U.S. imports of ferroalloy materials were Africa, 40%; Europe, 31%; the Western Hemisphere, 25%; Asia, 2%; and Oceania, 2%. The Republic of South Africa continued to be the United States main source of ferroalloy materials overall, accounting for 37% of total imported ferroalloys and metals. Of the total imported chromium and manganese alloys, the Republic of South Africa supplied 66% and 38%, respectively. The second leading suppliers of these materials were Turkey (15%) for chromium alloys and France (22%) for manganese alloys. The Republic of South Africa accounted for 100% of the unwrought manganese metal imports, while the United Kingdom supplied 34% of the imported chromium metal to the United States. Colombia and the Dominican Republic were the leading suppliers of ferronickel, accounting for 56% and 19% of U.S. ferronickel imports, respectively. Imports of ferrosilicon overall increased to a record-high amount, while those of 75% ferrosilicon, typically the largest share, decreased by 7%. The principal sources of ferrosilicon were Brazil, 33%; Norway, 15%; the U.S.S.R., 13%; Canada, 11%; and Venezuela, 11%. Imports of silicon metal overall decreased by 10%, owing mostly to a significant decrease in shipments from Brazil. The principal sources of silicon metal were Canada, 32%; Argentina, 17%; and Yugoslavia, 16%.

The United States exported ferrosilicon to 24 countries in 1987. Over one-half of that material was shipped to Canada. Nearly 70% of U.S. silicon metal exports went to Japan, with the remainder distributed among 33 other countries. Manganese metal was exported to 27 countries, with Japan and Canada receiving the largest shares.

Table 7.—U.S. exports of ferroalloys and ferroalloy metals

Alloy	1985		1986		1987	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Ferroalloys:						
Ferrocerium and alloys	28	$314	37	$319	90	$653
Ferrochromium and ferrochromium-silicon	10,262	7,688	6,035	5,693	4,568	5,730
Ferromanganese	6,927	4,762	4,323	2,650	2,851	2,144
Silicomanganese	3,089	136	2,004	687	697	493
Ferromolybdenum	631	2,698	166	928	81	605
Ferrophosphorus	49,674	5,776	38,377	4,393	34,699	4,334
Ferrosilicon	12,970	12,671	11,331	8,306	15,049	11,647
Ferrovanadium	454	4,791	513	4,647	436	4,081
Ferroalloys, n.e.c	14,498	24,581	10,029	11,561	19,073	14,938
Total ferroalloys[1]	98,533	63,417	72,814	39,184	77,543	44,626
Metals:						
Chromium	222	2,964	321	2,972	415	4,670
Manganese	5,162	7,242	5,146	7,892	5,775	9,748
Silicon	2,120	61,647	5,378	65,157	9,247	106,213
Total ferroalloy metals[1]	7,504	71,854	10,845	76,020	15,437	120,631
Grand total[1]	106,037	135,271	83,660	115,204	92,980	165,257

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

Source: Bureau of the Census.

Table 8.—U.S. imports for consumption of ferroalloys and ferroalloy metals

Alloy	1986			1987		
	Gross weight (short tons)	Content (short tons)	Value (thousands)	Gross weight (short tons)	Content (short tons)	Value (thousands)
Chromium alloys:						
Ferrochromium containing 3% or more carbon	348,443	198,168	$139,983	283,613	158,505	$112,546
Ferrochromium containing less than 3% carbon	39,969	25,582	32,707	42,246	26,940	37,723
Ferrochromium-silicon	9,221	3,532	5,743	8,356	3,117	4,920
Total chromium alloys[1]	397,633	227,282	178,432	334,215	188,562	155,189
Manganese alloys:						
Ferromanganese containing 1% or less carbon	18,130	16,179	16,782	20,132	17,852	17,203
Ferromanganese containing more than 1% to 4% carbon	66,225	54,068	28,483	50,442	41,359	22,951
Ferromanganese containing more than 4% carbon	311,296	240,800	75,216	297,104	230,166	73,476
Silicomanganese	198,646	[2]131,425	58,839	191,418	[2]124,315	58,461
Spiegeleisen	213	([3])	113	209	([3])	168
Total manganese alloys[1]	594,510	442,472	179,434	559,305	413,692	172,260
Silicon alloys (ferrosilicon):						
8% to 30% silicon	103	19	103	3,675	607	1,132
30% to 60% silicon, over 2% magnesium	3,797	1,741	2,781	6,965	3,252	5,286
30% to 60% silicon, n.e.c	49,690	24,644	16,717	58,747	29,076	22,456
60% to 80% silicon, over 3% calcium	11,227	6,971	9,846	15,191	10,019	11,267
60% to 80% silicon, n.e.c	156,322	117,620	70,221	145,855	109,531	68,410
80% to 90% silicon	--	--	--	--	--	--
Over 90% silicon	1,892	1,800	910	226	214	200
Total silicon alloys[1]	223,031	152,795	100,578	230,658	152,698	108,749

See footnotes at end of table.

Table 8.—U.S. imports for consumption of ferroalloys and ferroalloy metals —Continued

Alloy	1986 Gross weight (short tons)	1986 Content (short tons)	1986 Value (thousands)	1987 Gross weight (short tons)	1987 Content (short tons)	1987 Value (thousands)
Other ferroalloys:						
Ferrocerium and other cerium alloys	104	(3)	$1,151	105	(3)	$1,294
Ferromolybdenum	800	538	3,626	1,908	1,142	8,042
Ferronickel	37,902	13,056	53,672	45,391	21,136	57,481
Ferrophosphorus	(4)	(3)	2	--	--	--
Ferrotitanium and ferrosilicon-titanium	681	(3)	1,421	1,425	(3)	2,521
Ferrotungsten and ferrosilicon-tungsten	122	92	1,418	429	331	1,776
Ferrovanadium	736	594	6,423	422	342	3,777
Ferrozirconium	503	(3)	573	617	(3)	765
Ferroalloys, n.e.c.[5]	3,180	(3)	17,902	3,940	(3)	22,722
Total other ferroalloys[1]	44,028	XX	86,187	54,236	XX	98,379
Total ferroalloys[1]	1,259,202	XX	544,632	1,178,414	XX	534,577
Metals:						
Chromium	4,485	(3)	21,647	4,356	(3)	24,096
Manganese	9,674	(3)	9,803	8,991	(3)	9,614
Silicon (96% to 99% silicon)	8,856	(3)	8,397	2,662	(3)	2,584
Silicon (99% to 99.7% silicon)	31,263	31,006	31,507	33,448	33,144	32,960
Silicon (over 99.7% silicon)	732	(3)	25,276	820	(3)	38,754
Total ferroalloy metals[1]	55,010	XX	96,631	50,277	XX	108,008
Grand total[1]	1,314,212	XX	641,263	1,228,690	XX	642,585

XX Not applicable.
[1]Data may not add to totals shown because of independent rounding.
[2]Manganese content only.
[3]Not recorded.
[4]Less than 1/2 unit.
[5]Principally ferrocolumbium.

Source: Bureau of the Census.

WORLD REVIEW

Demand for ferroalloys increased in many countries compared with that of 1986. Prices for ferroalloys rose steadily as supplies tightened, and a continuing production shift from traditional suppliers to developing countries was observed as plant closings occurred in some industrialized countries. Overall production was little changed.

The European Economic Community (EEC) imposed a 6.2% import duty on Yugoslav ferrosilicon and announced that it would make permanent a provisional antidumping duty of $58 per ton against 75% ferrosilicon coming into Europe from Brazil. The EEC also imposed a $58 per ton antidumping duty against ferrosilicon from the U.S.S.R. after imports were found to be entering Western Europe at significantly reduced prices.[2] H-C-FeCr producers inside the EEC asked the European Commission to investigate possible dumping of that material by Finland.

The United States threatened to impose additional import duties on silicon-containing materials from Brazil in retaliation to Brazil's strict import regulations on U.S. computer software.[3]

Albania.—Albania planned to double ferrochromium production capacity as part of its 1986-90 5-year plan.

Argentina.—Silarsa S.A., a new company formed by Stein Ferroalloys S.A. and two units of the A. Johnson & Co. Group of the United States, planned a new joint venture to produce 16,000 tons per year of silicon metal, primarily for sale in the United States. Startup was scheduled for 1988.[4] Electrometalúrgica Andina S.A. increased silicon metal production capacity to 11,000 tons per year by activating a new 12-megavolt-ampere (MV•A) furnace at its San Juan facility.[5]

Australia.—The country's first silicon metal smelter, a joint venture between Pioneer Concrete Ltd. and French metals producer Pechiney, started production in Tasmania. The plant's single 14-megawatt furnace is capable of producing 12,000 tons per year.[6] Agnew Clough and the Australian Industry Development Corp. established a trust to build a 25,000-ton-per-year silicon metal production facility in the Wundowie area. Total cost of the project was projected to be A$70 million with construction beginning in 1988.[7] Tasmanian Electro Metallurgical Co. Pty. Ltd. raised the ratings of two electric furnaces to 29 MV•A and that of a third to 36 MV•A, upgrading their total capacity to about 200,000 tons per year for H-C-FeMn or 120,000 tons per year for silicomanganese.

Brazil.—Cia. de Ferro-Ligas da Bahia S.A., Brazil's only ferrochromium producer, experienced power rationing, which held back production. Production of some other ferroalloys, such as H-C-FeMn, 50% ferrosilicon, and a number of specialty alloys, also decreased owing to electric power problems from a prolonged drought. However, production of ferrosilicon overall (300,000 tons) and silicon metal (44,000 tons) both increased 8% compared with that of 1986.

Currently the world's fifth largest ferroalloy producer overall, Brazil continued to capture more of the world market for silicon products as exports of ferrosilicon and silicon metal increased nearly 25%.

Comargo Correa Metals S.A. neared completion on the construction of its new silicon metal production facility. The plant consisted of four 18-MV•A furnaces with a combined capacity of 35,000 tons per year. Startup of the facility was scheduled for April 1988. The company also planned for a second phase of the project with an equal amount of capacity to be brought on-line in 1990.[8] Bozel Mineração e Ferroligas S.A. started a new 15-MV•A silicon metal furnace in Minas Gerais with the capacity to produce 9,000 tons annually.[9] Several Brazilian companies planned ferrosilicon capacity expansions, including Cia. de Cimento Portland Maringa, which completed construction of a 15-MV•A furnace at its ferroalloy plant in São Paulo.[10]

Cia. Vale do Rio Doce (CVRD) signed an agreement with Prometal Produtos Metalúrgicos S.A. to produce ferromanganese at Paraupebas near the Azul manganese mine. CVRD would retain 40% of the ownership, with Prometal holding the remaining 60% and the U.S.S.R. supplying 50% of the $100 million investment in equipment. The U.S.S.R. was to be repaid over a period of 12 years with one-half of the plant's output, aproximately 80,000 tons per year.

Canada.—Timminco Ltd.'s Chromasco Div. shut down two of three furnaces at its facility in Beauharnois. The company had been producing ferromanganese and ferrosilicon, but future plans include only ferrosilicon production.

China.—Silicon metal producers in China, after more than doubling their production capacity over the past several years, continued to increase exports and captured nearly one-half of the Japanese market. Exports of silicon metal to Japan were 61,704 tons, a 68% increase over those of 1986. China also significantly increased its exports of silicon metal to the United States and Western Europe. China increased production of ferrosilicon to meet increasing demand from its domestic steel industry while further expanding into world markets. Ferrosilicon shipments to Japan were nearly five times the amount reported in 1986. In January, the Chinese Government lifted a 30% export duty on ferrosilicon However, during the course of the year, strict export controls were being considered as a means of ensuring material for domestic needs.[11]

China Metallurgical Import and Export Corp. and Australia's Broken Hill Pty. Co. Ltd. agreed to study the feasibility of establishing a 66,000-ton-per-year manganese ferroalloy plant at Yichang.[12]

Dominican Republic.—The ferronickel producer, Falconbridge Dominicana C. por A., suspended shipments in December owing to a prohibitive duty on mineral exports imposed by the Dominican Government.

France.—Pechiney Electrométallurgie considered a plan to switch production at its Dunkirk plant from ferrosilicon to either silicomanganese or charge chrome. The company decided to close its St. Beron facility owing to high energy costs, labor costs, and the availability of low-cost imports from Brazil and China. Pechiney also halted production of ferrovanadium at its Chedde plant. A decision on future production at its Laudon ferrosilicon plant was pending.[13] Ferroaleaciones Españolas S.A. of Spain started construction of a new 16,500-ton-per-year ferrochromium plant at Dunkirk. Completion was expected in 1988.[14]

Germany, Federal Republic of.—Elektrowerk Weisweiler GmbH resumed production of L-C-FeCr, after a temporary stoppage owing to low market demand.

Greece.—Société Minière et Métallurgique de Larymna S.A. continued production of ferronickel despite earlier plans to restucture and start ferrochromium production.[15]

India.—Bulk ferroalloy (i.e., ferrochromium, ferromanganese, and ferrosilicon) production increased 10% during fiscal year 1986-87, despite electric power shortages caused by the country's worst drought in nearly 100 years. Increased demand from the stainless steel industry fueled a 40% increase in H-C-FeCr output and resulted in one company's (Ferro Alloys Corp. Ltd.) temporary suspension of exports. Indian Metals and Ferro Alloys Ltd. continued construction of a 50,000-ton-per-year ferrochromium plant and expected completion sometime in 1988. One of the country's major ferrosilicon producers, VBC Alloy Co., announced plans to diversify into specialty ferroalloy products.[16]

Japan.—Awamura Metal Industry Co. Ltd. and Kurimoto Iron Works Ltd. both halted ferrochromium production, which resulted in lower overall production for the year. However, increased ferrochromium imports replaced lost production. Stainless steel production exceeded that of each of the preceding 5 years and created an increased demand for ferrochromium. Consuming industries (i.e., iron and steel, chemical, and aluminum) also demanded more ferrosilicon and silicon metal than in 1986. The Japanese Ferroalloy Association reported that overall production of ferrosilicon dropped more than 25% in 1987 to 87,900 tons. However, a significant increase in imports again helped close the demand gap. Japanese silicon metal imports also increased nearly 10% compared with those of 1986. Overall production of manganese ferroalloys decreased nearly 20% to about about 467,000 tons. Nippon Mining Co. annouced that it would close its 10,000-ton-per-year ferronickel smelter owing to excessive supply.[17]

Norway.—Elkem A/S, the world's largest silicon metal producer, announced that it would temporarily cut production at its Meraker plant from 35,000 to 19,000 tons per year owing to market conditions. Despite the cut, Elkem's share of world silicon metal production was expected to remain above 20%.[18] Tinfos Jernverk A/S announced the permanent closure of its ferrosilicon and silicon metal plant at Notodden. Production at the Notodden plant, which had a combined ferrosilicon-silicon capacity of over 90,000 tons per year, was stopped at the end of 1986.[19]

Portugal.—Cia. Portuguesa de Fornos Eléctricos S.A.R.L.'s Nelas ferrosilicon production facility, which was shut down in late 1986, remained closed pending a court decision on the company's future viability. High electrical power costs and totally depleted stocks were stated as Fornos' major obstacles to reactivating the plant.[20]

South Africa, Republic of.—Batlhako Ferrochrome (Pty.) Ltd. started production at its new 27,500-ton-per-year ferrochromium plant in Bophuthatswana near the Ruighoek Mine. Marketing is to be handled by South African Manganese Amcor Ltd.

Middleburg Steel and Alloys Ltd. (MSA) modernized its L-C-FeCr ferrochromium production facilities at Middleburg, Transvaal. As a result of the modernization, MSA increased L-C-FeCr production at Middleburg from about 36,000 to about 50,000 tons per year. MSA also planned to increase the H-C-FeCr production capacity of its direct-current plasma arc furnace at Krugersdrop, Transvaal, from 18,000 to 40,000 tons per year.

Chromcorp Technology (Pty.) Ltd. planned to build a 120,000-ton-per-year H-C-FeCr plant near Rustenburg, Transvaal. The plant will consist of two 30-MV•A furnaces and is expected to cost $26 million.

Rand Carbide Ltd. decided to cut ferrosilicon production by 20%, owing to an appreciation of the rand on exchange markets. The company said it would concentrate on selling its remaining production locally.[21]

Spain.—Facing high labor and power costs, ferroalloy producers entered rationalization talks with the Government. Industry sources expected the talks to result in production cutbacks and possible plant closures.[22]

Swaziland.—Swazi Chrome planned a new 55,000-ton-per-year ferrochromium production facility. Construction was expected to begin once a plan for power rates could be negotiated with the Swazi Government.

Sweden.—SwedeChrome AB started production of H-C-FeCr at its Malmö facility. The company expected to reach full production, 86,000 tons per year, sometime in 1988. Ferroalloy producer, Vargön Alloys AB, was bought from Fides of Switzerland by a group of Vargön's management and Mellanfondon, a Swedish Wage Earner Fund. Company officials did not expect any significant changes in output.[23]

Turkey.—Etibank neared completion of additional H-C-FeCr capacity at its Elazig plant. The additional 55,000 tons per year will double capacity at Elazig and was all slated for export.[24]

U.S.S.R.—Owing to increased demand from its domestic steel industry, the Soviet Union was believed to be planning a 20% cut in ferrosilicon exports. Exports of Soviet ferrosilicon to the United States and Japan had significantly increased over the past several years.[25]

Venezuela.—C.V.G. Ferrosilicon de Venezuela C.A. (FESILVEN) planned to increase its ferrosilicon production capacity from 65,000 to 95,000 tons by 1988. FESILVEN also began the initial planning of a silicon metal project.[26]

Yugoslavia.—Hek Jugohrom completed the conversion of a 24-MV•A furnace from H-C-FeCr to ferrosilicon production and planned a similar conversion for a 14-MV•A furnace. On the other hand, Dalmacija Carbide and Ferro Alloy Works switched production of one furnace from ferrosilicon to H-C-FeCr, adding about 35,000 tons of capacity.

Zimbabwe.—Zimbabwe Mining and Smelting Co. (Zimasco) started construction of a new induction remelting furnace that was expected to increase its H-C-FeCr capacity about 10% to 175,000 tons per year. Zimasco also planned to restart a 15,000-ton-per-year H-C-FeCr furnace, which had been held in reserve for use when other furnaces were under repair. Zimbabwe Alloys Ltd. converted a furnace from ferrochromium-silicon to H-C-FeMn production.

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[1]Physical scientist, Branch of Ferrous Metals.
[2]Metal Bulletin (London). No. 7243, Dec. 10, 1987, p. 19.
[3]American Metal Market. V. 95, No. 232, Dec. 1, 1987, p. 1.
[4]Metal Bulletin (London). No. 7159, Feb. 10, 1987, p. 9.
[5]American Metal Market. V. 95, No. 155, Aug. 11, 1987, p. 1.
[6]Metal Bulletin (London). No. 7242, Dec. 7, 1987, p. 17.
[7]———. No. 7155, Jan. 27, 1987, p. 11.
[8]———. No. 7236, Nov. 16, 1987, p. 13.
[9]The Tex Report. V. 19, No. 4457, June 12, 1987, p. 7.
[10]———. V. 19, No. 4563, Nov. 13, 1987, p. 11.
[11]———. V. 19, No. 4582, Dec. 11, 1987, p. 10.
[12]Skillings' Mining Review. V. 76, No. 10, Mar. 7, 1987, p. 6.
[13]Page 19 of work cited in footnote 6.
[14]Metal Bulletin (London). No. 7157, Feb. 3, 1987, p. 15.
[15]Metals Week. V. 58, No. 50, Dec. 14, 1987, p. 1.
[16]Metal Bulletin Monthly (London). No. 203, Nov. 1987, p. 11.
[17]American Metal Market. V. 95, No. 140, July 21, 1987, p. 2.
[18]Metal Bulletin (London). No. 7224, Oct. 5, 1987, p. 9.
[19]The Tex Report. V. 19, No. 4392, Mar. 10, 1987, p. 4.
[20]Metal Bulletin (London). No. 7247, Dec. 24, 1987, p. 11
[21]The Tex Report. V. 19, No. 4411, Apr. 6, 1987, p. 2.
[22]Metal Bulletin (London). No. 7227, Oct. 15, 1987, p. 17.
[23]———. No. 7216, Sept. 7, 1987, p. 15.
[24]———. No. 7224, Sept. 24, 1987, p. 17.
[25]———. No. 7244, Dec. 14, 1987, p. 13.
[26]Page 11 of work cited in footnote 4.

Table 9.—Ferroalloys: World production, by country, furnace type, and alloy type[1]

(Thousand short tons)

Country, furnace type,[2] and alloy type[3]	1983	1984	1985	1986[p]	1987[e]
Albania: Electric furnace, ferrochromium[e]	39	44	47	51	51
Argentina: Electric furnace:					
Ferromanganese	28	26	26	22	22
Silicomanganese	15	15	8	14	13
Ferrosilicon	17	22	21	25	24
Other	([4])	4	5	6	6
Total	60	67	60	67	65
Australia: Electric furnace:[5]					
Ferromanganese	59	[r]78	78	67	[6]57
Silicomanganese	22	[r]35	28	[e]25	[6]47
Ferrosilicon	21	[r]20	21	[e]17	21
Total[7]	101	[r]133	127	109	125
Austria: Electric furnace, undistributed	15	14	13	13	13
Belgium: Electric furnace, ferromanganese[e]	96	105	99	96	96
Brazil: Electric furnace:					
Ferromanganese	114	117	149	181	[6]171
Silicomanganese	197	205	199	196	[6]207
Ferrosilicon	[r]153	[r]167	200	240	[6]255
Silicon metal	23	30	32	41	[6]44
Ferrochromium	85	138	140	121	[6]116
Ferrochromium-silicon	6	8	10	10	[6]9
Ferronickel	[r]33	[r]37	37	38	[6]39
Other	[r]47	[r]60	68	68	[6]67
Total[7]	[r]658	[r]762	835	894	[6]908
Bulgaria: Electric furnace:					
Ferromanganese[e 8]	33	24	33	35	34
Ferrosilicon[e]	19	17	15	17	17
Other[e]	1	1	1	1	1
Total[7]	53	42	50	53	52
Canada: Electric furnace:[e]					
Ferromanganese[8]	118	128	130	139	141
Ferrosilicon	[6]94	88	93	97	99
Silicon metal	[6]28	28	28	29	33
Total[7]	[6]239	244	250	265	273
Chile: Electric furnace:[e]					
Ferromanganese	6	5	7	7	7
Silicomanganese	NA	NA	1	2	2
Ferrosilicon	5	7	5	4	4
Other	2	2	1	2	2
Total[7]	13	15	14	14	14
China: Furnace type unspecified:[e 9]					
Ferromanganese[8]	540	540	540	[r]660	720
Ferrosilicon	215	215	215	[r]220	250
Silicon metal	24	24	24	[r]30	50
Ferrochromium[10]	130	130	130	130	140
Other[11]	80	80	80	80	110
Total[7]	990	990	990	[r]1,120	1,270
Colombia: Electric furnace:[e 12]					
Ferrosilicon	1	1	1	1	1
Ferronickel	36	47	33	51	57
Total	37	48	34	52	58
Czechoslovakia: Electric furnace:					
Ferromanganese[e 8]	103	96	103	101	101
Ferrosilicon[e]	33	[r]31	[r]33	33	33
Silicon metal[e]	5	4	5	6	6
Ferrochromium[e]	28	26	28	28	28
Other[e 11]	10	9	10	9	9
Total[7]	179	166	177	[e]176	176
Dominican Republic: Electric furnace, ferronickel	58	71	76	64	[6]96
Egypt: Electric furnace, ferrosilicon	7	8	[e]8	8	8
Finland: Electric furnace, ferrochromium	65	65	147	147	148

See footnotes at end of table.

Table 9.—Ferroalloys: World production, by country, furnace type, and alloy type[1] —Continued

(Thousand short tons)

Country, furnace type,[2] and alloy type[3]	1983	1984	1985	1986[p]	1987[e]
France:					
Blast furnace:					
Spiegeleisen[e]	1	1	1	1	1
Ferromanganese	297	362	367	302	300
Electric furnace:					
Silicomanganese[13]	36	38	26	24	24
Ferrosilicon	212	226	217	216	216
Silicon metal	72	78	[e]77	[e]77	77
Ferrochromium[10]	22	21	1	[e]1	1
Other[14]	117	134	107	85	85
Total[7]	757	860	797	707	705
German Democratic Republic: Electric furnace:					
Ferromanganese[e 8]	[r]70	[r]69	69	75	75
Ferrosilicon[e]	26	[r]25	25	29	29
Silicon metal[e]	4	4	4	4	4
Ferrochromium[e]	[r]21	21	21	24	24
Other[e 11]	20	[r]17	17	17	17
Total[7]	[r]141	[r]137	137	149	149
Germany, Federal Republic of:					
Blast furnace:					
Ferromanganese[e]	148	263	179	[r]206	199
Ferrosilicon[e]	44	77	47	[r]76	77
Electric furnace:					
Ferromanganese[8]	19	[r]24	[r]28	[r]39	33
Ferrosilicon[e]	34	[r]39	[r]44	[r]55	44
Ferrochromium[e]	42	[r]50	[r]55	[r]66	61
Other[e11]	36	[r]60	[r]62	[r]67	66
Total[7]	323	[r]513	[r]414	509	480
Greece: Electric furnace:					
Ferrochromium	20	36	39	42	[6]46
Ferronickel[e]	55	58	66	[6]11	6
Total[7]	75	94	105	54	52
Hungary: Electric furnace:[e]					
Ferrosilicon	11	10	10	10	10
Silicon metal	2	2	2	2	2
Other	2	2	2	2	2
Total	15	14	14	14	14
Iceland: Electric furnace, ferrosilicon	55	67	67	74	77
India: Electric furnace:					
Ferromanganese	166	134	180	197	190
Silicomanganese	3	35	[e]1	[e]1	1
Ferrosilicon	54	56	44	55	55
Silicon metal[e]	4	[7]3	3	3	4
Ferrochromium	39	61	73	93	95
Ferrochromium-silicon	2	4	14	[e]11	13
Other	([4])	([4])	[e]1	[e]1	1
Total[7]	269	295	316	362	358
Indonesia: Electric furnace, ferronickel	23	25	26	25	17
Italy: Electric furance:					
Ferromanganese	69	56	19	[e]28	28
Silicomanganese	41	80	71	[e]66	66
Ferrosilicon	57	78	83	[e]55	55
Silicon metal[e]	15	15	15	13	13
Ferrochromium	13	14	64	[e]22	22
Other[15]	47	56	17	[e]33	33
Total[7 15]	242	299	270	[e]217	217

See footnotes at end of table.

Table 9.—Ferroalloys: World production, by country, furnace type, and alloy type[1] —Continued

(Thousand short tons)

Country, furnace type,[2] and alloy type[3]	1983	1984	1985	1986[p]	1987[e]
Japan: Electric furnace:					
Ferromanganese	429	535	487	396	[6]366
Silicomanganese	245	257	239	164	[6]101
Ferrosilicon	174	169	166	118	[6]81
Ferrochromium[10]	[r]328	[r]350	375	309	[6]291
Ferronickel	199	239	250	221	[6]224
Other[16]	[r]12	[r]14	14	11	[6]9
Total[7]	1,387	1,564	1,531	1,218	[6]1,073
Korea, North: Furnace type unspecified:[e] [9]					
Ferromanganese[8]	77	77	77	77	77
Ferrosilicon	33	33	33	33	33
Other[11]	22	22	22	22	22
Total	132	132	132	132	132
Korea, Republic of: Electric furnace:					
Ferromanganese	58	65	68	59	[6]64
Ferrosilicon	36	39	38	34	[6]14
Other	48	55	60	73	[6]100
Total[7]	142	159	167	167	[6]178
Mexico: Electric furnace:					
Ferromanganese	155	177	169	172	[6]178
Silicomanganese	46	46	43	67	[6]88
Ferrosilicon	27	25	30	19	[6]20
Ferrochromium	3	8	7	3	[6]7
Other	2	2	3	2	[6]1
Total[7]	232	258	253	263	[6]294
New Caledonia: Electric furnace, ferronickel[e]	193	125	155	[r]144	127
Norway: Electric furnace:					
Ferromanganese	312	314	237	226	209
Silicomanganese	215	310	267	271	287
Ferrosilicon	407	482	425	389	397
Silicon metal[e]	[6]85	100	112	110	110
Ferrochromium[e]	4	4	--	--	--
Ferrochromium-silicon[e]	([4])	([4])	--	--	--
Other[e] [14]	7	4	3	3	3
Total[7]	1,028	1,215	1,045	998	1,006
Peru: Electric furnace:					
Ferromanganese	([4])	--	--	([4])	([4])
Ferrosilicon	([4])	--	--	([4])	([4])
Total[7]	([4])	--	--	1	1
Philippines: Electric furnace:					
Ferrosilicon[e]	22	20	22	22	--
Ferrochromium	30	53	56	[e]61	--
Total	52	73	78	[e]83	--
Poland:					
Blast furnace:					
Spiegeleisen	4	4	3	[e]3	4
Ferromanganese	93	99	88	94	94
Electric furnace:					
Ferromanganese[e] [8]	53	53	54	54	54
Ferrosilicon[e]	57	56	57	56	55
Silicon metal[e]	11	11	12	12	11
Ferrochromium[e]	53	53	54	54	53
Other[e] [11]	19	19	18	18	18
Total[7]	290	295	287	[e]291	289

See footnotes at end of table.

Table 9.—Ferroalloys: World production, by country, furnace type, and alloy type[1] —Continued

(Thousand short tons)

Country, furnace type,[2] and alloy type[3]	1983	1984	1985	1986[p]	1987[e]
Portugal: Electric furnace:					
Ferromanganese[e 17]	44	51	46	22	28
Silicomanganese[e 17]	20	26	28	11	17
Ferrosilicon[e]	[6]9	10	10	6	5
Silicon metal[e]	[6]11	12	12	8	6
Other	([4])	([4])	([4])	([4])	([4])
Total[7]	85	99	96	46	55
Romania: Electric furnace:[e]					
Ferromanganese	88	96	88	90	89
Silicomanganese	42	45	43	44	43
Ferrosilicon	53	57	55	56	55
Silicon metal	4	5	5	5	5
Ferrochromium	46	50	49	49	46
Total[7]	234	253	240	244	239
South Africa, Republic of: Furnace type unspecified:[9]					
Ferromanganese	184	261	365	372	380
Silicomanganese	144	199	287	334	303
Ferrosilicon	55	99	83	92	94
Silicon metal	30	38	39	39	39
Ferrochromium	744	956	939	959	1,024
Ferrochromium-silicon	20	30	6	6	6
Other[18]	1	([4])	([4])	1	1
Total[e 7]	[r]1,178	[r]1,583	[r]1,720	1,802	1,846
Spain: Electric furnace:					
Ferromanganese[e]	94	94	95	95	99
Silicomanganese[e]	77	77	77	77	77
Ferrosilicon[e]	68	66	67	67	66
Silicon metal[e]	19	66	68	68	77
Ferrochromium[e]	15	15	19	19	22
Other[e]	6	1	4	4	6
Total[7 11]	279	321	331	[e]331	347
Sweden: Electric furnace:					
Ferrosilicon	21	26	31	[e]28	33
Silicon metal	22	22	[e]22	[e]22	22
Ferrochromium	132	148	149	[r]143	143
Ferrochromium-silicon	20	34	29	[e]28	28
Other	1	1	([4])	([4])	([4])
Total[11]	197	230	232	[e]221	226
Switzerland: Electric furnace:[e]					
Ferrosilicon	2	3	3	3	3
Silicon metal	2	2	2	2	2
Total	4	5	5	5	5
Taiwan: Electric furnace:					
Ferromanganese	24	22	20	22	[6]19
Silicomanganese	20	25	25	23	[6]21
Ferrosilicon	20	26	19	15	[6]8
Total[7]	65	73	64	61	[6]47
Turkey: Electric furnace:					
Ferrosilicon[e]	5	[7]8	8	8	[6]4
Ferrochromium	33	53	[e]53	[e]55	[6]10
Total	38	61	[e]61	[e]63	[6]14
U.S.S.R.:					
Blast furnace:					
Spiegeleisen[e]	55	55	55	55	55
Ferromanganese[e]	606	606	606	606	606

See footnotes at end of table.

Table 9.—Ferroalloys: World production, by country, furnace type, and alloy type[1] —Continued

(Thousand short tons)

Country, furnace type,[2] and alloy type[3]	1983	1984	1985	1986[p]	1987[e]
U.S.S.R. —Continued					
Electric furnace:[19]					
Ferromanganese[e]	551	661	744	772	772
Silicomanganese[e]	187	198	209	220	220
Ferrosilicon[e]	794	827	827	882	937
Silicon metal[e]	70	70	66	72	72
Ferrochromium[e]	457	463	463	468	474
Ferrochromium-silicon[e]	13	13	13	14	15
Other[14]	250	250	254	265	265
Total[7]	2,984	3,144	3,237	3,354	3,415
United Kingdom:					
Blast furnace, ferromanganese	91	83	85	[e]83	88
Electric furnace, undistributed[e]	14	14	11	11	11
Total[7]	106	97	96	[e]94	99
United States: Electric furnace:[20]					
Ferromanganese	86	[21]171	[21]154	[21]117	[6 21]113
Silicomanganese	W	([22])	([22])	([22])	([22])
Ferrosilicon	314	490	442	339	[e]356
Silicon metal	122	141	121	124	[6]147
Ferrochromium	20	[23]95	[23]110	[23]105	[6 23]118
Ferrochromium-silicon[24]	16	([25])	([25])	([25])	([25])
Other[26]	198	190	151	130	150
Total[7]	757	1,088	977	816	884
Uruguay: Electric furnace, ferrosilicon	([4])	([4])	([4])	([4])	([4])
Venezuela: Electric furnace:					
Ferromanganese	2	2	[e]2	--	--
Silicomanganese	10	10	24	32	31
Ferrosilicon	51	49	67	56	55
Total[7]	63	61	94	88	86
Yugoslavia: Electric furnace:					
Ferromanganese	44	49	[r e]42	[r e]44	44
Silicomanganese	29	41	[r e]74	[r e]72	72
Ferrosilicon	86	104	[e]103	99	105
Silicon metal	29	31	[r e]31	[r e]39	39
Ferrochromium	70	69	[r e]52	[r e]50	50
Ferrochromium-silicon	7	12	[r e]10	[r e]11	11
Other	12	12	[e]12	17	17
Total[7]	[r]276	[r]318	325	331	336
Zimbabwe: Electric furnace:					
Ferromanganese	2	2	2	[e]2	2
Ferrosilicon	30	47	59	[e]55	55
Ferrochromium	174	196	172	[e]171	171
Total[7]	207	245	233	[e]228	228
Grand total[7]	[r]14,339	[r]16,477	16,432	16,221	16,364
Of which:					
Blast furnace:					
Spiegeleisen[27]	60	60	59	59	59
Ferromanganese[27]	1,235	1,413	1,325	1,291	1,288
Ferrosilicon	44	77	47	76	77
Total blast furnace	1,339	1,550	1,431	1,426	1,424
Electric furnace:[9]					
Ferromanganese[28]	[r]2,823	[r]3,154	3,129	3,058	2,992
Silicomanganese[28 29]	[r]1,349	[r]1,642	1,650	1,643	1,620
Ferrosilicon	[r]3,278	[r]3,713	3,647	3,533	3,574
Silicon metal	[r]582	[r]686	680	706	763
Ferrochromium[30]	[r]2,629	[r]3,119	3,243	3,171	3,141
Ferrochromium-silicon[24 30]	[r]68	101	82	80	82
Ferronickel	[r]497	[r]602	643	554	566
Other[31]	[r]940	[r]995	912	917	991
Undistributed	29	28	24	24	24
Total electric furnace	[r]12,195	[r]14,040	14,010	13,686	13,753

See footnotes at end of table.

Table 9.—Ferroalloys: World production, by country, furnace type, and alloy type[1] —Continued

(Thousand short tons)

Country, furnace type,[2] and alloy type[3]	1983	1984	1985	1986[p]	1987[e]
Furnace type unspecified:					
Ferromanganese[9]	[r]801	[r]878	982	1,109	1,177

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data; included with "Other."

[1]Table includes data available through July 15, 1988.

[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, silicon metal, 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 footnotes. 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]Less than 1/2 unit.

[5]Data for year ending Nov. 30 of that stated.

[6]Reported figure.

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

[8]Includes silicomanganese.

[9]Although furnace type has not been specified for any ferroalloy production for China, North Korea, and the Republic of South Africa, all output of these countries has been included under "Electric furnace" (and metallothermic) output except for their production of ferromanganese, which is reported separately.

[10]Includes ferrochromium-silicon, if any was produced.

[11]Includes ferrochromium-silicon and ferronickel, if any was produced.

[12]Colombia is reported to produce ferromanganese also, but output is not reported quantitatively and no basis is available for estimation.

[13]Includes silicospiegeleisen.

[14]Includes ferronickel, if any was produced.

[15]Series excludes calcium silicide.

[16]Includes calcium-silicon, ferrotungsten, ferromolybdenum, ferrovanadium, ferrocolumbium, and other ferroalloys.

[17]Estimated figures based on reported exports and an allowance for domestic use.

[18]Ferrovanadium only; other minor ferroalloys may be produced, but no basis is available for estimation.

[19]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 trade, including data from trading partner countries.

[20]U.S. production of ferronickel cannot be reported separately in order to conceal corporate proprietary information.

[21]U.S. output of ferromanganese for 1984-87 includes silicomanganese and manganese metal.

[22]U.S. output of silicomanganese for 1984-87 included with "Ferromanganese."

[23]U.S. output of ferrochromium for 1984-87 includes ferrochromium-silicon, chromium briquets, exothermic chromium additives, other miscellaneous chromium alloys, and chromium metal.

[24]U.S. output of ferrochromium-silicon includes chromium briquets, exothermic chromium additives, other miscellaneous chromium alloys, and chromium metal.

[25]U.S. output of ferrochromium-silicon for 1984-87 included with "Ferrochromium."

[26]Includes ferronickel.

[27]Spiegeleisen for the Federal Republic of Germany is included with "Blast furnace ferromanganese."

[28]Ferromanganese includes silicomanganese (if any was produced) for countries carrying footnote 8 on "Ferromanganese" data line.

[29]Includes silicospiegeleisen for France.

[30]Ferrochromium includes ferrochromium-silicon (if any was produced) for countries carrying footnote 10 on "Ferrochromium" data line.

[31]Other includes ferronickel production for France, Norway, the U.S.S.R., and the United States.

Fluorspar

By David E. Morse[1]

In the United States, fluorspar was shipped by one major producer and two smaller producers that supplied less than 10% of the Nation's requirements. Supplementing fluorspar as a domestic source of fluorine was byproduct fluosilicic acid production from some phosphoric acid and hydrofluoric acid (HF) producers. Imports of fluorspar continued to supply most of the United States requirements; domestic consumption and imports both increased slightly in 1987.

Domestic Data Coverage.—Domestic production and consumption data for fluorspar are developed by the Bureau of Mines from four separate, voluntary surveys of U.S. operations. Surveys are conducted to obtain fluorspar mine production and shipments, fluosilicic acid production, and fluorspar briquet consumption. Of the five fluorspar mining operations to which a survey request was sent, 100% responded. Production statistics in table 1 are withheld to protect company proprietary data. Of the 13 fluosilicic acid producers, 100% responded, representing 100% of the quantity reported. Of the five briquet producers, 80% responded, representing 89% of the quantity reported. The consumption survey was sent to approximately 70 operations quarterly and to 40 additional operations annually. Of the operations surveyed quarterly, 88% responded. Of the operations surveyed on an annual basis, 70% responded. Together, quarterly and annual responses represented 83% of the apparent consumption data shown in table 1.

Table 1.—Salient fluorspar statistics[1]

	1983	1984	1985	1986	1987
United States:					
Production:					
Finished (shipments)[e] ----short tons--	61,000	72,000	66,000	78,000	70,000
Value, f.o.b. mine ----thousands--	[e]$10,000	W	W	W	W
Exports ----short tons--	9,236	12,266	9,671	16,215	2,860
Value ----thousands--	$962	$1,292	$1,063	$1,801	$340
Imports for consumption ----short tons--	453,314	703,711	552,959	552,785	585,911
Value[2] ----thousands--	$47,032	$65,241	$49,639	$45,675	$48,430
Consumption, reported ----short tons--	564,187	752,581	567,623	578,837	598,368
Consumption, apparent[3] ----do----	613,705	742,431	682,965	571,288	719,512
Stocks, Dec. 31:					
Domestic mines: Finished ----do----	W	W	W	W	W
Consumer ----do----	99,253	120,267	46,590	89,872	33,411
World: Production ----do----	[r]4,667,843	[r]5,287,206	5,426,275	[p]5,231,914	[e]5,244,077

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Does not include fluosilicic acid (H_2SiF_6) or imports of hydrofluoric acid (HF) and cryolite.
[2]C.i.f. U.S. port.
[3]U.S. primary and secondary production plus imports, minus exports, plus adjustments for Government and industry stock changes.

Legislation and Government Programs.—At yearend, the National Defense Stockpile fluorspar inventory was unchanged from yearend 1986 and remained well below the stockpile goals of 1.4 million short tons for acid grade and 1.7 million tons for metallurgical grade. Depletion allowances against Federal taxes of 22% and 14%, respectively, remained in effect for domestic and foreign production by U.S. companies.

In September, the United States joined 22 other nations in the signing of a protocol in Montreal, Canada, that would freeze and later reduce world production and consumption of chlorofluorocarbons. U.S. Senate debate discussions concerning the Montreal protocol were scheduled for early 1988.

DOMESTIC PRODUCTION

Illinois remained the leading producing State, accounting for over 90% of all U.S. shipments. Data on shipments of fluorspar by State and grade are withheld to avoid disclosing company proprietary data.

Ozark-Mahoning Co., the Nation's largest fluorspar producer and a subsidiary of Pennwalt Corp., operated two mines and a flotation plant in Pope and Hardin Counties, IL. Ozark-Mahoning also dried imported fluorspar to supplement its production. Hastie Trucking and Mining Co. operated near Cave-In-Rock, IL. Inverness Mining Co., a former producer, dried imported fluorspar at its facilities at Cave-In-Rock, IL, and East Liverpool, OH, for sale primarily to consumers in the ceramic industry. J. Irving Crowell, Jr. & Son produced and shipped metallurgical-grade fluorspar from its Crowell-Daisy Mine in Nye County, NV.

Reported shipments of fluorspar briquets for use in steel furnaces increased slightly to approximately 90,000 tons valued at $12.7 million. Fluorspar briquets were produced by two plants owned by Cameto Inc., one plant owned by Mercier Corp., one plant owned by National Briquetting Co., and one plant owned by Oglebay Norton Co. Oglebay Norton also dried, packaged, and shipped imported ceramic- and acid-grade fluorspar.

Nine plants processing phosphate rock for the production of phosphoric acid and one plant producing HF sold or used 50,000 tons of byproduct fluosilicic acid, which was the equivalent to 88,600 tons of fluorspar. Three fluosilicic acid producer plants were idle in 1987.

CONSUMPTION AND USES

Acid-grade fluorspar, containing greater than 97% calcium fluoride (CaF_2), was used primarily as a feedstock in the manufacture of HF. Ceramic-grade fluorspar, containing 85% to 95% CaF_2, was used for the production of glass and enamel, to make welding rod coatings, and as a flux in the steel industry. Metallurgical-grade fluorspar, containing 60% to 85% or more CaF_2, was used primarily as a fluxing agent by the steel industry.

Reported domestic consumption of both acid- and subacid-grades increased compared with that of 1986. The HF and steel industries accounted for 73% and 22%, respectively, of reported consumption. According to the American Iron and Steel Institute (AISI), domestic production of raw steel increased from the revised quantity of 81.6 million tons in 1986 to 89.2 million tons in 1987. A comparison of the AISI data with fluorspar consumption data collected by the Bureau of Mines from the U.S. steel industry shows, on the average, a decreasing rate of fluorspar consumption per ton of raw steel produced during 1985-87. In 1987, AISI combined raw steel output from open hearth and basic oxygen furnaces; a calculation of the rate of fluorspar consumption from these types of furnaces is no longer possible.

Type of furnace	Fluorspar consumption (pounds per short ton)		
	1985	1986[r]	1987
Open hearth	10.78	13.51	NA
Basic oxygen	2.68	2.95	NA
Electric	2.08	2.03	1.91
Industry average	3.08	3.03	2.96

[r]Revised. NA Not available.

In the ceramic industry, fluorspar was used as a flux and as an opacifier in the production of flint glass, white or opal glass, and enamels. Fluorspar was used in the manufacture of glass fibers, aluminum, cement, and brick, and was also used in the melt shop by the foundry industry.

Five companies reported fluorspar consumption for the production of HF. The U.S. Department of Commerce, Bureau of the Census, reported that anhydrous, technical, and aqueous HF, 100% basis, "produced and withdrawn from the system," was nearly 212,900 short tons, compared with the revised 1986 quantity of 252,809 tons.

HF was used to produce synthetic cryolite and aluminum fluoride for the aluminum industry, in petroleum alkylation, in uranium and rare metals processing, for glass etching, and to manufacture herbicides and fluoride salts. The largest use of HF was for the production of a wide range of fluorocarbon chemicals including fluoropolymers and chlorofluorocarbons. Chlorofluorcarbons were produced by five companies. According to data from the U.S. International Trade Commission, production of trichlorofluoromethane (F-11) increased 12% to 112,700 short tons; dichlorodifluoromethane (F-12) increased 14% to 184,200 tons; and chlorodifluoromethane (F-22) increased 5% to 142,000 tons, compared with revised 1986 figures.

The manufacture of synthetic cryolite and aluminum fluoride for use in aluminum reduction cells was a major use of HF. An estimated 40 to 60 pounds of fluorine was consumed for each ton of aluminum produced. Aluminum fluoride was used by the ceramic industry for some body and glaze mixtures and in the production of specialty refractory products. It was used in the manufacture of aluminum silicates and in the glass industry as a filler.

HF was consumed in the manufacture of uranium tetrafluoride that was used in the process of concentrating uranium isotope 235 for use as nuclear fuel and in fission explosives. It was also used in stainless steel pickling, petroleum alkylation, glass etching, oil and gas well treatment, as a cleaner and etcher in the electronics industry, and in the manufacture of a host of fluorine chemicals used in dielectrics, metallurgy, wood preservatives, pesticides, mouthwashes, decay-preventing dentifrices, plastics, and water fluoridation.

Fluosilicic acid was used primarily in water fluoridation, either directly or after processing to sodium silicofluoride, and to make aluminum fluoride for the aluminum industry.

Table 2.—U.S. consumption (reported) of fluorspar, by end use

(Short tons)

End use or product	Containing more than 97% calcium fluoride (CaF_2)		Containing not more than 97% calcium fluoride (CaF_2)		Total	
	1986	1987	1986	1987	1986	1987
Hydrofluoric acid (HF)	420,180	438,803	--	--	420,180	438,803
Glass and fiberglass	1,230	2,219	897	9,597	2,127	11,816
Enamel and pottery	W	W	2,298	1,168	2,298	1,168
Welding rod coatings	9,100	6,883	2,178	918	11,278	7,801
Primary aluminum and magnesium	W	W	--	W	W	W
Iron and steel castings	--	W	5,827	4,548	5,827	4,548
Open-hearth furnaces	W	391	22,528	21,966	22,528	22,357
Basic oxygen furnaces	W	W	70,904	77,203	70,904	77,203
Electric furnaces	1,256	1,468	29,121	30,937	30,377	32,405
Other	12,607	1,516	711	751	13,318	2,267
Total	444,373	451,280	134,464	147,088	578,837	598,368
Stocks, Dec. 31	70,304	23,976	19,568	9,435	89,872	33,411

W Withheld to avoid disclosing company proprietary data; included with "Other."

Table 3.—U.S. consumption (reported) of subacid grades of fluorspar in 1987, by end use

(Short tons)

End use or product	Containing not more than 97% calcium fluoride (CaF_2)		
	Flotation concentrates	Lump or gravel	Briquets or pellets
Chemicals and allied products: Welding fluxes	178	740	--
Glass, ceramic, brick:			
Glass	9,563	34	--
Other glass and clay products	1,168	--	--
Primary metals:			
Iron and steel (foundries)	122	21,844	--
Steel mills:			
Basic oxygen furnaces	5,458	23,915	47,830
Electric furnaces	7,730	18,415	4,792
Open-hearth furnaces	--	4,235	313
Other identified end uses	--	751	--
Total	24,219	69,934	52,935

STOCKS

Fluorspar consumer stocks decreased significantly. Producer stock data are withheld to avoid disclosing company proprietary information.

PRICES

Domestic producer prices for all grades of fluorspar and fluorspar briquets reported in the Engineering and Mining Journal remained at 1986 levels. These price quotations serve as a general guide but do not necessarily reflect actual transactions.

Yearend price quotations from the Chemical Marketing Reporter (CMR) were $0.6875 per pound for anhydrous HF and $43.00 per 100 pounds for aqueous HF, 70%, in tanks; both prices were unchanged from yearend 1986. The CMR yearend price quotation for cryolite was $510 per ton and for fluosilicic acid, 100% basis, in tanks, was $250 per ton.

Table 4.—Prices of domestic and imported fluorspar

(Dollars per short ton)

	1986	1987
Domestic, f.o.b. Illinois-Kentucky:		
Metallurgical: 70% effective CaF_2 briquets	125	125
Ceramic, variable calcite and silica:		
88% to 90% CaF_2	100	100
95% to 96% CaF_2	170	170
97% CaF_2	165-175	165 -175
Acid, dry basis, 97% CaF_2:		
Carloads	173	173
88% effective CaF_2 briquets	180	180
European and South African:[1] Acid, term contracts	[r]127-163	92.45- 95.25
Mexican:[2]		
Metallurgical:		
70% effective CaF_2, f.o.b. vessel, Tampico	80.06	80.06
70% effective CaF_2, f.o.b. cars, Mexican border	75.63	75.63
Acid, bulk: 97+%, Mexican border	108.33	108.33

[r]Revised.
[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, Dec. 1986 and 1987.

FOREIGN TRADE

According to the Bureau of the Census, U.S. exports of fluorspar decreased by over two-thirds and had an average value of $119 per ton. Synthetic cryolite exports, with 80% going to Canada, decreased to 9,200 tons, representing 11,100 tons of equivalent fluorspar, valued at $2.2 million. According to the reported data, the average export value for synthetic cryolite was $237 per ton.

Imports for consumption of fluorspar increased slightly with Mexico remaining the most important supplier. Both acid and metallurgical grade were imported from China, which did not supply any fluorspar to the United States in 1986. Italy, a traditional supplier of acid-grade material, was absent from the U.S. market. Substantial quantities of acid-grade material from Canada appeared for the first time. The average unit value, in dollars per ton, of acid- and subacid-grade fluorspar, was $89.52 and $50.55, respectively.

U.S. import duties remained in effect for all grades of fluorspar. The duty was $1.875 per ton for acid grade and 13.5% ad valorem for ceramic- and metallurgical-grade material.

Imports for consumption of HF decreased slightly to a quantity equivalent to approximately 170,000 tons of fluorspar with an average value of $837 per ton. Imports of synthetic and natural cryolite had an average c.i.f. value of $565 per ton and represented 16,700 tons of equivalent fluorspar.

The United States also imported many fluorochemicals, including ammonium bifluoride, chlorodifluoromethane, dichlorodifluoromethane, fluorocarbon polymers, hexafluoropropylene, polytetrafluoroethylene, and trichlorofluoromethane.

Table 5.—U.S. exports of fluorspar, by country

Country	1986		1987	
	Quantity (short tons)	Value	Quantity (short tons)	Value
Australia	19	$1,914	--	--
Canada	14,969	1,546,600	2,036	$216,373
Dominican Republic	1,186	245,361	458	65,412
Ghana	21	3,990	211	31,636
Venezuela	20	3,177	155	26,894
Total	16,215	1,801,042	2,860	340,315

Source: Bureau of the Census.

Table 6.—U.S. imports for consumption of fluorspar, by country and customs district

Country and customs district	1986 Quantity (short tons)	1986 Value[1] (thousands)	1987 Quantity (short tons)	1987 Value[1] (thousands)
CONTAINING MORE THAN 97% CALCIUM FLUORIDE (CaF_2)				
Austria: San Francisco	--	--	1	$1
Canada:				
Buffalo	4	$2	--	--
Houston	--	--	3,821	298
New Orleans	--	--	2,312	295
Total	4	2	6,134	594
China:				
Houston	--	--	29,686	2,436
New Orleans	--	--	5,716	459
Total	--	--	35,402	2,895
France: Houston	138	55	157	57
Germany, Federal Republic of: Milwaukee	3	2	10	5
Kenya:				
Houston	6,468	878	827	714
New Orleans	1,456	135	1,764	106
Total	7,924	1,013	2,591	820
Mexico:				
Baltimore	455	27	--	--
El Paso	92,982	8,625	92,229	7,195
Houston	--	--	14,446	1,143
Laredo	84,324	7,384	49,360	4,701
New Orleans	16,284	1,469	21,290	1,759
Nogales	--	--	56	1
Philadelphia	--	--	709	55
Total	194,045	17,505	178,090	14,854
Morocco: New Orleans	16,132	1,405	29,838	2,684
South Africa, Republic of:				
Houston	28,292	2,422	16,625	1,330
New Orleans	138,554	12,173	163,037	14,960
Philadelphia	14,732	1,432	--	--
Total	181,578	16,027	179,662	16,290
Spain:				
Cleveland	6,562	880	--	--
New Orleans	22,957	2,021	19,912	2,243
Total	29,519	2,901	19,912	2,243
Grand total	429,343	38,910	451,796	40,442
CONTAINING NOT MORE THAN 97% CALCIUM FLUORIDE (CaF_2)				
Brazil: New York	9	8	--	--
Canada:				
Detroit	242	15	--	--
Seattle	--	--	34	6
Total	242	15	34	6
China: New Orleans	--	--	6,901	413
Italy:				
New York	283	9	71	36
Miami	--	--	23	16
Total	283	9	94	52
Malaysia: Laredo	147	7	--	--
Mexico:				
Baltimore	--	--	6,644	479
Detroit	2,217	139	--	--
El Paso	8,411	510	4,631	224
Laredo	22,241	1,007	15,395	638
New Orleans	78,808	4,433	92,124	5,620
Philadelphia	9,737	627	8,255	543
Seattle	--	--	34	5
Total	121,414	6,716	127,083	7,509

See footnote at end of table.

Table 6.—U.S. imports for consumption of fluorspar, by country and customs district—Continued

Country and customs district	1986 Quantity (short tons)	1986 Value[1] (thousands)	1987 Quantity (short tons)	1987 Value[1] (thousands)
CONTAINING NOT MORE THAN 97% CALCIUM FLUORIDE (CaF_2)—Continued				
United Kingdom:				
Boston	1,346	$7	--	--
Houston	1	3	3	$7
Total	1,347	10	3	7
Grand total	123,442	6,765	134,115	7,987

[1]Customs, insurance, and freight (c.i.f.) value at U.S. port.

Source: Bureau of the Census.

Table 7.—U.S. imports for consumption of hydrofluoric acid (HF), by country

Country	1986 Quantity (short tons)	1986 Value[1] (thousands)	1987 Quantity (short tons)	1987 Value[1] (thousands)
Canada	35,433	$33,448	37,833	$34,989
Colombia	--	--	20	22
France	--	--	22	14
Germany, Federal Republic of	362	380	124	141
Israel	--	--	17	16
Japan	5,214	6,303	3,061	2,458
Mexico	73,086	58,539	72,340	57,262
United Kingdom	701	893	281	309
Total	114,796	[2]99,561	113,698	95,211

[1]Customs, insurance, and freight (c.i.f.) value at U.S. port.
[2]Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

Table 8.—U.S. imports for consumption of cryolite, by country

Country	1986 Quantity (short tons)	1986 Value[1] (thousands)	1987 Quantity (short tons)	1987 Value[1] (thousands)
Canada	3,929	$2,025	2,372	$1,215
China	50	23	1,163	550
Denmark	4,032	2,270	4,666	2,176
Germany, Federal Republic of	144	99	163	110
Italy	--	--	1,406	857
Japan	2,826	2,308	3,029	2,324
Netherlands	137	97	210	129
United Kingdom	40	21	--	--
Other	186	116	596	332
Total	11,344	6,959	13,605	7,693

[1]Customs, insurance, and freight (c.i.f.) value at U.S. port.

Source: Bureau of the Census.

WORLD REVIEW

World fluorspar production and consumption were relatively unchanged from those of 1986. China, Mexico, Mongolia, and the U.S.S.R. were the major producers. Most of Mongolian output was exported to the U.S.S.R.; a major share of Mexican sales was to the United States.

Twenty-three nations, including the United States, the countries of the European Economic Community and others, signed a protocol in Montreal, Canada, that would, if ratified by two-thirds of the countries producing chlorofluorocarbons, freeze and later reduce world consumption. Chlorofluorocarbons were believed to be contributing to the destruction of stratospheric ozone. The protocol was historic because it was the first time that a significant number of countries had agreed to regulate a group of substances prior to firm evidence of environmental degradation. The effect of the protocol on future world consumption of fluorspar was not certain because many of the substitutes under development contained fluorine in their formulation, while others did not. Adequate substitutes, with proper testing, were expected to be available within the period 1992-95.

In Canada, the St. Lawrence Fluorspar Ltd. began commercial production of acid-grade fluorspar at St. Lawrence on the Burin Peninsula in Newfoundland. Fluorspar from the Blue Beach and Terefare vein systems was mined both underground and from shallow surface pits. The annual capacity of the treatment plant was 75,000 metric tons.

[1]Physical scientist, Branch of Industrial Minerals.

Table 9.—Sales of Mexican fluorspar, by grade

(Short tons)

Grade	1983	1984	1985	1986	1987
Acid	400,579	508,235	409,800	427,181	430,478
Ceramic	49,285	54,562	51,982	51,541	52,509
Metallurgical	117,190	230,375	309,490	246,226	245,332
Submetallurgical	93,563	117,113	57,779	73,242	105,158
Total	660,617	910,285	829,051	798,190	833,477

Source: Instituto Mexicano de la Fluorita A.C.

Table 10.—Fluorspar: World production, by country[1]

(Short tons)

Country[2] and grade[3]	1983	1984	1985	1986[p]	1987[e]
Argentina	31,950	25,526	35,100	26,500	26,500
Brazil (marketable):					
Acid grade	48,439	48,878	47,048	59,040	64,000
Metallurgical grade	29,415	34,578	32,754	34,188	35,500
Total	77,854	83,456	79,802	93,228	99,500
Canada: Acid grade	--	--	--	--	11,000
China:[e]					
Acid grade	110,000	110,000	110,000	110,000	110,000
Metallurgical grade	440,000	606,000	606,000	606,000	606,000
Total	550,000	716,000	716,000	716,000	716,000
Czechoslovakia[e]	106,000	106,000	105,000	105,000	105,000
Egypt	13	893	94	88	88
France:					
Acid and ceramic grades	155,957	175,378	176,370	163,142	165,000
Metallurgical grade	60,488	80,469	70,548	55,000	55,000
Total	216,445	255,847	246,918	218,142	220,000

See footnotes at end of table.

Table 10.—Fluorspar: World production, by country[1] —Continued

(Short tons)

Country[2] and grade[3]	1983	1984	1985	1986[p]	1987[e]
German Democratic Republic[e]	110,000	110,000	110,000	110,000	99,000
Germany, Federal Republic of (marketable)	88,964	91,787	91,644	97,912	97,600
Greece	330	330	[e]330	[e]330	330
India:[e]					
Acid grade	12,000	13,000	[4]12,243	[r]12,000	14,300
Metallurgical grade	5,000	6,000	[4]5,511	5,500	7,700
Total	17,000	19,000	[4]17,754	[r]17,500	22,000
Italy:					
Acid grade	113,439	121,618	105,215	100,200	101,000
Metallurgical grade	82,409	85,904	62,569	60,116	60,600
Total	195,848	207,522	167,784	160,316	161,600
Kenya: Acid grade	65,129	51,343	64,126	56,054	60,000
Korea, North: Metallurgical grade[e]	44,000	44,000	44,000	44,000	44,000
Korea, Republic of: Metallurgical grade	7,012	5,150	777	268	275
Mexico:					
Acid grade	448,640	379,725	417,469	466,954	[4]451,777
Ceramic grade	50,706	40,307	30,011	14,984	[4]13,244
Metallurgical grade	80,469	235,079	297,897	290,076	[4]338,005
Submetallurgical grade[5]	87,082	115,878	57,779	73,263	[4]105,158
Total	666,897	770,989	803,156	845,277	[4]908,184
Mongolia: Metallurgical grade	[r]780,400	[r]823,400	867,500	870,800	880,000
Morocco: Acid grade	66,469	72,642	81,956	91,500	94,000
Pakistan	--	3,002	3,499	4,798	4,400
Romania: Metallurgical grade[e]	22,000	22,000	22,000	22,000	20,000
South Africa, Republic of:					
Acid grade	256,563	318,892	341,949	323,382	307,500
Ceramic grade	7,061	4,963	6,310	8,491	7,700
Metallurgical grade	31,356	28,010	36,676	36,171	33,800
Total	294,980	351,865	384,935	368,044	[4]349,000
Spain:					
Acid grade	210,265	279,128	294,068	283,413	253,500
Metallurgical grade	45,840	46,788	42,808	27,946	27,600
Total	256,105	325,916	336,876	311,359	281,100
Sweden	2,231	3,807	3,493	3,307	3,300
Thailand:					
Acid grade	51,466	62,998	39,506	12,677	6,200
Metallurgical grade	176,324	253,783	289,972	172,411	137,800
Total	227,790	316,781	329,478	185,088	144,000
Tunisia: Acid grade	37,493	49,064	44,767	40,596	44,000
Turkey: Metallurgical grade[e]	2,200	2,200	2,200	2,200	2,200
U.S.S.R.[e]	595,000	606,000	617,000	617,000	617,000
United Kingdom	144,733	150,686	184,086	146,607	154,000
United States (shipments)[e]	61,000	72,000	66,000	78,000	70,000
Grand total	[r]4,667,843	[r]5,287,206	5,426,275	5,231,914	5,244,077

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through May 13, 1988.
[2]In addition to the countries listed, Bulgaria is believed to have produced fluorspar in the past, but production is not officially reported, and available information is inadequate for the formulation of reliable estimates of output levels.
[3]An effort has been made to subdivide production of all countries by grade (acid, ceramic, and/or metallurgical). Where this information is not available in official reports of the subject country, the data have been entered without qualifying notes.
[4]Reported figure.
[5]Same grade range as metallurgical but primarily contains greater quantities of silica impurities.

Gallium

By Deborah A. Kramer[1]

A small quantity of gallium was recovered domestically at one mine in 1987, but imported material continued to supply most of the U.S. demand. Although consumption declined from the record-high level of 1986, it was still higher than that in the past years. Research and development resulted in the manufacture of new optoelectronic devices and integrated circuits from gallium arsenide (GaAs). Much of the developmental work was funded through U.S. Department of Defense contracts to manufacture devices for military use. GaAs components were used commercially in light-emitting diodes (LED) and laser diodes for telecommunications systems and consumer electronic equipment. GaAs integrated circuits were used principally in defense applications.

Domestic Data Coverage.—Domestic consumption data for gallium are developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the 40 operations to which a survey request was sent, all responded, representing 66% of the consumption shown in tables 1, 2, and 3. Consumption data were adjusted to reflect full industry coverage.

Table 1.—Salient U.S. gallium statistics

(Kilograms unless otherwise specified)

	1983	1984	1985	1986	1987
Production[e]	--	--	--	[1]750	W
Imports for consumption	7,294	9,669	7,961	17,202	12,490
Consumption	6,425	7,060	7,396	16,043	10,729
Price per kilogram	$525	$525	$525	$525	$525

[e]Estimated. W Withheld to avoid disclosing company proprietary data.
[1]Reported figure.

DOMESTIC PRODUCTION

Primary gallium was recovered by St. George Mining Corp., a subsidiary of Musto Explorations Ltd., from its mine in St. George, UT. Because sales of gallium and the germanium dioxide coproduct reportedly were not generating enough working capital for the plant, Musto Explorations negotiated private placement of some of its stock to raise capital. The company also issued a convertible subordinated debenture to Eagle-Picher Industries Inc. in exchange for $1.5 million. Despite the additional investment, Musto Explorations announced that it was temporarily closing the plant in September for at least 4 months because of technical problems and lower than expected prices for gallium.

Eagle-Picher recovered and refined gallium from primary and secondary materials at its plant in Quapaw, OK. Recapture Metals Inc. recovered gallium from GaAs scrap at its facility in Blanding, UT.

Sulzer Bros. Inc. announced that it would construct a gallium extraction plant at

Kaiser Aluminum & Chemical Corp.'s alumina refinery in Gramercy, LA. The first 2 years' output from the 15,000-kilogram-per-year facility was earmarked for shipment to Europe in the form of a gallium chloride solution to be used in a solar neutrino detection experiment. Plant startup was scheduled for 1988.[2]

CONSUMPTION

Consumption of gallium, principally in the form of GaAs, declined from the record-high level of 1986, but was still higher than past levels. Almost all the gallium consumed was in the manufacture of optoelectronic devices and integrated circuits.

Varo Inc., Garland, TX, announced the formation of an Advanced Electronics Materials Group to develop military markets for GaAs-based materials and products, as well as related testing equipment. For the past 3 years, the company has been processing GaAs for use in night-vision equipment as part of a contract it received from the U.S. Army through a joint venture with ITT Corp. Epitronics Corp., a subsidiary of Alcan Aluminum Corp., reportedly began an expansion program that includes the addition of three metal organic chemical vapor deposition (MOCVD) reactors and additional product-testing equipment. The expansion, to be completed by yearend 1987, would increase the total number of MOCVD reactors to five, in addition to the company's liquid phase epitaxy system.

Under an agreement between Spire Corp., Bedford, MA, and Sumitomo Electric Industries Ltd., Japan, Spire would grow highly specialized GaAs and gallium aluminum arsenide (GaAlAs) epitaxial layers on GaAs wafers supplied by Sumitomo Electric. These wafers would be sold to Sumitomo Electric's customers in Japan for use in lasers.

Hewlett-Packard Corp. reportedly developed improved GaAlAs LED that either shine four to five times brighter than conventional LED or require only 3% to 5% of the conventional LED's current to shine as brightly. These new LED were used in the rear window brake lights for some Nissan 300ZX automobiles.

Product development and increases in automation of production technology for GaAs-based integrated circuits continued during 1987. Texas Instruments Inc. reportedly began automated large-scale production of GaAs monolithic microwave integrated circuits (MMIC) at its facility in Dallas, TX, to increase product yield and decrease production costs. The principal market for the GaAs components was in advanced military electronic warfare systems, and the MMIC would replace hybrid components in some applications with a decrease in circuit complexity.[3] Large-scale integration for producing GaAs-based digital integrated circuits was established at several domestic companies, including Vitesse Semiconductor Corp., Camarillo, CA; TriQuint Semiconductor Inc., Beaverton, OR; and Ford Microelectronics Inc., Colorado Springs, CO. Gate arrays and static random access memory components for computer applications were produced in commercial quantities.[4]

Table 2.—U.S. consumption of gallium, by end use

(Kilograms)

End use	1985	1986	1987
Electronics[1]	[r]4,959	[r]13,065	8,981
Light-emitting diodes	2,112	1,855	1,416
Research and development	260	1,048	268
Specialty alloys	65	75	64
Total	7,396	16,043	10,729

[r]Revised.
[1]Lasers, semiconductors, and other electronic devices.

Table 3.—Stocks, receipts, and consumption of gallium[1]

(Kilograms)

Purity	Beginning stocks	Receipts	Consumption	Ending stocks
1986:				
97.0% to 99.9%	105	75	75	105
99.99% to 99.999%	135	[r]1,266	1,399	[r]2
99.9999% to 99.99999%	966	[r]14,309	14,569	[r]706
Total	1,206	15,650	16,043	813
1987:				
97.0% to 99.9%	105	68	64	109
99.99% to 99.999%	2	58	58	2
99.9999% to 99.99999%	706	10,522	10,607	621
Total	813	10,648	10,729	732

[r]Revised.
[1]Consumers only.

PRICES

Prices quoted in the American Metal Market (AMM) for gallium materials in 1987 remained the same as those at yearend 1986. At yearend 1987, prices for gallium materials published in AMM were as follows, in dollars per kilogram: gallium metal, 99.99999% pure, in 100-kilogram lots, $525; gallium metal, 99.99% pure, in 100-kilogram lots, $435; gallium metal, 99.9999% pure, imported, $460 to $490; gallium oxide, 99.99% pure, imported, $400 to $420; and gallium oxide, 99.999% pure, $435.

FOREIGN TRADE

Data on exports of gallium metal and compounds were combined with data for other metal exports by the Bureau of the Census and could not be separately identified. Some exports of gallium were identified through the Journal of Commerce Trade Information Service-PIERS; however, this source contains information only on materials that are transported by ship and may not reflect the total quantity of gallium exported. According to PIERS, 408 kilograms of gallium was exported, mainly as scrap metal. The principal destinations were the Federal Republic of Germany and Japan. Substantial quantities of trimethylgallium and triethylgallium were exported, primarily to the Federal Republic of Germany.

Table 4.—U.S. imports for consumption of gallium (unwrought and waste and scrap), by country

Country	1986		1987	
	Kilograms	Value	Kilograms	Value
Canada	98	$52,095	107	$51,807
France	8,231	3,114,144	6,364	2,497,584
Germany, Federal Republic of	2,740	1,176,562	1,215	517,809
Hungary	17	2,580	--	--
Italy	--	--	13	5,680
Japan	123	45,328	451	202,409
Singapore	--	--	21	11,576
Suriname	--	--	96	48,960
Sweden	5	4,390	--	--
Switzerland	5,640	2,490,483	4,081	1,496,466
United Kingdom	348	68,769	142	41,757
Total	17,202	6,954,351	12,490	4,874,048

Source: Bureau of the Census.

WORLD REVIEW

World production data for gallium were unavailable, but production of primary gallium was estimated to be about 40,000 kilograms.

Czechoslovakia.—Annual production capacity at the Ziar nad Hronom gallium extraction plant was expected to increase from 3,000 to 4,000 kilograms by 1990.

France.—Société Minière et Métallurgique de Peñarroya announced that it planned to increase its annual capacity for recovering gallium from GaAs scrap to 10,000 kilograms by 1989. Peñarroya operated a secondary gallium recovery plant with an estimated capacity of less than 1,000 kilograms per year.

Spain.—Rhône-Poulenc S.A. of France reportedly signed an agreement with the Spanish Government to purchase the entire output of gallium-containing residues from the Alúminia Española S.A. alumina refinery in San Ciprian. Rhône-Poulenc planned to construct a plant near San Ciprian to recover gallium from the residues, estimated to contain up to 30,000 kilograms of gallium annually. No date was set for plant startup.

TECHNOLOGY

Several companies in the United States and Japan continued developmental work to produce GaAs epitaxial layers on silicon substrate wafers, and Kopin Corp. reportedly began shipments of 4-inch-diameter GaAs-on-silicon wafers in December. Two types of GaAs-on-silicon wafers were developed. In one type, the entire silicon wafer was coated with a thin layer of GaAs, called blanket epitaxy, and in the other type, islands of GaAs are deposited on specific areas of the wafer, called selective epitaxy. Both of these types of wafers were intended to combine the superior structural and thermal properties of silicon with GaAs' abilities to emit light and withstand high temperatures and high doses of radiation. Devices fabricated from blanket epitaxial wafers could replace bulk GaAs wafers for integrated circuit applications, while wafers produced by selective epitaxy would combine silicon integrated circuits with GaAs optoelectronic devices or GaAs integrated circuits.[5]

Through contracts awarded by the Defense Department, several companies planned to develop production facilities for advanced GaAs-based devices. American Telephone & Telegraph Co. (AT&T) was awarded a 4-year, $19.8 million contract to develop an advanced production facility at Reading, PA, for high-performance GaAs integrated circuits. High-speed logic and memory chips for sophisticated computers and communications systems were to be constructed by two new technologies. The team of Lockheed Corp., Motorola Inc., and Varian Inc. reportedly received a $1 million contract as a part of the Government's Microwave/Millimeter Wave Monolithic Integrated Circuits program, aimed at developing a new generation of GaAs integrated circuits for military weapons and communications equipment. A $4.4 million contract reportedly was awarded to General Electric Corp. to develop an advanced computerized control system for more rapid production of high-quality GaAs crystals. The resulting new technology was expected to be transferable to the production of other hard-to-grow crystals.[6] Under a $1.3 million contract, an industry team headed by Westinghouse Electric Co. planned to develop technology aimed at increasing the production rates for GaAs wafers by 20 times and reducing the cost. Spire reportedly received a $53,000 contract to investigate highly temperature-stable, low-shadow-loss metallization for GaAs space solar cells. Successful completion of the first phase would lead to research on prototype solar cells, then commercialization of the production techniques.

Texas Instruments reportedly completed the advanced development phase of its program to produce expendable decoys for protection of military aircraft against radar-directed antiaircraft missiles. The expendable decoys were only 6 inches long and 1 inch in diameter; their small size was made possible by the use of GaAs MMIC components. Additionally, Texas Instruments developed high-probability-of-intercept radar receivers and solid-state phased-array jammers using GaAs MMIC technology. The radar receivers would provide a high probability of intercepting advanced radar signals and radar site determination in dense electromagnetic radiation environments, and the jammers would be mounted on aircraft to receive and jam enemy radar signals.[7]

ITT reportedly developed a GaAs MMIC transmit-receive module, which was considered to be a key element in the development of active-aperture phased-array radar systems. Several thousand of these small modules integrated into a large electronic antenna array would replace a large transmitter and reduce power requirements by 40% or more, while providing high rates of target data transmission.

Epitaxx Inc., Princeton, NJ, reportedly was awarded a contract by the Small Business Innovation Research to develop a new indium gallium arsenide (InGaAs) photodetector. The new photodetector was expected to respond between a 0.5 to 1.7 micrometer spectral range and represented a technological breakthrough, because no other single photodetector could cover this range. Projected applications for the InGaAs photodetector included satellite imaging, optical power meters, range finding, and other military and communications applications.

Spire announced that it produced the highest efficiency one-sun GaAs solar cell, which can convert 23.7% of the available light to usable electricity. GaAs solar cells also were used in General Motors Corp.'s Sunraycer solar-powered vehicle, which won the first transcontinental race for solar-powered automobiles, held in Australia, and set a new world speed record for a land vehicle powered solely by sunlight. The Sunraycer's power source was a 7,200-solar-cell array consisting of 80% GaAs solar cells, provided by Applied Solar Energy Corp. and Mitsubishi Corp., and 20% silicon solar cells, which convert 16.5% of the sunlight into usable electricity. The car can reach speeds of up to 45 miles per hour on solar power.

Researchers at the National Aeronautics and Space Administration's Jet Propulsion Laboratory proposed two uses of zinc selenide (ZnSe) films to increase the performance and reduce the cost of GaAs solar cells. ZnSe can serve as a surface passivation layer and a sacrificial layer that would enable the repeated use of a GaAs substrate. The substitution of ZnSe films for GaAlAs films, which are normally used for solar cells, would lead to increased stability of the film under moisture and oxygen. Additionally, using a ZnSe film on a GaAs substrate would allow deposition of doped GaAs epitaxial layers on top of the ZnSe film, because of the close lattice match of the two materials. By dipping the entire cell into a nitric acid solution, the ZnSe film would dissolve, separating the doped GaAs epitaxial layers, which form an ultrathin, ultralight solar cell, from the GaAs substrate, which could be reused.

Personnel at IBM Corp. reportedly demonstrated an experimental integrated optic chip made from GaAs that can read data more than twice as fast as any similar chip. The experimental chip was aimed at short-distance communications applications, such as linking computers by fiber-optic communications systems. By altering the design and fabrication of the photodetector component of the chip, IBM was able to combine the photodetector component with the logic circuits on the same chip. Earlier attempts to combine these two types of components had failed because the high temperature used in processing the logic circuits caused problems with the photodetector.

In a review article on semiconductors, properties and uses of GaAs in optoelectronic devices and integrated circuits were highlighted. New markets for GaAs devices and emerging technology also were discussed.[8]

The Bureau of Mines investigated pressure leaching and carbochlorination as methods for recovering gallium and germanium from a geothite ore, zinc processing residues, and a manganese ore. In pressure leaching, at 200° C, with a total sulfur dioxide content in the reactor of less than 1,500 pounds per short ton of ore, 96% of the germanium was extracted with less than 2% of the gallium. With greater than 2,200 pounds of sulfur dioxide, gallium and germanium extractions were up to 97% and 96%, respectively. Carbochlorination between 300° C and 900° C extracted greater than 80% of the gallium and germanium as volatilized products that were recovered from the offgases.[9]

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[1]Physical scientist, Branch of Nonferrous Metals.

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Gem Stones

By Gordon T. Austin[1]

The value of natural gem materials, gem mineral specimens, and natural and cultured freshwater pearls produced in the United States was estimated to be $21.4 million, an increase of 130% over that of 1986. The significant increase reflects both a true increase in production and an increase in the number of producers surveyed. Small mine owners and professional and amateur collectors accounted for most of the production. Small mines produced tourmaline, jade, opal, sapphire, turquoise, agate, lapis lazuli, garnet, beryl, and quartz.

The combined value of synthetic and simulant gem stones was reported to be $15.3 million, an increase of 49% over that of 1986. The increase reflects an actual increase in production. Synthetic gem stones are manmade and have the same optical, physical, and chemical properties and the same appearance as the natural gem stone. Synthetic gem materials produced in the United States include ruby, sapphire, garnet, spinel, alexandrite, quartz, emerald, turquoise, lapis lazuli, coral, and diamond. Simulants are manmade gem materials that have an appearance similar to that of a natural gem material but have different optical, physical, and chemical properties. The gem simulants produced in the United States include turquoise, coral, lapis lazuli, malachite, and cubic zirconia. Cubic zirconia is the major simulant and is produced in colored and colorless varieties.

The gem stone materials are sold to wholesale and retail outlets, in gem and mineral shops, at gem and mineral shows, to cutting factories, and to jewelry manufacturers.

Domestic Data Coverage.—Domestic production statistics for gem materials were developed by the Bureau of Mines from the "Gems and Gem Stones Survey," a voluntary survey of U.S. operations, and from Bureau estimates of unreported production. Of the 267 operations to which a survey request was sent, 91% responded, accounting for 95% of the total production, 92% of the natural production, and 100% of the synthetic and simulant production.

The 267 operations surveyed in 1987 were an increase of about 154% compared with the number of operations surveyed in 1986. The response rate was essentially unchanged. Production by nonresponding operations and by professional and amateur collectors was based on information from published data, gem and mineral dealers, gem and mineral shows, and collectors.

DOMESTIC PRODUCTION

Production of natural gem materials in all 50 states exceeded a value of $1,000. Ten States supplied 82% of the total value of natural gem material produced. The States, in order of declining value of production, were Tennessee, California, Arizona, Montana, Maine, North Carolina, Idaho, Oregon, and New Hampshire. Production of synthetic and simulant gem materials was valued at $15.3 million. Twelve firms, five in California, four in Arizona, and one each in Massachusetts, Michigan, and New Jersey, produced synthetic and simulant gem material. The States, in order of declining value of production, were Massachusetts, California, New Jersey, Michigan, and Arizona.

Dia Em Resources Ltd. and LKA International Inc. continued to evaluate the emerald occurrences on their Rist and Ellis Mines at Hiddenite, NC. LKA designed and built a beryllometer to assist in sorting emeralds from waste materials. The beryllometer contains a nuclear source material that allows the emerald to be located by induced radiation. The emerald is not permanently affected by the radiation.

The largest diamond ever reported from California was recovered in northern California during 1987. The 14.33 carat alluvial diamond was recovered while panning for gold in Trinity County. The diamond is a knotted grayish-green semitranslucent industrial-grade stone with adamantine luster.

The Dow Chemical Co.; Amselco Exploration Inc., a subsidiary of British Petroleum Co. of Canada; and Exmin Corp., a subsidiary of the Belgian company Sibeka (Société d'Entreprises et d'Investissements S.A.), continued exploration for diamonds on leased lands in Michigan and Wisconsin. Exmin continued diamond exploration efforts in Minnesota.

Ashton Mining Co., a subsidiary of the Australian company Ashton Mining Inc., conducted exploration for diamond in the Crooked Creek and Goodnews Bay areas of Alaska during 1987. The work in the Goodnews Bay area resulted in the recovery of some microindustrial diamonds.

Diamond Co. NL, a wholly owned subsidiary of the Australian company Carr Boyd Minerals Ltd., negotiated mining leases and commenced diamond exploration work in northern Colorado. The joint venture between Lac Minerals Ltd. and Mobil Oil Co. continued its diamond exploration project in the State Line District on the Colorado-Wyoming border.

The Diamond Mining Task Force, appointed in 1986 by the Arkansas Governor to assist the State Parks, Recreation, and Travel Commission in determining if commercial diamond mining would be allowed at the Crater of Diamonds State Park, continued to collect data and undertake studies. The engineering firm of Howard, Needless, Tammer, and Bergendorf was hired to prepare an engineering and economic feasibility study of the proposed diamond mining project. At yearend, studies were under way and no decisions had been made concerning the mining project.

A major discovery of some of the finest topaz crystals ever found in the United States was made at a small pegmatite situated in Coos County, NH. The crystals were sharp, lustrous, blue to blue-green or bicolored blue and golden brown; many were flawless. The same deposit also yielded 30 kilograms of high-quality gem smoky quartz rough.

American Pearl Farms of Tennessee completed its first significant harvest of cultured freshwater pearls. American currently has five pearl farms under operation and acquired additional water acreage for a sixth farm to be established during 1988. The new farm is planned to be nine times larger than the existing farms.

The Zales Diamond, a 535-carat nontraditional-shaped stone, cut in the United States in 1986, was recut into a traditional shape. The loss in carat weight resulted in the stone's no longer being the world's largest polished diamond. A 3,500-carat blue sapphire was found in North Carolina, and a 5,500-carat North Carolina star sapphire was cut into a 3,000-carat stone. No value was established for either of the sapphires. The world's largest gem topaz, a 22,892-carat light golden topaz, was cut from a 26-pound waterworn crystal. The cushion-cut stone was purchased by the rockhound hobbyists of America for $40,000 and will be donated to the Smithsonian Museum of Natural History.

CONSUMPTION

Domestic gem materials production was consumed in commercial and amateur manufacture of jewelry, in gem and mineral collections, and in the production of objects of art. The value of U.S. apparent consumption was estimated to be $3,459 million, an increase of about 4%.

U.S. imports for consumption of colored gem stones, led by emerald, ruby, and sapphire, decreased slightly. The value of annual imports of emerald continued as the largest of any colored gem stone. The combined value of imported ruby and sapphire in 1987 was exceeded by the value of emerald by 6%. In 1986, the combined values of ruby and sapphire exceeded emerald by 17%.

The value of imports of other colored stones increased 21% compared with those of 1986, and the value of imported synthetic and imitation gem materials increased 28%. The value of pearls imported into the United States continued to decline for the third consecutive year, decreasing approximately 20% compared with that of 1986. The fluctuation in the value of imports is a direct reflection of purchasing trends in the marketplace.

PRICES

The U.S. price of a 1-carat, D-colored, flawless diamond fluctuated between $14,000 and $16,000, and was $14,000 at yearend. However, only a few hundred of these high-quality, 1-carat stones have been available each year, and their value has accounted for an insignificant percentage of the total value in the U.S. market. Prices of ruby, blue sapphire, and emerald rose 39%, 35%, and 45%, respectively, when their June 1987 prices were compared with their June 1986 prices. The price increases appear to be the result of a combination of things: the lower American dollar, the increased demand in the United States for quality stones, and a decrease in the supply of stones from the traditional producing areas. The price of American freshwater pearls increased slightly over that of 1986, and the demand remained firm.

Table 1.—Prices of U.S. cut diamonds, by size and quality

Carat weight	Description, color[1]	Clarity[2] (GIA terms)	Price range per carat,[3] 1987	Average price per carat[4]	
				June 1986	June 1987
0.04-0.07	H-I	VS	$440- $440	$420	$400
.04- .07	H-I	SI_1	420- 420	380	420
.08- .14	H-I	VS	470- 470	460	470
.08- .14	H-I	SI_1	440- 440	420	440
.18- .22	H-I	VS	680- 680	750	680
.18- .22	H-I	SI_1	600- 600	700	600
.23- .29	H-I	VS	900- 900	11,750	900
.23- .29	H-I	SI_1	750- 750	900	750
.30- .37	H-I	VS	1,175- 1,225	1,475	1,175
.30- .37	H-I	SI_1	950- 950	1,250	950
.46- .49	H-I	VS	1,425- 1,525	--	1,475
.46- .49	H-I	SI_1	1,300- 1,300	--	1,300
.70- .89	H-I	VS	2,175- 2,175	2,175	2,175
.70- .89	H-I	SI_1	1,900- 1,900	1,800	1,900
1.00[5]	D	IF	14,750-14,000	[6]12,000	[6]14,500
1.00	E	VVS_1	6,200- 5,875	[6]5,000	[6]6,000
1.00	G	VS_1	3,350- 3,475	[6]3,150	[6]3,250
1.00	H	VS_2	2,650- 2,950	[6]2,525	[6]2,550

[1]Gemological Institute of America (GIA) color grades: D—colorless; E—rare white; and H-I—traces of color.
[2]Clarity: IF—no blemishes; VVS_1—very, very slightly included; VS—very slightly included; VS_2—very slightly included, but more visible; and SI_1—slightly included.
[3]Rapaport Diamond Report. V. 10, No. 1, Jan. 2, 1987; and v. 10, No. 45, Dec. 25, 1987. These figures represent Rapaport Diamond Report opinion of New York wholesale asking price.
[4]Rapaport Diamond Report. V. 9, No. 22, July 11, 1986; and v. 10, No. 23, June 26, 1987.
[5]The Diamond Registry Bulletin. V. 18, No. 1, Dec. 1986, p. 8; and v. 18, No. 1, Dec. 1987, p. 8.
[6]The Diamond Registry Bulletin. V. 17, No. 7, July 1986, p. 8; and v. 17, No. 6, July 1987, p. 8.

Table 2.—Prices of U.S. cut colored gem stones, by size[1]

Gem stone	Carat weight	Price range per carat, 1987[2]	Average price per carat[3]	
			June 1986	June 1987
Amethyst	1	$6- $10	$8	$8
Aquamarine	1	100- 250	175	175
Emerald	1	1,800-3,000	1,775	2,400
Garnet, tsavorite	1	500-1,200	950	950
Ruby	1	2,300-3,500	2,150	3,000
Sapphire	1	550-1,500	725	1,050
Tanzanite	1	275- 450	354	354
Topaz	1	6- 9	7.50	7.50
Tourmaline, red	1	60- 125	145	92.50

[1]Fine quality.
[2]Jewelers' Circular-Keystone. V. 159, No. 2, Feb. 1988, p. 400. These figures represent a sampling of net prices that wholesale colored stone dealers in various U.S. cities charged their cash customers during the month.
[3]Jewelers' Circular-Keystone. V. 159, No. 8, Aug. 1987, p. 442.

FOREIGN TRADE

Export value of all gem materials was $740.8 million. Export value of all gem materials other than diamond increased 36% to $80.4 million. Of this total, other precious and semiprecious stones, cut but unset, were valued at $45.4 million; other precious and semiprecious stones, not set or cut, $21.0 million; synthetic gem stones and materials for jewelry, cut, $5.8 million; pearls, natural, cultured, and imitation, not strung or set, $1.8 million; and other, $369.4 million. Reexports of all gem materials other than diamond increased 12% to $61.7 million. Reexport categories were synthetic gem stones and materials for jewelry, cut, $0.6 million; precious and semiprecious stones, cut but not set, $40.1 million; and other precious and semiprecious stones, natural, not cut or set, $1.31 million.

The customs value of U.S. imports of rough and polished natural diamond, excluding industrial diamond, was down slightly to about $3.4 billion. Total imports of polished diamond came principally from Israel, 32%; Belgium, 28%; and India, 21%. They were valued at $3.0 billion, essentially unchanged from those of 1986. Imports of diamond greater than 0.5 carat came mostly from Israel, 38%; Belgium, 36%; and Switzerland, 8%. They decreased 15% in value to $1.1 billion. Imports in the less-than-0.5-carat category came mostly from India, 35%; Israel, 32%; and Belgium, 24%. The value increased 6% to $1.9 billion. The imports of rough diamonds increased 5% in caratage and decreased slightly in value. The Republic of South Africa accounted for only 7% of the value of the imports, down from 52% in 1986. However, the average carat value of imports from the Republic of South Africa increased from $499 to $758.

The total customs value of imported emerald decreased 8% to $141.6 million. The total value of ruby imports decreased 29% to $59.4 million, and sapphire imports decreased 22% to $74.0 million. Average carat values increased 24% for emerald to $68, 14% for ruby to $25, and 27% for sapphire to $28.

Table 3.—U.S. exports and reexports of diamond (exclusive of industrial diamond), by country

Country	1986 Quantity (carat weight)	1986 Value[1] (millions)	1987 Quantity (carat weight)	1987 Value[1] (millions)
Exports:				
Belgium-Luxembourg	205,565	$108.9	162,009	$122.9
Canada	19,176	13.7	24,943	17.8
France	3,148	6.9	1,943	4.3
Germany, Federal Republic of	2,286	3.1	3,842	4.0
Hong Kong	67,393	97.1	100,365	148.2
Israel	156,819	87.2	172,634	110.8
Japan	48,266	93.6	62,404	144.1
Singapore	5,810	7.5	5,686	7.0
Switzerland	19,318	85.4	30,161	76.3
Thailand	16,958	6.4	14,028	9.3
United Kingdom	6,405	7.8	4,151	8.2
Other	9,915	8.0	5,221	7.5
Total	561,059	525.6	587,387	660.4
Reexports:[2]				
Belgium-Luxembourg	806,945	89.5	1,184,952	101.1
Canada	6,516	.5	5,424	.8
China	10,392	.6	2,062	.1
Germany, Federal Republic of	39,479	2.7	24,840	2.6
Hong Kong	59,969	20.3	82,491	27.2
India	127,221	3.3	84,893	2.9
Israel	210,333	59.2	199,579	70.3
Japan	105,827	8.8	95,919	7.2
Netherlands	68,079	5.1	47,313	3.2
Switzerland	30,797	35.1	39,765	57.7
United Kingdom	398,044	27.6	101,300	18.4
Other	102,348	9.4	74,333	16.2
Total	1,965,950	262.1	1,942,871	307.7

[1]Customs value.
[2]Artificially inflated in 1986 by auction of approximately 1 million carats of U.S. Government stockpile industrial diamond stones with subsequent reexports as gem stones to Belgium-Luxembourg and India.

Source: Bureau of the Census.

Table 4.—U.S. imports for consumption of diamond, by kind, weight, and country

Kind, range, and country of origin	1986 Quantity (carat weight)	1986 Value[1] (millions)	1987 Quantity (carat weight)	1987 Value[1] (millions)
Rough or uncut, natural:[2]				
Belgium-Luxembourg	418,782	$73.8	323,742	$82.0
Brazil	29,444	3.4	44,287	5.4
Cape Verde	940	1.0	--	--
Guyana	2,122	.3	--	--
Israel	45,240	12.2	28,029	7.3
Netherlands	7,318	3.7	2,930	2.9
South Africa, Republic of	452,973	225.9	37,870	28.7
Switzerland	22,629	8.1	5,185	12.6
United Kingdom	135,099	66.0	797,759	208.3
Venezuela	37,096	1.0	7,901	.7
Other	155,618	39.7	121,657	72.1
Total	1,307,261	435.1	1,369,360	420.0
Cut but unset, not over 0.5 carat:				
Belgium-Luxembourg	1,540,601	471.9	1,307,990	468.2
Brazil	23,013	7.5	33,352	8.7
Canada	30,485	4.0	21,750	8.8
Hong Kong	131,717	25.0	241,251	41.8
India	2,886,722	629.0	3,198,504	670.8
Israel	1,555,742	542.7	1,511,724	629.8
Malaysia	2,151	.7	--	--
Netherlands	28,296	11.0	51,959	13.6
South Africa, Republic of	139,692	19.1	14,461	11.8
Switzerland	75,629	28.7	73,268	40.3
United Kingdom	36,714	17.9	18,321	15.8
Other	172,873	21.9	144,708	33.3
Total	6,623,635	1,779.4	6,617,288	1,942.9
Cut but unset, over 0.5 carat:				
Belgium-Luxembourg	412,645	371.1	384,789	380.1
Hong Kong	34,236	45.4	12,361	21.3
India	50,098	13.2	110,019	28.0
Israel	529,226	429.0	468,132	406.1
Netherlands	24,673	23.8	8,403	11.6
South Africa, Republic of	65,180	73.7	27,654	41.3
Switzerland	48,898	169.6	37,583	81.7
United Kingdom	35,303	63.8	29,155	42.6
Other	60,871	55.9	56,345	47.5
Total	1,261,130	1,245.5	1,134,441	1,060.2

[1]Customs value.
[2]Includes some natural advanced diamond.

Table 5.—U.S. imports for consumption of natural precious and semiprecious gem stones, other than diamond, by kind and country

Kind and country	1986 Quantity (carats)	1986 Value[1] (millions)	1987 Quantity (carats)	1987 Value[1] (millions)
Emerald:				
Argentina	437	(2)	--	--
Belgium-Luxembourg	16,262	$3.1	30,190	$3.9
Brazil	144,899	6.4	112,194	7.0
Colombia	199,935	52.3	195,403	44.6
France	10,674	3.0	8,401	1.9
Germany, Federal Republic of	60,471	3.2	38,034	3.9
Hong Kong	187,525	12.0	170,853	15.2
India	1,267,481	14.5	1,231,033	17.0
Israel	59,724	14.1	60,942	19.4
Japan	3,816	.8	5,637	.6
South Africa, Republic of	37,795	1.8	5	(2)
Switzerland	448,580	27.4	58,789	18.3
Taiwan	5,056	.3	3,697	(2)
Thailand	138,284	2.6	104,058	3.0
United Kingdom	20,461	6.1	7,652	2.2
Other	155,735	4.8	48,032	4.6
Total	2,757,135	152.4	2,074,920	141.6

See footnotes at end of table.

Table 5.—U.S. imports for consumption of natural precious and semiprecious gem stones, other than diamond, by kind and country —Continued

Kind and country	1986 Quantity (carats)	1986 Value[1] (millions)	1987 Quantity (carats)	1987 Value[1] (millions)
Ruby:				
Belgium-Luxembourg	16,528	$4.3	12,078	$0.7
Brazil	579	([2])	3,102	([2])
Colombia	1,558	.1	3,198	([2])
France	4,563	1.9	6,219	1.6
Germany, Federal Republic of	14,412	.9	18,267	.8
Hong Kong	85,954	3.4	42,687	3.6
India	247,687	2.1	302,323	.9
Israel	35,433	1.3	7,043	.6
Japan	82,786	.4	335,381	.5
Switzerland	256,921	16.5	41,492	14.1
Thailand	3,020,440	44.4	1,536,723	31.4
United Kingdom	19,496	5.8	11,523	2.9
Other	82,677	2.4	37,781	2.3
Total	3,869,034	83.5	2,357,817	59.4
Sapphire:				
Australia	2,219	.2	--	--
Austria	--	--	1,000	([2])
Belgium-Luxembourg	19,152	3.0	21,356	1.2
Brazil	28,604	([2])	2,580	([2])
Canada	4,643	.7	6,905	.7
Colombia	1,769	([2])	2,234	([2])
France	26,764	1.9	7,048	1.1
Germany, Federal Republic of	20,699	1.2	12,067	1.6
Hong Kong	132,201	4.9	63,684	5.4
India	127,121	1.0	84,973	.5
Israel	40,322	1.2	14,254	1.1
Japan	29,157	.5	48,460	.4
Korea, Republic of	7,527	.1	9,793	([2])
Singapore	946	([2])	7	([2])
Sri Lanka	22,149	2.2	55,241	3.1
Switzerland	370,520	21.0	46,786	11.3
Thailand	3,394,602	50.3	2,121,376	42.7
United Kingdom	60,736	5.5	110,112	3.9
Other	71,587	1.4	37,847	1.0
Total	4,360,718	95.1	2,645,723	74.0
Other:				
Rough, uncut:				
Australia		.6		.8
Brazil		15.9		20.7
Colombia		7.5		5.5
Hong Kong		1.1		1.4
Nigeria		.3		.2
Pakistan	NA	.6	NA	1.2
South Africa, Republic of		.7		.3
Switzerland		.4		.1
United Kingdom		.4		([2])
Zambia		.7		.1
Other		3.0		3.8
Total	NA	31.2	NA	34.1
Cut, set and unset:				
Australia		4.6		6.1
Brazil		11.0		17.2
Canada		.8		.6
China		5.1		2.7
Germany, Federal Republic of		11.4		13.7
Hong Kong		29.3		28.7
India	NA	4.8	NA	5.7
Japan		161.9		128.8
Switzerland		2.9		3.0
Taiwan		12.1		11.1
Thailand		6.1		11.7
United Kingdom		2.5		1.0
Other		19.3		21.2
Total	NA	271.8	NA	251.5

NA Not available.
[1]Customs value.
[2]Less than 1/10 unit.

Source: Bureau of the Census.

Table 6.—Value of U.S. imports of synthetic and imitation gem stones, including pearls, by country

(Million dollars[1])

Country	1986	1987
Synthetic, cut but unset:		
Austria	0.5	1.3
France	.9	.8
Germany, Federal Republic of	6.4	9.2
Japan	9.0	1.8
Korea, Republic of	2.8	11.6
Switzerland	1.5	4.6
Other	1.0	5.0
Total	22.1	34.3
Imitation:		
Austria	34.4	50.7
Czechoslovakia	2.0	2.1
Germany, Federal Republic of	12.0	7.1
Japan	7.2	3.7
Other	7.0	8.0
Total	62.6	71.6

[1]Customs value.

Source: Bureau of the Census.

Table 7.—U.S. imports for consumption of precious and semiprecious gem stones

(Thousand carats and thousand dollars)

Stones	1986		1987	
	Quantity	Value[1]	Quantity	Value[1]
Diamonds:				
Rough or uncut[2]	1,307	$435,029	1,369	$420,004
Cut but unset	7,885	3,024,902	7,752	3,003,090
Emeralds: Cut but unset	2,757	152,396	2,075	141,575
Coral: Cut but unset, and cameos suitable for use in jewelry	NA	2,291	NA	3,060
Rubies and sapphires: Cut but unset	8,230	178,655	5,004	133,396
Marcasites	NA	139	NA	766
Pearls:				
Natural	NA	3,406	NA	3,879
Cultured	NA	190,497	NA	151,854
Imitation	NA	9,655	NA	6,259
Other precious and semiprecious stones:				
Rough, uncut	NA	30,589	NA	34,079
Cut, set and unset	NA	65,392	NA	78,215
Other	NA	8,102	NA	13,716
Synthetic:				
Cut but unset[3]	63,532	22,074	82,697	30,958
Other	NA	2,586	NA	3,358
Imitation gem stones	NA	52,939	NA	65,311
Total	XX	4,178,652	XX	4,089,520

NA Not available. XX Not applicable.
[1]Customs value.
[2]Includes 19,243 carats valued at $675,326 in 1986.
[3]Quantity in thousands of stones.

Source: Bureau of the Census.

WORLD REVIEW

De Beers Consolidated Mines Ltd.'s sales of uncut diamonds through the Central Selling Organization in 1987 were reported to be a record $3.07 billion compared with $2.56 billion in 1986, an increase of approximately 20%. Sales of colored gem stones also remained very strong.

Emerald was mined in Australia, Brazil, Colombia, Mozambique, Pakistan, the Republic of South Africa, the U.S.S.R., Zambia, and Zimbabwe. Sapphire was produced in Australia, Colombia, Kenya, Malawi, Nigeria, Sri Lanka, Tanzania, Thailand, and the United States. Aquamarine was produced in Afghanistan, Brazil, China, India, Nigeria, Pakistan, the Republic of South Africa, Tanzania, the United States, and Zambia. Ruby was produced in Afghanistan, Burma, India, Kenya, Sri Lanka, Tanzania, Thailand, and the United States.

Angola.—Sociedade Portugesa de Empreendimentas and Endeama (SPE), a Portuguese company, signed a 2-year agreement with the Angolan state mining company to mine and appraise diamonds. SPE will also assist in diamond exploration and training Angolan personnel.[2] Visitors to Angola reported that Cuban soldiers stationed there were becoming good sources for Angolan rough diamonds. Angolan diamond production continued to suffer because of the civil war.

Australia.—Argyle Diamond Mines Joint Venture completed the second year of production from the AK-1 lamproite pipe. Production of 30.3 million carats exceeded the planned production of 25 million carats. Argyle Diamond Sales Ltd. launched a major sales campaign in October 1987 directed at significantly increasing the international market for "cognac" or "champagne" colored diamonds. The terms are used to help market the brown-colored gem diamonds Argyle produces each year.[3] Additionally, Argyle formed a direct relationship with the India diamond-cutting trade to upgrade its diamond cutting technology to reduce the amount of Argyle near-gem material that is reclassified as industrial because of cutting difficulties.[4]

Freeport Bow River Properties Inc., the operating company of the Freeport-McMoRan Australia Ltd. and Gem Exploration and Minerals Ltd. joint venture, started construction of the Bow River alluvial diamond project. The project will process 4,000 metric tons per day of gravel. Diamond output is expected to exceed 600,000 carats per year. The diamond production is forecast to be 18% to 25% gem quality, 65% to 72% near-gem quality, and 8% to 10% bort. Also, Freeport-McMoRan Australia made an encouraging diamond discovery while drilling its project at Orraroo in South Australia. Work continued on the joint venture diamond project between Freeport-McMoRan Australia and Swan Resources at Springfield Basin in New South Wales.

Carr Boyd Minerals Ltd., in partnership with the De Beers subsidiary Stockdale Prospecting Ltd., and Afro-West Mining and Gem Exploration and Minerals Ltd. are continuing separate diamond exploration projects in various Australian locations. Capricorn Resources Australian NL initiated offshore diamond prospecting 150 kilometers northwest of Wyndham on the northern coast of Western Australia. Ashton Mining Ltd. continued the management of two ongoing diamond exploration ventures. Gem Exploration completed a bulk-sampling program on a diamond prospect near the Kununurra District of East Kimberley and investigated magnetic anomalies in West Kimberley. The results were not announced. Auridian Consolidated NL continued its diamond exploration activities in North Shaw, Halls Creek, Pilbara, Mount Behn, Van Emmereck, Mount Barnett, and Pentagon areas.

Production of sapphire in 1987 was estimated to be $18 million and represented about 75% of the rough sapphire imported into Thailand, the world's leading sapphire processing and marketing country. The opal production in 1987 was estimated to be $58 million and represented about 85% of the world production of natural opal.[5] The South Sea cultured pearl production was estimated at $20 million. Australia produces about 25% of all South Sea pearls; however, the production represents approximately 80% of the high-quality goods.[6]

Botswana.—Debswana, the Botswana diamond mining company that is a 50-50 joint venture between De Beers and the Government of Botswana, sold its significant diamond stockpile to De Beers. The stockpile was estimated to contain a high proportion of large, high-quality gem material. The purchase was paid for with a combination of cash and newly issued De Beers company shares. The Government of Botswana now owns 2.6% of De Beers and the right to appoint two members to the Board of Directors of De Beers and De Beers' Diamond Trading Co.[7] Botswana produced a record high 13.2 million carats in 1987; approximately 71% were gem quality.

Brazil.—Mining and production started on a diamond-rich kimberlite pipe in the State of Mato Grosso, approximately 20 kilometers from Julina. This is the first production from a kimberlite pipe in Brazil. All production to date was from secondary alluvial sources.

The new alexandrite deposit mine discovered in early 1987 near Italira in Gerau Mines was temporarily closed late in the year by the Government. The location produced a large quantity of fine gem-quality alexandrite and promises to be prolific for the next several years.[8]

Table 8.—Diamond (natural): World production, by country[1]

(Thousand carats)

Country	1983 Gem[2]	1983 Industrial	1983 Total	1984 Gem[2]	1984 Industrial	1984 Total	1985 Gem[2]	1985 Industrial	1985 Total	1986[p] Gem[2]	1986[p] Industrial	1986[p] Total	1987[e] Gem[2]	1987[e] Industrial	1987[e] Total
Angola	775	259	1,034	652	250	902	464	250	714	240	10	[e]250	180	10	190
Australia	3,720	2,480	6,200	3,415	2,277	5,692	4,242	2,828	7,070	13,145	16,066	29,211	[3]13,650	[3]16,683	[3]30,333
Botswana	4,829	5,902	10,731	5,810	7,104	12,914	6,318	6,317	12,635	9,610	3,500	13,110	[3]9,367	[3]3,840	[3]13,207
Brazil	90	450	530	200	550	750	233	217	450	310	315	625	320	325	645
Central African Republic	230	65	295	236	101	337	190	87	277	259	99	358	245	105	350
China[e]	200	800	1,000	200	800	1,000	200	800	1,000	200	800	1,000	200	800	1,000
Ghana	34	306	340	35	311	346	60	572	632	50	510	560	60	540	600
Guinea	23	17	[e]40	44	3	47	123	9	132	190	14	204	[3]163	[3]12	[3]175
Guyana[e]	5	5	10	6	8	14	4	7	11	3	6	[3]9	4	7	11
India	12	2	14	13	2	15	14	2	16	13	2	15	13	2	15
Indonesia[e]	5	22	27	5	22	27	5	22	27	5	22	27	5	25	30
Ivory Coast[e 4]	NA	NA	NA	[r]20	[r]5	[r]25	[r]15	[r]5	[r]20	[r]10	[r]4	[r]14	15	5	20
Liberia	132	198	330	108	132	240	66	72	138	63	189	252	60	190	250
Namibia	915	48	963	884	46	930	865	45	910	[r]970	40	1,010	980	40	[3]1,020
Sierra Leone	242	103	345	240	105	345	243	106	349	215	100	315	200	100	300
South Africa, Republic of:															
Finsch Mine	1,765	3,278	5,043	1,714	3,184	4,898	1,770	3,184	4,954	1,821	3,208	5,029	1,455	2,701	[3]4,156
Premier Mine	800	1,844	2,644	765	1,785	2,550	820	1,864	2,684	882	1,977	2,859	772	1,713	[3]2,485
Other De Beers' properties[5]	1,400	569	1,969	1,452	593	2,045	1,500	569	2,069	1,428	529	1,957	1,427	546	[3]1,973
Other	589	66	655	585	65	650	460	35	495	342	41	383	409	30	439
Total	4,554	5,757	10,311	4,516	5,627	10,143	4,550	5,652	10,202	4,473	5,755	10,228	4,063	4,990	[3]9,053
Swaziland	--	--	--	7	10	17	9	12	21	17	23	[e]40	17	23	40
Tanzania	183	78	261	193	84	277	165	71	236	133	57	190	133	57	190
U.S.S.R.[e]	3,700	7,000	10,700	4,300	6,400	10,700	4,400	6,400	10,800	4,400	6,400	10,800	4,900	7,100	12,000
Venezuela	45	234	279	40	232	272	35	180	215	45	189	234	50	200	250
Zaire	3,355	8,627	11,982	5,169	13,290	18,459	4,032	16,127	20,159	4,661	18,643	23,304	4,670	18,680	23,350
Total	23,039	32,353	55,392	[r]26,093	[r]37,359	[r]63,452	26,233	39,781	66,014	39,012	52,744	91,756	39,295	53,734	93,029

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.

[1]Table includes data available through June 3, 1988. Total diamond output (gem plus industrial) for each country is actually reported except where indicated by a footnote to be estimated. In contrast, the detailed separate production data for gem and industrial diamond are Bureau of Mines estimates in the case of every country except Australia (1983-87), Botswana (1987), Central African Republic (1983-86), Guinea (1984-87), and Liberia (1984-86), for which source publications give details on grade as well as totals. The estimated distribution of total output between gem and industrial diamond is conjectural, and for most countries, is based on the best available data at time of publication.

[2]Includes near-gem and cheap-gem qualities.

[3]Reported figure.

[4]Estimates based on reported exports; excludes smuggled diamonds.

[5]Other De Beers Group output from the Republic of South Africa includes Kimberley Pool, Koffiefontein Mine, and the Namaqualand Mines.

Canada.—Dia Met Minerals of Vancouver continued to negotiate the financing for drilling the Jack kimberlite pipe in British Columbia. The pipe, located 55 kilometers north of Golden, British Columbia, contains minute gem-quality diamonds. Additional pipes in the area were sampled during the summer months. Information from the summer program is not available at this time.

Central African Republic.—African Star Mining Co., a subsidiary of the U.S. firm O'Hair Mining and Drilling Co., established the first large-scale mechanized diamond mining operation in the Central African Republic. Two mines and associated washing plants with an initial production rate of 2,500 cubic meters per day were under construction with production scheduled to begin in early 1988. The firm planned to increase production to 5,000 cubic meters per day in 60 to 90 days after startup. The estimated average grade of the project reserves is 0.4 carat per cubic meter that grade 95% gem quality. Annual production is forecast to be approximately 670,000 carats per year. The planned production of the two operations is 200% of the current total production of the Central African Republic.

China.—Boarara Mining Ltd. of Australia entered into an agreement with Southolme Ltd. of Hong Kong to explore and develop diamond projects in Hunan Province in China. Diamonds are found along the 1,000-kilometer length of the Yuan Jiang River terraces and channels, which are often 20 to 30 meters deep and up to 300 to 400 meters wide. The terraces have been mined for years by local farmers. A source pipe for the diamonds has not been found.

The Yuan Jiang River Alluvial Project, a joint venture between City Resources (Asia) Ltd. (a subsidiary of the Australian company City Resource Ltd.), China Hunan International Development Corp., and China Geology Import and Export Group, was formed to explore for and produce diamonds and gold on the lower reaches of the Yuan Jiang River. City Resources will supervise and control the work and the Chinese partners will furnish the labor force. The project area is approximately 120 square kilometers.

China produced diamonds, aquamarine, quartz crystal, citrine, turquoise, peridot, sapphire, jet, pearls, and jade.

Guinea.—Diamond production at Badge Oil's Aredor project decreased. The diamonds from Aredor are noted for their size and quality with an average price of $284 per carat in 1987. The stones average 0.82 carat; however, an average of 55 gems over 10 carats and 10 stones over 15 carats was recovered each month. During 1987, a 100.2-carat stone was sold for $1.6 million, and a 143-carat stone was sold for $3.9 million. Production costs have been lowered from $260 per carat in 1984 to about $90 per carat in 1987.[9]

India.—Orissa Mining Corp. discovered a large deposit of high-quality ruby in Orissa State. The deposit in the Jilligdhar area of the Kalahandi District has made the company one of the largest producers of gem stones in the country. The smaller fine-quality stones sell wholesale at about $1,000 per carat. The lower quality stones suitable for cabochons sell for a few hundred dollars per carat once they are cut. The Government-owned Mineral Development Corp. announced the discovery of a major new diamond deposit in Chittaurgarh Province. Early reports indicate that the deposit may be more productive than any area currently being mined.

Indonesia.—Acorn Securities Ltd. continued negotiations with the Government of Indonesia for a long-term production agreement for the South East Kalimantan diamond project. The first parcel of diamonds from the project, 1,032 carats, was evaluated at an average value of $170 per carat. The parcel of 6,342 stones was 97% gem quality. Acorn has a reserve base of 16 million cubic meters with an average grade of 0.2 carat of diamond, 80 milligrams of gold, and 20 milligrams of platinum per cubic meter.

Pakistan.—Production from a new emerald deposit in Gujjar Kallay in the Swat District resulted in an increase in the average monthly production from 350 carats to 4,000 carats. The stones are of very good quality. Pakistan continued to produce high-quality pink topaz, other gem topaz, and tourmaline.

Sierra Leone.—Diamond Corp., a subsidiary of De Beers, negotiated with the Government of Sierra Leone regarding a $3 million loan to rehabilitate the mining equipment for the National Diamond Mining Co.'s operations at Yengema.[10] Oliver Resources PLC, through its Sierra Leone subsidiary, was granted exclusive gold and diamond licenses on about 78 square kilometers of alluvial deposits along tributaries of the Pampana River.

South Africa, Republic of.—Thirteen additional marine diamond concessions were allocated off of the South African west coast. Fourteen companies or individuals are working the concessions that were issued in 1983 and 1984. The 1987 marine diamond production was estimated at 55,000 carats. De Beers began reactivation of the Koffiefontein Mine in the Orange Free State. The Mine, idle since 1982, is expected to be back in production in early 1988.

TECHNOLOGY

Shalev Computerized Systems Ltd. in Ramat Hasharon, Israel spent $2 million developing Robo Gem, a robot that automatically calculates the best possible shape and optimum yield of virtually all rough gems except diamond. The robot is more exact than human cutters, increases yields from rough stones an average of 10%, and reduces the cost of cutting by up to 70%.[11]

Zui Yehuda of Israel developed a method for treating diamonds that reportedly improves the clarity of fractured diamonds dramatically. In most diamonds the treatment can easily be identified with a 10X loupe. Many of the treated stones showed a yellow concentration of color along fractures. All of the treated stones displayed a distinct rainbow of color when viewed along the thin side of the fracture.[12]

Enhancement of all types of gem materials through chemical and physical means has become much more commonplace and has included a wider variety of gem materials in the past few years. Irradiation by the electromagnetic spectrum (X-rays, gamma rays, etc.) and by energetic particles (neutrons, electrons, alphas, etc.) is being used to enhance or change the color of diamonds, topaz, tourmaline, quartz, beryl, sapphire, zircon, scapolite, and pearls. Blue topaz is normally irradiated, but this does not imply that all of these gem materials are regularly irradiated.[13]

A number of gem materials can be enhanced by chemical treatment or impregnations. The treatment may alter the bulk of the gem material or only penetrate the surface. This includes bleaching, oiling, waxing, plastic impregnations, color impregnations, and dying. The treatments that alter only the surface of the gem material include surface coatings of various types, interference filters, foil backings, surface decoration, and inscribing. Chemical treatment is more widespread than the common dying of quartz, treatment of turquoise, and oiling of emeralds. Chemical treatment and impregnations have been used to enhance chalcedony, coral, ivory, pearl, tiger's eye, emerald, lapis lazuli, opal, ruby, sapphire, turquoise, beryl, quartz, jade, diamond, and amber.[14]

The oldest and most common method of gem material enhancement is heat treating. Heat treatment of gem materials was used in Greece and Rome well before the Christian Era. Heat treatment can cause color change, structural change, and improve clarity. In the past, heat treatment was common for quartz and gem corundum. Today, materials that are heat treated to enhance their appearance include sapphire, topaz, beryl, tourmaline, quartz, zircon, amber, diamond, and zoisite.[15]

Testing can determine if certain types of gem materials have been treated. However, not all types of treatments for all types of gem materials can be detected.

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[12]Rapaport Diamond Report. Diamond Treatment Alert. No. 220, Dec. 4, 1987, p. 8.
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[14]Pages 61-78 of work cited in footnote 12.
[15]Pages 25-44 of work cited in footnote 12.

Gold

By John M. Lucas[1]

World gold mine production reached its highest recorded level in 1987. U.S. mine production also reached its highest level, registering a strong 33% increase over 1986 production. Nevada was again the principal gold-producing State, having increased pro-

Table 1.—Salient gold statistics

	1983	1984	1985	1986	1987
United States:					
Mine production _ _ _ _ _ thousand troy ounces_ _	2,003	2,085	2,427	r3,739	4,966
Value _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ thousands_ _	$849,071	$751,833	$771,032	r$1,376,855	$2,224,691
Percentage derived from:					
Precious metals ores_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _	83	87	92	96	91
Base-metal ores _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _	14	11	5	2	6
Placers_ _	3	2	3	2	3
Refinery production:					
Domestic and foreign ores thousand troy ounces_ _	1,972	2,101	2,076	r2,396	3,613
Secondary (old scrap) _ _ _ _ _ _ _ _ _ _ do_ _ _ _	r1,784	r1,769	r1,602	r1,345	2,034
Exports:					
Refined _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ do_ _ _ _	1,881	3,482	2,888	r3,554	2,288
Other_ do_ _ _ _	1,258	1,499	1,078	1,441	1,558
Imports for consumption:					
Refined _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ do_ _ _ _	3,599	6,032	6,361	13,800	2,423
Other_ do_ _ _ _	994	1,837	1,865	1,949	1,420
Gold contained in imported coins[1] _ _ _ _ _ do_ _ _ _	1,948	2,769	2,064	1,101	1,084
Net deliveries from foreign stocks in Federal Reserve Bank _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ do_ _ _ _	-220	381	484	4,692	3,059
Stocks, Dec. 31:					
Industry[2] _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ do_ _ _ _	r611	r752	r596	r925	732
Futures exchange _ _ _ _ _ _ _ _ _ _ _ _ do_ _ _ _	2,530	2,359	[3]2,110	[3]2,809	[3]2,625
Department of the Treasury:					
American Eagle gold coin sales _ _ _ _ do_ _ _ _	--	--	--	r [4]2,212	1,481
Bicentennial of the U.S. Constitution coin sales _	--	--	--	--	[5]203
Gold medallion sales[6] _ _ _ _ _ _ _ _ _ _ do_ _ _ _	634	419	48	([7])	--
Olympic gold coin sales _ _ _ _ _ _ _ _ _ do_ _ _ _	--	[8]156	24	([9])	--
Statue of Liberty gold coin sales_ _ _ _ do_ _ _ _	--	--	[9]121	([10])	--
Consumption in industry and the arts_ _ _ do_ _ _ _	r3,078	r3,140	r3,097	r3,126	3,228
Price:[11] Average per troy ounce _ _ _ _ _ _ _ _ _ _ _	$424.00	$360.66	$317.66	$368.24	$447.95
Employment[12] _	6,500	6,900	6,900	r8,300	11,100
World:					
Mine production _ _ _ _ _ thousand troy ounces_ _	r45,163	r46,827	49,184	p51,620	e52,481
Official reserves[13] _ _ _ _ _ _ million troy ounces_ _	r1,143.5	r1,142.5	r1,145.2	r1,145.5	1,143.9

eEstimated. pPreliminary. rRevised.
[1]Calculated by the Gold Institute from reports by the Bureau of the Census.
[2]Unfabricated refined gold held by refiners, fabricators, dealers, and U.S. Department of Defense.
[3]Commodity Exchange Inc. only. Stocks held by other exchanges estimated to be less than 2% of totals shown.
[4]Sales program began Oct. 20, 1986.
[5]Sales program began July 1, 1987.
[6]Sales program began July 15, 1980.
[7]No sales. No action was taken on the reauthorization bill by the 99th Congress.
[8]Includes coins sold in 1982 and 1983 for delivery in 1984.
[9]Authorization sales program fulfilled in 1985.
[10]Sales completed by yearend 1985 for delivery in early 1986.
[11]Engelhard Industries quotation.
[12]Mine Safety and Health Administration.
[13]Held by market economy country central banks and governments and international monetary organizations.
Source: International Monetary Fund.

duction more than tenfold since 1979. The overall demand for gold for use in fabricated products in the market economy countries declined from the level of 1986 partly because of a drop in coinage in Japan. Gold continued to be used in high-technology applications, especially in the aerospace and electronics industries.

Despite an apparent excess of supply over identifiable demand, the firmness of the price during the year suggested that the surplus had been easily absorbed by investors, especially in Europe and North America.

Table 2.—Volume of U.S. gold futures trading

(Million troy ounces)

Exchange	Location	1983	1984	1985	1986	1987
Chicago Board of Trade	Chicago	10.15	9.73	5.42	4.00	8.074
Commodity Exchange Inc	New York	1,038.28	911.55	788.40	842.96	1,029.31
International Monetary Market[1]	Chicago	99.40	.88	(2)	(2)	26.16
MidAmerica Commodity Exchange	do	11.59	2.02	1.04	.70	.65
Total		1,159.42	924.18	794.86	847.66	1,064.19

[1]A division of the Chicago Mercantile Exchange.
[2]Less than 1,000 ounces traded. Trading ceased July 10, 1985, and resumed June 16, 1987.

Domestic Data Coverage.—Domestic mine production data for gold are developed by the Bureau of Mines from two separate, voluntary surveys of U.S. operations. Typical of these surveys is the lode-mine production survey of copper, gold, lead, silver, and zinc mines. Of the 555 lode gold operations to which a survey request was sent, 69% responded, representing 95% of the total lode-mine production of gold shown in tables 6 and 7. Production for the nonrespondents was estimated using reported prior year production levels, adjusted by trends in employment and other guidelines such as company annual reports, the news media, and State agency reports.

Legislation and Government Programs.—As required by legislation enacted in 1986, up to 1 million $5 gold coins, each containing 0.24 ounce[2] of gold, were to be minted to commemorate the Bicentennial of the U.S. Constitution. The first of these coins was struck on July 1.

Legislation to mint 1 million gold coins, each containing 0.24 ounce of gold, and 10 million silver coins, each containing 0.77 ounce of silver, commemorating the 1988 Olympic games, was approved as Public Law 100-141. Both coins were to be legal tender. The coin prices were to be established by the U.S. Department of the Treasury. They were to include a surcharge of $35 on each gold coin and $7 on each silver coin, to be used to support the training of present and future U.S. athletes in the 1988 Olympic games. A sunset provision was to terminate minting activity on June 30, 1989.

DOMESTIC PRODUCTION

Numerous properties were brought into production and decisions to expand production capacity were implemented at a number of existing mines. A large percentage of the new mines beginning or planned were to employ heap-leaching and recovery techniques pioneered by the Bureau of Mines.

Of the 4.9 million ounces of gold produced in the Nation, 76% was attributable to the 25 leading producers. The average recoverable gold content of precious metals ores processed from lode mines was 0.05 ounce per short ton, while placer gravels yielded an average of 0.03 ounce per cubic yard washed.

The revisions in domestic refinery production data for 1983-87 shown in table 10 reflect the inclusion of newly reported data and account more accurately for the contribution of several existing refineries, plus the addition of some previously unreported metal of both primary and secondary origin.

Table 3.—Mine production of gold in the United States, by State

(Troy ounces)

State	1983	1984	1985	1986	1987
Alaska[1]	39,523	19,433	44,733	48,271	86,548
Arizona	61,991	54,897	52,053	W	95,240
California	38,443	85,858	187,813	425,617	602,605
Colorado	63,063	60,010	43,301	120,347	178,795
Idaho	W	W	44,306	70,440	97,773
Michigan	--	--	W	W	W
Montana	161,436	181,190	160,262	W	234,365
Nevada	960,657	1,020,546	1,276,114	r2,098,980	2,679,470
New Mexico	W	W	45,045	39,856	W
North Carolina	--	--	--	12	--
Oregon	322	W	W	W	W
South Carolina	--	--	W	W	W
South Dakota	309,784	310,527	356,103	W	W
Utah	238,459	W	135,489	W	W
Washington	W	W	W	W	W
Total	2,002,526	2,084,615	2,427,232	r3,739,015	4,966,382

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

[1]These figures, reported to the Bureau of Mines, probably understate production. Data collected by the State indicate production to have been as follows, in troy ounces: 1983—169,000; 1984—175,000; 1985—190,000; 1986—160,000; and 1987—230,000.

Alaska.—Despite continuing conflict between environmentalists and Alaska's small- and medium-size placer miners during 1987, placer mine production, which accounted for 97% of the State's gold production, increased for the fourth consecutive year. The quantity of gold produced in Alaska and reported to the Bureau of Mines increased by nearly 80% over that reported in 1986. However, an informal annual survey of Alaska's gold producers, begun several years ago by the Alaska State Division of Geological and Geophysical Surveys (DGGS), again suggested that a much larger quantity, nearly 230,000 ounces, had actually been produced. This figure compares with similarly derived figures for 1982-86 of 174,900, 169,000, 175,000, 190,000, and 160,000 ounces, respectively. The value of 1987 production was estimated by the State at nearly $105 million, up 71% over the 1986 estimate. The DGGS, in its annual review of mining activity in the State, cosponsored by the Alaska Division of Business Development, noted that the production increase was the result of increased production from a few major operations, offsetting a reduction in the number of small placer operations.[3] Expenditures for exploration, development, and production, a large portion of which was for precious metals, together increased 37%. Direct employment increased by 349 jobs to nearly 3,000. There were 202 mechanized placer mines and 3 lode mines reportedly in operation in Alaska during 1987. There was a significant decrease in the number of small placer mines from 1985 through 1987. Many small family-operated mines were squeezed out of business, reportedly because of regulatory and legal problems.

According to the State review, the number of small placer mines in Alaska declined by 27% during 1987. The most severe constraint on small miners in 1987 was a court injunction that prohibited the Bureau of Land Management (BLM) from allowing placer mines to disturb more than 5 acres of land on four major State drainages until BLM completes cumulative environmental impact statements and other assessments on the land in question. The injunction was a result of a lawsuit brought by the Sierra Club against BLM. It was expected to halt some placer mining in key interior Alaska mining districts for 1 to 3 years. Also during the year, the Corps of Engineers was directed to begin developing a permit process for Alaskan placer mines starting in 1988. The Corps of Engineers is responsible for permitting activities on all wetlands, regardless of ownership.

Other difficulties facing Alaskan miners were continuing water-quality problems and a legal challenge by a coalition of environmentalists and native groups challenging the mining claim location and leasing system of Alaska. The Governor directed State agencies to develop an acceptable plan regarding water quality before the 1988 mining season to protect the rights of both placer miners and other water users.

The Valdez Creek Mine, a placer gold mine owned by Valdez Creek Mining Co. Inc., a consortium of Canadian firms, was the State's largest gold producer for the fourth consecutive year. According to published data, the mine, off the Denali Highway near Anchorage, produced more than 32,000 ounces of gold. By modifying its open pit mining technique, and by using a winter-protected screening plant and sluice box recovery system, the company determined in 1987 that it could reliably operate throughout the winter at temperatures as low as -25° to -35° F. Near Nome, the Alaska Gold Co., 85%-owned by Sharon Steel Corp., operated its No. 5 and No. 6 floating bucketline dredges during the season, processing about 1.4 million cubic yards of gravel. This amount is nearly double the quantity processed in 1986, when only one dredge was being used. In Norton Sound, offshore Nome, Western Gold Exploration and Mining Co. Ltd. Partnership (WestGold), 50% held by Inspiration Gold Inc., completed a successful first season of offshore mining with its mining vessel, the *BIMA,* recovering 36,600 ounces of gold. Also near Nome, the Windfall Gold Mining Co. again operated its Copper Gulch open pit, stripping 270,000 cubic yards of overburden and sluicing an estimated 630,000 cubic yards of gravel.

Callahan Mining Corp., owner of 79.5% of Livengood Placers Inc., which mines properties 60 miles north of Fairbanks, reported that its contract operator recovered nearly 2,800 ounces of gold in 1987 from previously worked areas. Work during the 1987 season concentrated on higher grade ore pockets encountered in the bottom of the pit. The contractor stripped 585,000 cubic yards of overburden to prepare another area for sluicing during the 1988 season, from which 3,000 ounces of recovery was expected.

At Ester Dome near Fairbanks, the Grant gold mine of Silverado Mines Ltd. was reopened in December, following a nearly 2-year redevelopment period during which operations were converted from underground to open pit mining. Gold recovery at the mine's 250-ton-per-day mill and carbon-in-pulp recovery plant reportedly was running at about 94% by yearend. Contiguous to the Grant pit is the Ryan Lode property owned by Citigold Alaska Inc., a subsidiary of La Teko Resources Ltd. of Canada, where the owners completed their first full year of a full-scale heap-leaching test. The operation reportedly reversed the conventional heap-leaching procedures customarily used in the lower 48 States, such as Nevada, by using heap leaching to process small tonnages of high-grade ore rather than a large tonnage of low-grade ore. About 6,100 ounces of doré reportedly was recovered by La Teko in 1987, making it the State's largest lode gold producer.

The $82 million Greens Creek Mine on Admiralty Island was scheduled to begin production at the rate of 84,000 tons per year of silver-gold-lead-zinc-bearing concentrates in September 1988. In addition to 6.4 million ounces of silver, the mine was expected to yield 36,000 ounces of gold per year and employ a workforce of about 250. The mine was being developed by Amselco Minerals Inc. and its partners Hecla Mining Corp., CSX Oil and Gas Corp., and Exalas Resources Corp.

Exploration for gold continued in many areas of the State. On Chichagof Island, Golden Sitka Resources Inc. continued exploration at the Hirst-Chichagof underground mine. At the old Alaska-Juneau Mine at Juneau, once the largest gold mine in the Nation, Echo Bay Mines Ltd. continued underground exploration, reserve development, and evaluation with the possibility of beginning production in mid-1991. Echo Bay and Coeur d'Alene Mines Corp. also acquired the Kensington Mine near Berner's Bay, 50 miles north of Juneau. Plans called for an evaluation and feasibility period lasting into early 1989.

A report prepared by the Bureau of Mines described the history, characteristics, and mineral development potential of 21 lode gold deposits in or near the Chugach National Forest of Alaska. It includes findings from a recent 4-year mineral evaluation of the forest conducted by the Bureau and the U.S. Geological Survey. Of the 21 lode deposits described, 14 contain a combined identified resource of 117,750 tons averaging 0.55 ounce of gold per ton and 0.2 ounce of silver per ton.[4] In another report the Bureau estimated the remaining lode gold endowment of eight Alaskan mining districts using historic production data. To assess the remaining endowment, a computerized production data base was compiled from Bureau records. Based on a conservative extrapolation of grade-tonnage curves generated by the study, a substantial total endowment of 8.4 million ounces remained in the eight districts. The Chichagof, Fairbanks, Juneau, and Willow Creek Districts have the greatest remaining endowment.[5]

Arizona.—Higher prices for gold, especially during the last three-quarters of the year, reportedly led to a significant increase in exploration activity in the State, with gold or gold and silver listed as the objective of 29 out of 33 projects undergoing exploration during the year.

In La Paz County, Cyprus Copperstone Gold Corp. produced the first gold from its new $13.9 million Copperstone Mine in

November. Copperstone produced about 6,000 ounces of gold in 1987 and more than 60,000 ounces was expected in 1988. Surface mine life, based on currently known open pit reserves of 510,000 total contained ounces, was estimated at 6 years. Gold ore reserves were 6 million tons containing an average of 0.085 ounce of gold per ton. Drilling around and under the current open pit area revealed higher grade ore that may be obtained through underground mining.

Three properties in advanced stages of exploration and development were Ivy Mineral Inc.'s Gold Bug Mine, 30 miles northwest of Chloride in Mohave County, and Echo Bay's Congress Mine and Stan West Mining Corp.'s McCabe Mine, both in Yavapai County, southeast of Prescott. All three were expected to reach production in 1988.

California.—Gold production in California increased by 41%, reaching its highest level since 1942. Several new mines commenced production in 1987, capacity increases were under way at several operating properties, and several properties were in various preproduction phases ranging from ore reserve confirmation and permitting to final plant construction.

In Imperial County, east of Brawley, the Mesquite Mine of Gold Fields Mining Corp., a wholly owned subsidiary of Consolidated Gold Fields PLC of the United Kingdom, completed its first full year of production. According to Consolidated's annual report, Mesquite's production during the fiscal year, all from heap leaching, amounted to over 180,000 ounces. The necessary permits were being sought to increase ore production from 3.3 million tons per year to nearly 5 million tons annually by mining the nearby Cherokee, Rainbow, and Vista deposits.

At the McLaughlin Mine near Clearlake in northern California, one of the State's largest gold mines, production increased nearly 10% to almost 190,000 ounces at an average cash cost per ounce of $229 compared with $240 in 1986. Homestake Mining Co., one of the Nation's top gold producers, announced that design engineering studies were begun in September on a $25 million expansion program aimed at increasing the annual production rate at McLaughlin by 50,000 ounces by 1989.

On the outskirts of the town of Jamestown in Tuolumne County, Sonora Gold Corp.'s new Jamestown Mine completed its first full year of production. The new open pit, opened on the site of the old Harvard Mine, was designed to yield about 130,000 ounces of gold and 59,000 ounces of silver per year. The mine reportedly contains sufficient reserves to last 14 years at a gold price threshold of $300 per ounce. The mine's new $85 million flotation mill was officially opened in March. To the south in Mariposa County, Goldenbell Resources Inc. continued work on its Pine Tree gold property, a planned 130,000-ounce-per-year open pit scheduled to begin production in late 1988 or early 1989. Sonora and Goldenbell are members of the ABM Mining Group Inc. of Vancouver, British Columbia, Canada.

Other gold mines beginning or resuming production in California during 1987 included the Kramer Hills, Standard Hill, Sixteen-to-One, Goldstripe, Mount Gains, Yellow Aster, and Morning Star. At the Kramer Hills property on the edge of Edwards Air Force Base in San Bernardino County, Beaver Resources Inc. reportedly began full-scale open pit mining in early 1987. Heap leaching was being used for recovery, and plans were formulated to expand the capacity of the property from about 12,000 ounces to 48,000 ounces per year. The company reportedly concluded an agreement with Noranda Exploration Inc. and Hemlo Gold Mines Inc. to explore and develop an adjoining property.

Near the town of Mojave in Kern County, Billiton Minerals USA Inc., a wholly owned subsidiary of Shell Mining Co., began mining at the Standard Hill gold mine in August. Royal Gold Inc. of Denver, CO, began production at two mines in 1987. In July, Royal and its partner, Lucky Chance Mining Co., poured the first gold from the old Sixteen-to-One Mine near Alleghany in Sierra County. This underground mine has been a prolific gold producer periodically since 1896 with estimated total production exceeding 1 million ounces. The partners expected to recover about 14,000 ounces of gold annually from high- and low-grade milling ores as well as small quantities of hand-sorted specimen gold and "jewelry rock" containing visible gold. Royal's second mine to resume work was its recently acquired Goldstripe property in Plumas County near Lake Almanor. Seasonal mining, begun in September at a rate of 1,600 tons per day, was by open pit. Gold was recovered using agglomeration heap leaching. At full capacity, annual production of Goldstripe was expected to be about 20,000 ounces. In early 1987, Royal sold its interest in the Colosseum Mine in San Bernardino County to Colosseum California Inc. and Dallhold Investments Pty. Ltd. of Perth, Western Australia. In Mariposa County, Mount Gains Resources Inc., using heap leaching, reportedly produced about

3,000 ounces of gold from tailings and ore mined from the underground workings at the old Mount Gains Mine. Near yearend, Terramar Resources Corp. of Vancouver, Canada, was negotiating with the owners to gain control of the property. Glamis Gold Inc. reported that the first gold was poured at its Yellow Aster Mine near Randsburg in Kern County from production on the Lamont zone. Production on the Descarga dumps was ready to begin at yearend. The Lamont and Descarga were to feed the system for about 2 years, during which time the main Yellow Aster ore body was to be permitted and phased into production. Glamis' other California Mine, the Picacho in eastern Imperial County, yielded 24,000 ounces during the fiscal year ending October 31. In San Bernardino County, Vanderbilt Gold Corp. completed its first year of mining at its Morning Star open pit and heap-leaching facility.

Properties under development and nearing production during the year included the Snow Caps open pit and heap-leaching operation in Inyo County, belonging to Sunshine Mining Co. and First Sierra Assets Inc.; and the Bagdad-Chase Mine of Bentley Resources Ltd. in San Bernardino County. In the same county, Viceroy Resources Corp. moved toward an early 1988 startup at its Castle Mountain property in the Hart Mountains; Alpine County's Zaca Mine, owned by Pegasus Gold Inc. and California Gold Mines Ltd., was expected to begin production within 2 years.

Colorado.—In Rio Grande County, the Summitville Mine, an open pit heap-leaching operation, completed its first full year of production. Galactic Resources Ltd. of Vancouver, Canada, reported that gold produced through the third quarter of 1987 amounted to nearly 60,000 ounces. At a recovery rate of greater than 10,000 ounces per month toward yearend, gold produced by the end of the leaching season in November amounted to over 88,000 ounces, thus making Summitville by far the State's largest gold producer.

The State's second largest mine, the Sunnyside gold mine in San Juan County, also completed its first full year of production under its new owner, Echo Bay, which had extensively refurbished the mine. Sunnyside, at Silverton, operated by Echo Bay's wholly owned subsidiary, Sunnyside Gold Corp., produced over 47,000 ounces of gold and over 446,000 ounces of silver in 1987. In an effort to reduce production costs, the owners reportedly devoted 1987 to modernizing equipment, increasing productivity, and developing more underground areas.

Golden Cycle Gold Corp. of Colorado Springs reported that, with its partner, Texasgulf Minerals and Metals Inc., working together under a joint venture named Cripple Creek and Victor Gold Mining Co., more than 28,000 ounces of gold was recovered from a continuing dump-leaching operation known as the Mine Dump Project. Heap leaching has been employed in the project since 1984 to recover gold from mine dumps in the Cripple Creek area of Teller County. Texasgulf, a subsidiary of Société National Elf Aquitaine, a French corporation, was manager of the partnership. The company continued exploration of its Minerex area in Teller County, and a decision was made to move ahead with the construction of a new open pit and heap-leaching project, also in Teller County, known as the Portland area. By yearend 1987, work on the Portland area included the partial construction of a leach pad and the mining and stockpiling of 120,000 tons of ore bearing an average grade of 0.8 ounce of gold per ton. An estimated 16,100 ounces was to be recovered from the Portland area in 1988. The partners also constructed a new 150-ton-per-day mill designed to incorporate portions of their existing Carlton mill while providing capacity to handle a wider range of ore grades. Work was also under way to develop another Teller County property named the Proper Stopes. Included on the property were the old Chicago Tunnel and Poverty Gulch areas. Underground mining was expected to yield nearly 4,000 ounces during 1988. Another old gold-producing mine, the Camp Bird Mine, was being reopened near yearend by Chipeta Mining Corp., and several partners collectively known as the Camp Bird Venture. Chipeta, wholly owned by Western Mining Corp. Holdings Ltd. of Australia, owns 76% of the venture. The partners expect to recover about 10,000 ounces of gold during the 1987-88 fiscal year.

In Gilpin County near Idaho Springs, Franklin Consolidated Mining Co. Inc. in a joint venture with Consolidated Knobby Lake Mines Ltd. of Vancouver, Canada, reportedly reopened the old underground Franklin Mine. Toward yearend, mining and milling were reportedly progressing at a rate of nearly 100 tons of ore per day. In Gunnison County, Great West Gold and Silver Inc. reportedly began heap leaching at its Vulcan (Good Hope) property.

The Leadville Corp. began construction of a production facility at the Diamond shaft site on its Resurrection Mine near Leadville in Lake County. When completed in mid-1988, the property was expected to produce about 30,000 ounces of gold per year. In the

Alma mining district of Park County, Cobb Resources Corp. negotiated a joint venture agreement with Boulder Gold Inc. of Australia for the purpose of returning the old London gold mine to productive status. At yearend, surface and underground development and engineering studies were under way and the construction of a new 500-ton-per-day mill was being considered. Battle Mountain Gold Co. (BMG) acquired the San Luis project in Costilla County. Subsequent drilling and examination of the property confirmed estimated proven and probable minable reserves of about 390,000 ounces of gold. BMG planned to bring the property into production in 1989 at an annual rate of 40,000 ounces of gold. Exploration and preproduction development continued on a number of other properties throughout Colorado.

Idaho.—Data contained in a review prepared by the Idaho Geological Survey[6] indicated that the value of gold production in that State rose by nearly 74% over that of 1986 and the number of exploration projects, mostly for gold, increased to 61 in 1987 from 38 in 1986, with epithermal-type disseminated gold deposits reported to be the principal targets.

During the year, a task force composed of industry, government, and conservation groups drafted the first modern regulations in the United States governing the use of cyanide in mining. The rules were designed to safeguard against accidents involving the use of cyanide, especially in heap leaching. State approval of the proposed regulations was pending at yearend.

The State's largest gold mine, the Pioneer Metals Corp.-TRV Minerals Corp.-Mining Finance Corp.'s Stibnite-West End Mine, a seasonal open pit and heap-leaching operation south of Yellow Pine in Valley County, produced over 30,000 ounces of gold during the year. Hecla signed an agreement with Pioneer for the latter to process oxidized gold-bearing tailings material from the old Yellow Pine tungsten and antimony mine near Stibnite. Pioneer was to begin processing the material in 1988. During the term of the agreement, 1988-91, about 25,000 ounces of gold was expected to be credited to Hecla's account.

Coeur d'Alene Mines completed its first full year of production at its new Thunder Mountain Mine in eastern Valley County. This open pit heap-leaching facility, which operated from May through October, yielded more than 27,000 ounces of gold during 1987. The mine was selected by the Pacific Northwest Pollution Control Association as the Idaho recipient of the association's 1987 State Industrial Pollution Control Award.

Nerco Inc.'s Delamar silver and gold mine in Owyhee County produced 30,200 ounces of gold and 1.7 million ounces of silver in 1987. A new heap-leaching facility to be used in tandem with the existing agitation-leach recovery system was added in 1987. The addition was designed to recover an additional 65,000 ounces of gold and 1.4 million ounces of silver from lower grade ore over the next 7 years.

In the Yankee Fork mining district, U.S. Antimony Corp. (USAC) continued to operate its 300-ton-per-day flotation and cyanide leach mill at Preacher's Cove near Yankee Fork on the Salmon River. Feed for the mill is derived from USAC's properties on Estes Mountain and near Custer, plus shipments of ore from small miners delivered for custom milling. Exploration and geological studies by USAC at its Custer pit reportedly suggested the presence of a substantial ore body. Open pit mining on the company's Yellow Jacket property southwest of Salmon began in July. Detailed drilling at the Valley Creek property near Stanley was under way to test the possibility of an open pit mine. Also near Stanley, Sunbeam Mining Co., a subsidiary of Geodome Resources Ltd., was in the permitting stage toward opening its open pit Sunbeam (Jordan Creek) Mine and vat-leaching mill. Sunbeam anticipated recovery of 40,000 to 50,000 ounces per year when production begins in 1988.

Near the town of Bridge in Cassia County, Noranda Inc. submitted a mine development proposal to the U.S. Forest Service outlining its plan to develop a small heap-leaching operation in the Black Pine Mountains. If approved, the Black Pine Mine would begin production in 1988, mining from three small open pits. Other properties under development by other companies include the Robinson Dyke and Buffalo Gulch Mines, both near Elk City, and the Atlanta gold mine at Atlanta Hill. A dozen or so placer mines were also operated during the year. The largest, situated near Lucille, was by A & T Mining.

Montana.—At least three gold mines commenced production in 1987 while several others had been proposed or neared a projected 1988 startup. Fewer new applications for exploration were filed in 1987, according to a State report summarizing mining and mineral developments in Montana during 1987,[7] but applications for renewals increased while drilling activity and performance also increased. Exploration apparently shifted during the year from basic prospecting to work aimed at proving the worth of earlier discoveries.

Pegasus acquired a 100% working interest in the developing Montana Tunnels property in Jefferson County from its partner in the venture, U.S. Minerals Exploration Co. Pegasus reported that 1987 production at the open pit gold-silver-zinc-lead mine amounted to 31,000 ounces of gold, 529,000 ounces of silver, 8.6 million pounds of lead, and 14.4 million pounds of zinc. The company forecast 1988 gold production at 85,000 ounces. Expansions at Pegasus' other Montana gold mine, the Zortman-Landusky open pit heap-leaching facility in Phillips County, reportedly led to the production of 106,900 ounces of gold and nearly 203,000 ounces of silver from over 9.6 million tons of ore mined and loaded for leaching. Gold production during 1986 was about 86,000 ounces. The 1987 expansion included the addition of a new carbon adsorption plant and improvements that extended the leaching season to 11 months. Following 4 years of exploration and engineering studies at its Beal project near Fairmont Springs, Silver Bow County, Pegasus announced that development was initiated toward a 1988 startup. The new open pit heap-leaching operation was expected to produce 35,000 ounces of gold annually.

The State's second largest gold mine, Placer Dome U.S. Inc.'s Golden Sunlight Mine at Whitehall, reportedly produced nearly 90,000 ounces of gold and 300,000 ounces of silver in 1987. A new $4.5 million sand tailings treatment plant contributed 6,700 ounces to the overall recovery at the Jefferson County facility. A slight decline in production from that of 1986 reportedly related to lower grade ore encountered when systematic mining was shifted to another area of the ore body.

In Fergus County, the Appaloosa Joint Venture, consisting of Chelsea Resources Ltd. and Cimarron Exploration Inc., poured its first gold at the Spotted Horse Mine during August. Head grades entering the 50-ton-per-day cyanide mill were reportedly expected to average over 1.0 ounce of gold per ton.

At the Jardine Joint Venture in Southern Park County, equal partners Homestake and American Copper and Nickel Co. Inc. completed an underground exploration and engineering studies program and moved toward construction of an underground mine capable of producing 42,000 ounces per year when production begins in mid-1989.

The State reported that placer mining activity was widespread during 1987, but that many small operations were forced to shut down early owing to a lack of water. Nevertheless, placer operations were reportedly conducted along the following drainages: Grasshopper Creek near Bannack, Quartz Creek east of Superior, Sauerkraut Creek near Lincoln, Washington Gulch southeast of Avon, and Brown's Gulch west of Nevada City. Indian Creek west of Townsend was the site of the largest concentration of placer operations.

In addition to the developed and developing mines outlined above, exploration and/or preproduction development was conducted on numerous properties including the Hog Heaven project in Flathead County; Chartam Mine in Broadwater County; Lincoln project (Big Blackfoot), Cruse-Belmont; Pauper's Dream Mines in Lewis and Clark County; Tzarena and Rainbow projects in Silver Bow County; Bagdad Mine in Granite County; Elkhorn Mine in Jefferson County; and the Gold Coin Mine in Deer Lodge County.

Nevada.—In 1987, 13 of the 25 leading domestic gold mines were in Nevada. That State has registered a tenfold increase in gold production since 1979. The increased precious metals mining and exploration activity, combined with the associated growth of the parallel service industry has, for some communities, reportedly begun to strain the capacity of existing community services in some areas. According to State data, employment in the precious metals sector had increased from about 4,100 in 1983 to more than 5,900 by late 1987.

Some of the gold mines reported to have begun or resumed production in 1987 include the Chimney Creek Mine of Goldfields Mining Corp., the Gold Bar Mine of Atlas Gold Mining Inc., the Lewis Mine owned by Hycroft Resources & Development Corp., the Illipah Mine of Echo Bay, the Tuscarora (formerly Dexter) Mine of Horizon Gold Shares Inc. and Fischer-Watt Gold Co., the Big Springs Mine belonging to Freeport-McMoRan Gold Co. and FMC Gold Corp., the Kingston (Victorine) Mine of Nevada Goldfields Corp., the Silver Sun project of the Federal Claim Staking Agency Inc., and the Surprise Mine owned by BMG.

The Chimney Creek Mine in Humboldt County began production in December at an annual rate of 150,000 ounces per year. Open pit mining with milling, heap-leaching, and carbon-in-pulp recovery is employed. The Atlas Gold open pit Gold Bar Mine began mining in January 1987 and poured its first gold in January 1988. Gold recovery was by milling and heap leaching followed by agitated carbon-in-leach recovery. Production at this Eureka County mine was expected to be 45,000 to 50,000 ounces per year. Atlas Gold reported that exploration and drilling on its Gold Bar block several miles northeast of the mine revealed several areas containing gold mineralization. Vancouver, British Columbia-based Granges Exploration Ltd.'s Lewis Mine and the adjoining Crofoot Mine (also controlled by Granges Ltd.) in Humboldt County were expected to yield a combined 80,000 ounces per year. The Lewis began production in June and the Crofoot, under construction at yearend, poured its first gold bar in early 1988. The open pit Illipah Mine, Echo Bay's seventh gold mine in North America, began production in October and was expected to yield 30,000 ounces per year. The mine, in White Pine County, recovers gold using heap-leaching and carbon-in-pulp methods. The Tuscarora Mine at the town of Tuscarora in Elko County is an open pit and heap-leaching operation with an estimated annual production rate of 5,000 to 14,000 ounces. It began production in November.

In Elko County, Freeport-McMoRan's Big Spring Mine, consisting of two open pits with heap leaching, produced its first gold in October. At the company's Jerritt Canyon Mine nearby, mill throughput was increased by 13%. Combined with improved recovery, this increase resulted in a 17% increase in 1987 gold production to 316,000 ounces. The Jerritt Canyon operation consisted of two open pits. A third pit was due to be opened in 1988. In addition to milling, heap leaching is also employed to effect recovery from lower grade ore. Nevada Goldfields, a wholly owned subsidiary of Golconda Minerals NL of Western Australia, completed construction of its 600-ton-per-day mill at the Kingston project in Lander County. It poured its first gold in April. The newly reopened underground operation was expected to yield 49,000 ounces in 1988. At the company's Aurora Mine in Mineral County, construction of a new 300-ton-per-day mill was completed in December. Open pit and underground mining were used to effect an expected yield of 81,000 ounces of gold and 193,000 ounces of silver over the next 5 years. In August, BMG placed its new Surprise Mine into production. Surprise was the first of a number of satellite ore bodies to be developed at the company's Fortitude Mine in Lander County. The combined 1987 output from the Fortitude and Surprise was about 257,000 ounces. Cash costs at the BMG operation amounted to $121 per equivalent ounce (with byproduct silver converted to equivalent ounces of gold) in 1987. This compares with $144 per equivalent ounce in 1986 and $177 in 1985. The Silver Sun project near Silver Peak in Esmeralda County reportedly began heap leaching in late May.

Favorable gold prices and continued successes with exploration aimed at expanding ore reserves encouraged a number of companies to expand their production capacity. In its 5-year business plans Newmont Gold Co. (NGC), the Nation's largest gold producer in 1987, began a new $400 million capital investment program to substantially increase production at its Carlin gold properties in Eureka County. A planned 50% increase in production to 930,000 ounces of gold in 1988, reaching 1.6 million ounces in 1991, will be sustained from open pit ore deposits now under development. The planned gain in gold production will result from expansions of the two existing mills at NGC's property, completion of a third mill and a leach facility now under construction at the Rain ore body, and construction in 1988-89 of a fourth mill in the northern area of the 400-square-mile property in northeastern Nevada in 1988-89. Leaching of low-grade ore will also be expanded from the current 8 million tons per year to more than 20 million tons per year. During 1987, NGC, processing newly mined and stockpiled ore, produced 589,000 ounces of gold from its Carlin area mines. Near yearend, NGC announced a significant increase in its gold reserves to 15 million ounces from 12.3 million ounces reported at yearend 1986. Exploration drilling in the Deep Post ore body in the northern area of its property and below the shallow ore body at Post encountered mineralization that assayed 0.93 ounce per ton over an interval of 470 feet. This hole, one of several 2,000-foot-deep holes drilled at Deep Post, reportedly provided the richest drill-hole assay over so long an interval in the history of exploration in NGC's vast Nevada holdings.

At the Round Mountain Mine in Nye County, the mine's owners, Echo Bay, Homestake, and Case Pomeroy & Co., announced plans to double the mine's output to 300,000 ounces per year by 1989 at a cost of $140 million. Round Mountain, reportedly the world's largest heap-leaching operation, produced nearly 191,000 ounces in 1987. In White Pine County, Amselco Minerals and Nerco Minerals Co. disclosed plans to construct a new 1,000-ton-per-day mill to process the carboniferous ore fraction segregated during operation at the ongoing 60,000 to 100,000-ounce-per-year Alligator Ridge Mine.

In Humboldt County, AMAX Inc. initiated a $14 million expansion program at its

Sleeper Mine. The expansion, when completed in 1988, was expected to boost annual gold production by about 40% to almost 200,000 ounces. Components of the expansion include the addition of a second open pit and a large increase in heap-leaching capacity. Near yearend, Silver State Mining Corp. announced plans to triple gold production at its Nevada mines. In addition to a new 16,000-ounce-per-year mine scheduled to begin in White Pine County in 1988, the company plans to expand the existing operations at its Tonkin Springs Mine in Eureka County to produce 50,000 ounces per year. Part of the expansion was to include the construction of the Nation's first commercial bioleaching facility. The new facility, under construction at yearend, was designed to exploit the mine's substantial reserves of gold contained in sulfide mineralization. Silver State also holds a 29.3% interest in the Dee Mine, a 50,000-ounce-per-year producer in Elko County.

As geologists learn more about the characteristics and occurrence of gold deposits in Nevada, their discovery rate continues to grow. Exploration along the so-called Carlin trend or gold belt, a highly mineralized zone extending northwest through and beyond NGC's Elko County deposits, led in 1987 to several significant discoveries, including NGC's Deep Post ore body mentioned above. Exploration and deep drilling on the adjoining Goldstrike property owned by American Barrick Resources Corp. led to the discovery of a major deep-seated, high-grade, gold-bearing sulfide deposit. The result was to increase Barrick's Goldstrike reserves from 625,000 ounces to 10 million ounces or possibly more. The deep deposit underlying the Goldstrike operations, where over 40,000 ounces was produced by heap leaching of low-grade surface deposits during 1987, has been designated as the Betze-Post deposit. Because this deposit extends to the southeast onto NGC land, the two companies have concluded a mutual layback agreement. Negotiations were under way at yearend for the joint mining of the new discovery. Forty miles to the southwest, another apparent gold belt paralleling the Carlin trend extends through the area hosting the Gold Bar and Tonkin Springs Mines northwestward through numerous other properties including Battle Mountain's Fortitude deposits. As if to lend additional support for the existence of a second gold belt, reportedly called the Battle Mountain trend, Echo Bay announced in early 1987 that exploration on its McCoy property near Battle Mountain had located a large deposit of precious metals. Incomplete exploration of the find, known as the Cove discovery, had by yearend demonstrated ore reserves bearing 2.1 million ounces of gold and 97.7 million ounces of silver. Before the end of 1987, Echo Bay had opened a surface mine on the lower grade open portion of the Cove deposit and heap leaching of the ore was under way at yearend. Cove reportedly will eventually consist of both an open pit and an underground mine. Construction of a new mill to process ore from both the McCoy and the Cove was also under way at yearend.

New Nevada gold mines completing their first full year of production included the Hog Ranch, Weepah, Austin Gold Venture, Paradise Peak, Florida Canyon, Relief Canyon, Sleeper, and McCoy.

Oregon.—Gold mining and exploration in Oregon during 1987 increased over that of 1986, according to a summary report prepared by the Oregon Department of Geology and Mineral Industries.[8]

There were 20, mostly small, lode and placer mines producing gold during 1987. Active lode mines included the following: the Virtue, Lower Grandview, Golden Eagle, Iron Dyke, and Gold Ridge in Baker County; the Greenback and the Gold Blanket in Josephine County; the Maid of the Mist in Jackson County; the Oregon King (a heap-leaching operation) in Jefferson County; the Pyx in Grant County; and the Ruth in Marion County. The largest of these mines, the Iron Dyke of Silver King Mines Inc., reportedly produced 15,000 tons of copper-gold-silver ore that was trucked to the Silver King mill at Cuprum, ID.

Active placer mines included the Bonanza Creek Co. placer on Pine Creek in Baker County, the State's largest placer operation. Goldwater Inc.'s placer, also on Pine Creek, reportedly has been active for about 6 months per year for several years. The Broken Pick placer has also been recovering gold for several years in Baker County. Small placer operations were also active along Josephine Creek, Sucker Creek, Coyote Creek, Lower Grave Creek, and Galice Creek, all in Josephine County; and along Coffee Creek in Douglas County.

An epithermal deposit undergoing extensive exploration and drilling was the Quartz Mountain gold property in Lake County near the California border, where Quartz Mountain Gold Corp. and Galactic Resources had reportedly drilled 460 holes by yearend. Five high-grade areas were reportedly delineated within two separate deposits: the Crone Hill deposit and the Quartz Butte deposit. Drill-proven and probable reserves on the property were reported to be in excess of 2.0 million ounces at yearend. The company also had several other nearby deposits under investigation at yearend.

South Carolina.—In Chesterfield County near Jefferson, Westmont Mining Inc., a Denver, CO-based subsidiary of the Costain Group PLC of the United Kingdom, reportedly poured its first gold in August following earlier heap-leaching tests at its recently reopened Brewer Mine. The open pit Brewer is one of several permitted gold mines in the State. Westmont began heap leaching in late November and expected to recover 150,000 ounces of gold during the planned 6-year life of the mine. Plant and equipment costs reportedly totaled about $8 million.

At the Haile Mine in Lancaster County, opened in 1985, Piedmont Mining Corp. reported producing 7,836 ounces of gold and 5,708 ounces of silver from nearly 250,000 tons of ore mined and still being leached at yearend. Exploration at the new open pit heap-leaching mine during the year resulted in a 56% increase in proven and probable ore reserves to about 1.6 million tons averaging 0.056 ounce per ton.

Piedmont also controls the nearby Blackmon Mine and a number of former gold-producing properties in southern North Carolina. In 1987, Piedmont introduced its Piedmont Gold Piece, a one-half ounce, 9999-fine commemorative piece celebrating the rebirth of gold mining in the southeast. Gold for the new medallion was recovered from the Haile Mine.

In August, Ridgeway Mining Co., controlled by BP Minerals America Inc. and Galactic Resources, received the final permits to proceed with construction of its Ridgeway gold mine, 4 miles east of Ridgeway in Fairfield County. An environmental group immediately filed suit challenging the decision by State authorities to issue the permits. At yearend, the case was nearing a resolution that would allow the mine to proceed. In the meantime, construction of the facility began in September and was continuing at yearend. Beginning in late 1988 or early 1989, the 1,800-acre facility was expected to produce 133,000 ounces per year for 10 or more years. Open pit mining with conventional carbon-in-pulp milling and heap leaching will be employed. At a capital cost of about $94 million, the new mine is expected to employ close to 200 people.

Other companies exploring, mostly for gold, in the State included Amselco Minerals, Billiton Exploration, Newmont Minerals Co., St. Joe Gold Inc., Texasgulf, American Copper, Boise Cascade Co., and FMC.

South Dakota.—A task force appointed by the Governor convened to draft new mining rules aimed at enforcing the reclamation of surfaced-mined areas and to supplement laws passed earlier by the State legislature. The State Board of Minerals and Environment passed the draft regulations.

On January 14, the Governor unveiled that State's new gold South Dakota Centennial Medallion. In April, the State entered the gold bullion market with its new 999-fine gold "Bison" medallion. The gold for both pieces was mined at the Homestake Mine at Lead.

At the Homestake Mine in Lawrence County, the Nation's largest underground gold mine, Homestake reported milling 2.3 million tons of ore yielding 326,000 ounces of gold. Owing to the installation of a new gravity-separation circuit in midyear, the overall gold recovery percentage was increased slightly from that of 1986. Homestake's average cash costs increased to $328 per ounce from $285 in 1986, chiefly because of a decline in underground ore grade and expenses related to prestripping costs at the mine's Open Cut operation. The Open Cut became fully operational during the year with the startup of crushing and conveying facilities. Underground and surface exploration added 2.9 million tons of ore to reserves, more than replacing ore mined during 1987.

St. Joe Gold announced its intentions to proceed with development of its Richmond Hill gold mine, 5 miles northwest of Lead in Lawrence County. The proposed open pit heap-leaching operation, expected to begin in early 1988, would be mined at a rate of up to 2 million tons per year over a 10-year period.

In midyear, Brohm Resources Inc. began construction of a heap-leaching facility, to be followed by construction of an oxide heap-leaching facility and a conventional milling plant to process sulfide ores at its Gilt Edge Mine near Galena in Lawrence County. Production was expected to begin in July 1988 at a rate of about 42,000 ounces per year.

Also in Lawrence County, Wharf Resources (USA) Inc. reportedly recovered 46,000 ounces of gold at its open pit heap-leaching operation near Terry Peak. In the fall, Wharf added a third heap-leaching pad and was expecting metal recovery to resume in 1988 from the Annie Creek portion of the open pit. Near yearend, the company proposed adding a fourth heap-leach pad, subject to approval of permitting agencies. To the south near Deer Mountain, Golden Reward Mining Co. continued plans to open a $20 million open pit mine at its Golden Reward Property, also scheduled to begin production in 1988.

Goldstake Explorations (SD) Inc. announced its intentions to process about 5 million tons of old gold-bearing tailings along an 18-mile stretch of Whitewood Creek in Mead County south of Whitewood. The operation, using gravity-concentration and leaching-recovery techniques, will be conducted by Goldstake and its partner, Strawberry Hill Mining Co. of Deadwood, SD. Production at an expected rate of about 42,000 ounces per year was scheduled to begin in 1988.

Utah.—Following several years of an ongoing $400 million modernization project due for completion in mid-1988, the giant Bingham Canyon Mine, near Salt Lake City, completed its first full year of copper and byproduct gold and silver production. The mine was the Nation's sixth largest gold producer in 1987. The mine's owner, BP Minerals, expects, upon completion of the modernization program, to produce annually 300,000 ounces of gold, 2.3 million ounces of silver, 190,000 tons of copper, and 12 million pounds of molybdenum.

Gold production from the Mercur Mine, near Tooele, was over 108,000 ounces in 1987. Dump leaching contributed nearly 11,500 ounces of production to the total. Mercur's average cash cost in 1987 was $216 per ounce, compared with $199 per ounce in 1986. The higher 1987 costs were attributed to treatment of marginally lower grades during the year. In 1987, the mine's owner, Barrick, spent over $17 million on the construction of a 750-ton-per-day autoclave circuit, to treat refractory ore, plus other improvements to the overall operations. Gold recovery from the mine's refractory ore fraction using the new autoclave reportedly will be increased to over 85%. During the year Barrick acquired a 50% interest in the Barney's Canyon area, 20 miles to the north. Favorable exploration there in 1987 by Barrick and its partner Royal Minerals Inc. was to be followed by drilling in 1988.

Tenneco Minerals Co. reportedly planned to reenter the precious metals mining business by developing its Goldstrike project in the Bull Valley mining district of Washington County. Tenneco sold its Nevada gold properties: Borealis, Manhattan, and McCoy in 1986 to Echo Bay.

Washington.—Gold production at 210,000 ounces surpassed record-high level of 154,000 ounces in 1986, according to a review published by the State.[9]

Revisions to Washington's laws governing the leasing of State-owned land were adopted on October 9, 1987, and became effective November 10, 1987. The major changes applied to the annual rental, advance minimum royalty payments, term length for prospecting leases, and the ability of the State Department of Natural Resources to use public auction procedures to issue placer gold mining contracts and to designate areas for recreational prospecting. A plan outlining proposed operations, a new requirement, was added and must be approved prior to beginning prospecting.

Production at the State's largest gold mine, the Cannon Mine in Chelan County, owned by Asamera Minerals (U.S.) Inc. and Breakwater Resources Ltd., amounted to a record high 136,913 ounces of gold and 184,000 ounces of silver during the fiscal year ending September 30. The large underground mine at Wenatchee employing nearly 200 people, milled 487,006 tons bearing an average grade of 0.308 ounce of gold per ton. Modifications to the mill in 1986 resulted in an increase in gold recovery from 86% to 91%. The mill product is shipped to Japan and Montana for smelting and gold recovery.

The State's second largest mine, Hecla's Republic Unit (Knob Hill) at Republic in Ferry County, reported producing 70,095 ounces of gold and 341,272 ounces of silver. Average ore grades increased significantly during 1987 as mining moved into the recently discovered higher grade Golden Promise area of the mine. The recovered grade was up 43% to 0.97 ounce of gold per ton compared with 0.68 ounce per ton in 1986. Republic's silver output more than doubled in 1987. Proven and probable ore reserve tonnage increased 38% during the same period. Also in Ferry County, the Valley Mine, operated by High Country Mining and Exploration, completed its first full year of underground mining in September. Other Ferry County mines included the South Penn and the Gold Dike Mines. At the South Penn, Chemgold Inc., a subsidiary of Glamis Gold Ltd., and its partner Crown Resources Corp. reported mining 33,000 tons of ore grading 0.03 ounce per ton. The partners expected to recover about 900 ounces of gold during the 2-year life of the project. At the Gold Dike Mine east of

Danville, Vulcan Mountain Co. resumed mining and heap-leach recovery. Toward the end of the year, Vulcan and Sundance Mining Development Inc. signed an exploration agreement with U.S. Borax and Chemical Corp. covering the Gold Dike property and the adjoining Gold Hill property.

According to the State review, a minimum of 55 companies and individuals explored for metals in Washington State during 1987. Nearly all of these reportedly explored for gold and silver.

Other States.—In Wyoming, placer operations were reportedly recovering gold from various drainages in the Atlantic City-South Pass area.[10] Consolidated McKinney Resources Inc. of Vancouver, Canada, reportedly began drilling near the Old Carissa Mine in the South Pass area south of Lander, WY. Northeast of the Carissa Mine and also in Freemont County, the Gyorvary Mining Co. reportedly began construction on an addition to its mill at the Mary Ellen Mine. In southeastern Wyoming, exploration work was also reportedly under way around old workings in the Medicine Bow Mountains.

In Minnesota, the State's mining tax laws were revised during 1987 and were expected to stimulate mining and encourage increased exploration activity. Over 900,000 acres of land was leased from the State during 1987, and reportedly there were 27 companies conducting exploration and drilling, principally for gold.

Mineralco Inc. of Ottawa, IL, had been exploring for gold in the vicinity of Hixon Lake in Oneida County south of Rhinelander, WI, for several years. Mineralco's request for a permit to drill test holes beneath the lake was denied by State authorities at yearend. Toward yearend, Kennecott announced that it planned to seek State and local permits to develop a copper-gold-silver deposit at its Flambeau property in Rusk County near Ladysmith. CoCa Mines Inc. retained its 65% interest in the Raspberry Gold Prospect in northern Minnesota. Further exploration was planned for 1988.

At Callahan Mining Corp.'s Ropes gold mine near Ishpeming, MI, gold mining proceeded into the second full year of operation. Callahan reported milling nearly 670,000 tons of ore averaging 0.079 ounce of gold per ton and 0.199 ounce of silver per ton during 1987. Metal sales during the year amounted to 43,453 ounces of gold and 58,814 ounces of silver.

In Maine, Scintilore Explorations Ltd. of Ontario, Canada, reportedly continued work at its Big Hill silver-zinc-gold deposit at Pembroke, Washington County, east of Portland.

Table 4.—Mine production of gold in the United States, by month

(Troy ounces)

Month	1983	1984	1985	1986[r]	1987
January	134,435	140,586	174,916	286,427	382,389
February	131,636	144,945	175,486	288,372	385,088
March	153,808	174,242	204,492	295,941	385,701
April	162,224	166,908	182,938	315,556	412,902
May	179,950	183,068	193,338	310,003	416,780
June	178,929	195,337	191,202	325,925	420,181
July	179,521	186,620	199,189	317,392	420,219
August	192,095	183,123	200,682	327,663	423,006
September	189,237	178,483	235,618	327,664	430,158
October	183,524	186,413	220,586	323,703	428,511
November	165,903	174,313	226,005	310,089	420,276
December	151,264	170,577	222,780	310,280	441,171
Total	2,002,526	2,084,615	2,427,232	3,739,015	4,966,382

[r]Revised.

Table 5.—Twenty-five leading gold-producing mines in the United States in 1987, in order of output

Rank	Mine	County and State	Operator	Source of gold
1	Carlin Mines Complex	Eureka, NV	Newmont Gold Co	Gold ore.
2	Homestake	Lawrence, SD	Homestake Mining Co	Do.
3	Jerritt Canyon (Enfield Bell)	Elko, NV	Freeport-McMoRan Gold Co	Do.
4	Fortitude and Surprise	Lander, NV	Battle Mountain Gold Co	Do.
5	Mesquite	Imperial, CA	Goldfields Mining Co	Do.
6	Bingham Canyon	Salt Lake, UT	Kennecott-Utah Copper Div.	Copper ore.
7	Round Mountain	Nye, NV	Round Mountain Gold Corp	Gold ore.
8	McLaughlin	Napa, CA	Homestake Mining Co	Do.
9	Paradise Peak	Nye, NV	FMC Gold Co	Do.
10	Sleeper	Humboldt, NV	Amax Gold Inc	Do.
11	Cannon	Chelan, WA	Asamera Minerals (U.S.) Inc	Do.
12	Mercur	Tooele, UT	Barrick Mercur Gold Mines Inc	Do.
13	Zortman-Landusky	Phillips, MT	Pegasus Gold Inc	Do.
14	McCoy	Lander, NV	Echo Bay Mining Co	Do.
15	Golden Sunlight	Jefferson, MT	Golden Sunlight Mines Inc	Do.
16	New Summitville	Rio Grande, CO	Summitville Consolidated Mining Co. Inc	Do.
17	Republic Unit	Ferry, WA	Hecla Mining Co	Do.
18	Foley Ridge and Annie Creek	Lawrence, SD	Wharf Resources (U.S.A.) Inc	Do.
19	Dee	Elko, NV	Dee Gold Mining Co	Do.
20	Jamestown	Tuolumne, CA	Sonora Mining Corp	Do.
21	Pinson and Prebble	Humboldt, NV	Pinson Mining Co	Do.
22	Horse Canyon (Cortez)	Eureka, NV	Cortez Gold Mines	Do.
23	Florida Canyon	Pershing, NV	Florida Canyon Mining Co	Do.
24	Star-Pointer	White Pine, NV	Silver King Mines Inc	Do.
25	Bald Mountain	Eureka, NV	Placer Dome (U.S.) Inc	Do.

Table 6.—Gold produced in the United States, by State, type of mine, and class of ore

Year and State	Placer (troy ounces of gold)	Lode: Gold ore: Short tons	Lode: Gold ore: Troy ounces of gold	Lode: Gold-silver ore: Short tons	Lode: Gold-silver ore: Troy ounces of gold	Lode: Silver ore: Short tons	Lode: Silver ore: Troy ounces of gold
1983	53,887	24,141,617	1,593,406	1,124,556	43,445	7,512,261	35,057
1984	37,597	30,497,262	1,736,998	1,587,850	55,382	4,380,945	25,785
1985	73,299	35,908,918	2,170,920	1,043,854	41,801	3,836,130	31,288
1986	r73,331	r60,682,634	3,543,557	869,099	28,399	5,532,818	22,207
1987:							
Alaska	W	W	W	--	--	--	--
Arizona	W	W	W	--	--	--	--
California	23,463	10,842,152	579,142	--	--	--	--
Colorado	2	4,126,225	162,385	--	--	--	--
Idaho	--	W	W	W	W	W	W
Michigan	--	W	W	--	--	--	--
Montana	W	14,286,880	232,883	--	--	W	W
Nevada	20,133	45,095,541	2,619,809	--	--	8,150,597	37,496
New Mexico	--	17,086	291	W	W	--	--
Oregon	W	W	W	--	--	--	--
South Carolina	--	W	W	--	--	--	--
South Dakota	--	W	W	--	--	--	--
Utah	--	W	W	--	--	W	W
Washington	--	W	W	--	--	--	--
Total[1]	163,385	83,271,030	4,450,076	W	W	8,695,125	39,415
Percent of total gold	3	XX	90	XX	W	XX	1

Year and State	Lode: Copper ore: Short tons	Lode: Copper ore: Troy ounces of gold	Lode: Other[2]: Short tons	Lode: Other[2]: Troy ounces of gold	Total[1]: Short tons	Total[1]: Troy ounces of gold
1983	137,668,016	258,222	858,749	18,509	171,305,199	2,002,526
1984	132,899,873	198,729	472,359	30,124	169,838,289	2,084,615
1985	149,464,862	74,633	4,476,684	35,291	194,730,448	2,427,232
1986	116,775,362	r52,811	334,932	18,710	r184,194,845	r3,739,015

See footnotes at end of table.

Table 6.—Gold produced in the United States, by State, type of mine, and class of ore —Continued

	Lode				Total[1]	
	Copper ore		Other[2]			
	Short tons	Troy ounces of gold	Short tons	Troy ounces of gold	Short tons	Troy ounces of gold
1987:						
Alaska	--	--	--	--	W	86,548
Arizona	162,367,487	48,430	W	W	162,788,204	95,240
California	--	--	--	--	10,842,152	602,605
Colorado	--	--	219,232	16,408	4,345,457	178,795
Idaho	W	W	--	--	2,536,037	97,773
Michigan	--	--	--	--	W	W
Montana	3,144,140	257	W	W	17,433,284	234,365
Nevada	--	--	63	2,032	53,246,201	2,679,470
New Mexico	W	W	--	--	W	W
Oregon	--	--	--	--	W	W
South Carolina	--	--	--	--	W	W
South Dakota	--	--	--	--	W	W
Utah	W	W	--	--	W	W
Washington	--	--	--	--	W	W
Total[1]	221,702,975	261,228	W	W	314,905,178	4,966,382
Percent of total gold	XX	5	XX	W	XX	100

[r]Revised. W Withheld to avoid disclosing company proprietary data; included in "Total." XX Not applicable.
[1]Data may not add to totals shown because of items withheld to avoid disclosing company proprietary data.
[2]Includes lead, zinc, copper-lead, lead-zinc, copper-zinc, copper-lead-zinc ores, and old tailings, etc.

Table 7.—Lode gold produced in the United States, by State

Year and State	Amalgamation		Cyanidation		Smelting of concentrates			Smelting of ore		Total ore processed[1] (short tons)	Total gold recovered (troy ounces)
	Ore treated (short tons)	Gold recovered (troy ounces)	Ore treated (short tons)	Gold recovered (troy ounces)	Ore concentrated (short tons)	Concentrates smelted (short tons)	Gold recovered (troy ounces)	Ore smelted (short tons)	Gold recovered (troy ounces)		
1983	137,658	24,689	28,415,818	1,631,608	142,546,432	3,044,307	306,609	205,291	[2]9,996	171,305,199	[2]1,972,902
1984	124,983	23,274	34,902,191	1,752,492	134,735,157	3,605,791	257,238	75,958	[2]14,214	169,838,289	[2]2,047,218
1985	20,812	3,741	39,602,183	2,088,815	154,886,138	3,220,471	231,706	221,315	[2]34,179	194,730,448	[2]2,358,441
1986	850,236	33,710	[r]64,666,550	3,357,244	118,529,487	2,838,702	[2]262,703	148,572	[2]6,455	[r]184,194,845	[2]3,660,112
1987:											
Alaska	--	--	W	W	--	--	--	--	--	W	W
Arizona	--	--	W	W	162,367,487	2,374,838	49,155	W	W	162,788,204	[2]95,240
California	W	W	9,419,527	520,738	W	W	W	--	--	10,842,152	579,142
Colorado	W	W	W	W	W	W	W	W	W	4,505,268	178,793
Idaho	--	--	2,120,911	94,490	W	W	W	W	W	2,536,037	97,773
Michigan	--	--	W	W	--	--	--	--	--	W	W
Montana	--	--	12,751,923	210,592	W	W	W	W	W	17,433,284	[2]234,365
Nevada	--	--	52,921,138	2,623,355	W	W	W	W	W	53,246,201	2,659,337
New Mexico	--	--	W	W	W	W	W	W	W	W	W
Oregon	W	W	--	--	--	--	--	W	W	W	W
South Carolina	--	--	W	W	--	--	--	--	--	W	W
South Dakota	--	--	W	W	--	--	--	--	--	W	W
Utah	--	--	W	W	W	W	W	W	W	W	W
Washington	--	--	W	W	W	W	W	--	--	W	W
Total	W	W	88,430,702	4,194,564	216,889,426	4,060,599	562,447	W	W	314,905,178	4,802,997

[r]Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."

[1]Includes old tailings and some non-gold-bearing ores not separable, in amounts ranging from 0.15% to 0.25% of the totals for the year stated.

[2]Includes some placer production to avoid disclosing company proprietary data.

Table 8.—Gold produced in the United States by cyanidation[1]

Year	Extraction in vats, tanks, and closed containers[2]		Leaching in open heaps or dumps[3]	
	Ore treated (short tons)	Gold recovered[4] (troy ounces)	Ore treated (short tons)	Gold recovered (troy ounces)
1983	11,317,285	1,086,205	17,098,533	545,403
1984	13,503,143	1,165,983	21,399,048	586,509
1985	20,542,717	1,555,835	19,059,466	532,980
1986	r27,106,861	2,358,641	37,559,689	998,603
1987	22,754,932	2,404,403	65,675,770	1,790,161

rRevised.
[1]May include small quantities recovered by leaching with thiourea, by bioextraction, and by proprietary processes.
[2]Includes autoclaves.
[3]May include tailings and waste ore dumps.
[4]May include small quantities recovered by gravity methods.

Table 9.—Gold produced at placer mines in the United States, by method of recovery[1]

Method of recovery	Mines producing	Washing plants	Material washed (thousand cubic yards)	Gold recoverable: Quantity (thousand troy ounces)	Gold recoverable: Value (thousands)	Gold recoverable: Average value per cubic yard
Bucketline dredging:						
1983	3	4	4,785	30	$12,512	$2.615
1984	2	3	4,840	29	10,387	2.147
1985	3	4	3,958	32	10,185	2.573
1986	3	4	4,081	30	11,227	2.751
1987	4	5	9,333	112	49,989	5.356
Dragline dredging:						
1983	2	13	[2]110	[3]3	1,333	3.481
1984	4	13	[2]126	[3]4	1,593	[4]2.908
1985	3	14	[2]156	[3]4	1,348	[4]2.224
1986	3	14	[2]14	[3]4	1,342	[4]12.862
1987	3	3	[2]93	[3]2	971	[4]6.262
Hydraulicking:						
1983	1	1	3	([5])	117	43.342
1984	1	1	28	([5])	90	3.220
1985	--	--	--	--	--	--
1986	1	1	100	([5])	17	.166
1987	--	--	--	--	--	--
Nonfloating washing plants:						
1983	6	6	961	18	7,450	7.750
1984	8	8	310	3	1,036	3.343
1985	6	6	959	31	9,690	10.102
1986	4	4	276	25	9,244	33.528
1987	6	6	832	15	6,698	8.048
Underground placer, small-scale mechanical and hand methods, suction dredge:						
1983	23	24	[2]167	[3]3	r1,310	7.831
1984	10	11	197	1	454	2.304
1985	19	19	621	6	2,061	3.320
1986	24	24	r887	14	r5,175	r5.833
1987	15	15	480	35	15,530	32.356
Total placers:[6]						
1983	35	48	[2]6,026	[3]54	r22,722	r [4]3.707
1984	25	36	[2]5,501	[3]38	13,560	[4]2.242
1985	31	43	[2]5,694	[3]73	23,284	[4]3.913
1986	35	47	r [2]5,358	[3]73	r27,003	r [4]4.823
1987	28	29	[2]10,738	[3]163	73,188	[4]6.816

rRevised.
[1]Data are only for those mines that report annually on the Bureau of Mines voluntary survey; there are many more, usually smaller and less well-established operations, mainly in Alaska, that do not report.
[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.
[4]Gold recovered as a byproduct at sand and gravel operations is not used in calculating average value per cubic yard.
[5]Less than 1/2 unit.
[6]Data may not add to totals shown because of independent rounding.

Table 10.—U.S. refinery production of gold[1]

(Thousand troy ounces)

Raw material	1983	1984	1985	1986[r]	1987
Concentrates and ores: Domestic and foreign	1,972	2,101	2,076	2,396	3,613
Old scrap	[r]1,784	[r]1,769	[r]1,602	1,345	2,034
New scrap	1,357	1,543	1,510	1,618	1,273
Total[2]	[r]5,114	[r]5,413	[r]5,188	5,359	6,920

[r]Revised.
[1]Data may include estimates.
[2]Data may not add to totals shown because of independent rounding.

CONSUMPTION AND USES

The use of karat gold in jewelry manufacturing increased 12%, while the industrial use of fine gold for electroplating, principally for electronic applications, increased about 7%. Gold-filled composites used in the industrial sector showed a substantial decline during the year, as did the use of gold in dentistry. The increased demand for karat gold in the jewelry and arts category may reflect increased purchases of domestically fabricated karat gold jewelry in place of imported items, such as gold chain, which became relatively expensive as the U.S. dollar weakened.

The volume of contracts traded on the Nation's futures exchanges increased substantially during the year, with volume on the Commodity Exchange Inc. (COMEX) in New York up by nearly 20% over that of 1986.

On June 16, the Chicago Mercantile Exchange (CME), through its International Monetary Market division, resumed trading gold futures contracts following a nearly 2-year hiatus. The CME's decision to resume trading gold futures (100-ounce contracts) reportedly was prompted in part by growing investor interest in gold as well as by the recent exchange volume overload problems experienced by the New York-based COMEX.

The popularity of the new American Eagle gold coin program was confirmed when the U.S. Mint announced in April that it had exceeded its original 12-month sales projection of 2.2 million coins by 100,000 coins.

Table 11.—U.S. consumption of gold,[1] by end-use sector[2]

(Thousand troy ounces)

End use	1983[r]	1984[r]	1985[r]	1986[r]	1987
Jewelry and the arts:					
Karat gold	1,414	1,420	1,398	1,412	1,589
Fine gold for electroplating	21	23	24	86	89
Gold-filled and other	230	216	216	218	216
Total[3]	1,665	1,658	1,638	1,716	1,894
Dental	325	305	299	255	223
Industrial:					
Karat gold	42	39	39	39	40
Fine gold for electroplating	370	453	381	369	394
Gold-filled and other	673	675	731	741	673
Total[3]	1,085	1,167	1,151	1,149	1,108
Small items for investment[4]	3	8	7	6	3
Grand total[3]	3,078	3,140	3,097	3,126	3,228

[r]Revised.
[1]Gold consumed in fabricated products only; does not include monetary bullion.
[2]Data may include estimates.
[3]Data may not add to totals shown because of independent rounding.
[4]Fabricated bars, medallions, coins, etc.

STOCKS

Commercial.—Stocks of refined bullion held by industrial users at yearend were 21% lower than at yearend 1986. The decline may reflect increased fabrication as well as a reluctance on the part of fabricators to finance inventories in excess of their requirements during a period of relatively strong gold prices. Stocks of gold certified for delivery by COMEX, the Nation's largest futures exchange, declined by about 7% from gold on deposit at yearend 1986. Gold stocks held by other domestic exchanges are small compared with those held by COMEX.

Table 12.—Yearend stocks of gold in the United States

(Thousand troy ounces)

	1983	1984	1985	1986	1987
Industry	r611	r752	r596	r925	732
Futures exchange	2,530	2,359	[1]2,110	[1]2,809	[1]2,625
Department of the Treasury[2]	263,406	262,814	262,672	262,032	262,388
Earmarked gold[3]	341,402	337,328	337,399	332,733	329,678

rRevised.
[1]Commodity Exchange Inc. only. Stocks held by other exchanges estimated to be less than 2% of totals shown.
[2]Includes gold in Exchange Stabilization Fund.
[3]Gold held for foreign and international official accounts at New York Federal Reserve Bank.

PRICES

The annual average U.S. price of gold rose 22% in 1987. The rising prices were generally accompanied by increased trading in gold futures on the Nation's commodity exchanges.

Table 13.—U.S. gold prices[1]

(Dollars per troy ounce)

Period	Low		High		Average
	Price	Date	Price	Date	
1983	374.65	Nov. 21	509.25	Feb. 15	424.00
1984	307.90	Dec. 20	408.85	Mar. 5	360.66
1985	284.64	Feb. 25	341.30	Aug. 19 and 28	317.66
1986	326.70	Jan. 2	438.50	Oct. 8	368.24
1987:					
January	400.48	Jan. 5	423.83	Jan. 19	409.81
February	391.51	Feb. 18	408.29	Feb. 2	402.85
March	405.34	Mar. 3	425.58	Mar. 30	410.46
April	420.07	Apr. 7	476.44	Apr. 27	440.35
May	452.64	May 29	476.95	May 20	461.73
June	439.61	June 22	458.66	June 11	451.23
July	446.13	July 7	464.17	July 31	452.45
August	454.95	Aug. 17	475.09	Aug. 4	462.58
September	455.40	Sept. 1	466.42	Sept. 4	461.78
October	455.77	Oct. 2	482.47	Oct. 19	466.80
November	458.98	Nov. 5	493.99	Nov. 30	467.91
December	478.96	Dec. 17	501.25	Dec. 14	487.68
Year	391.51	Feb. 18	501.25	Dec. 14	447.95

[1]Engelhard Industries daily quotation.

FOREIGN TRADE

Owing to a precipitous drop in imports, the United States was a net exporter of gold, albeit by the slimmest of margins, for the first time since 1981. As in other recent years, the Nation was a net importer of refined gold and of all gold-containing materials except waste and scrap. The emergence of substantial buying interest on the part of private Taiwanese as well as the Central Bank of Taiwan, combined with the continuing weakening of the U.S. dollar against the Taiwanese dollar, led to a large percentage of refined bullion exports to Taiwan, especially toward yearend.

The quantity of gold contained in imported coins declined for the third consecutive year, reflecting continuing domestic investor interest in domestically minted bullion coins as well as the increasingly effective promotional campaigns by the U.S. Mint.

Table 14.—U.S. exports of gold, by country[1]

Year and country	Ore and concentrates[2] Quantity (troy ounces)	Ore and concentrates[2] Value (thousands)	Waste and scrap Quantity (troy ounces)	Waste and scrap Value (thousands)	Doré and precipitates Quantity (troy ounces)	Doré and precipitates Value (thousands)	Refined bullion Quantity (troy ounces)	Refined bullion Value (thousands)	Total[3] Quantity (troy ounces)	Total[3] Value (thousands)
1983	12,757	$5,190	1,175,830	$469,789	69,213	$26,037	1,881,233	$825,418	3,139,033	$1,326,434
1984	3,298	545	1,422,849	503,237	72,470	24,502	3,482,473	1,284,718	4,981,090	1,813,002
1985	2,448	771	980,147	303,413	95,774	30,147	2,888,309	919,433	3,966,678	1,253,764
1986	5,344	1,589	979,069	352,471	456,267	158,005	r3,554,411	r1,306,958	r4,995,091	r1,819,023
1987:										
Belgium-Luxembourg	--	--	40,922	19,157	--	--	350	121	41,272	19,278
Brazil	--	--	--	--	--	--	6,658	896	6,658	896
Canada	13,759	6,012	265,179	111,432	412,854	177,305	774,178	332,922	1,465,970	627,670
France	87	13	367,556	163,320	9,102	4,066	34,879	16,089	411,624	183,489
Germany, Federal Republic of	--	--	7,506	3,177	89,485	39,093	1,855	714	98,846	42,984
Hong Kong	--	--	--	--	--	--	28,670	13,017	28,670	13,017
Japan	--	--	3,630	921	4,001	1,058	3,944	1,309	11,575	3,289
Mexico	--	--	1,370	366	1,130	493	5,328	2,142	7,828	3,001
Peru	--	--	417	185	723	400	54,641	24,460	55,781	25,045
Sweden	--	--	37,652	16,064	1,620	729	--	--	39,272	16,794
Switzerland	83	25	163	68	80,113	36,172	158,453	63,890	238,812	100,155
Taiwan	--	--	--	--	228	88	1,181,877	561,976	1,182,105	562,064
United Kingdom	30,596	13,768	175,860	74,944	7,327	3,331	24,790	11,193	238,573	103,237
Other	--	--	2,927	1,197	3,504	1,273	12,781	5,457	19,212	7,929
Total[3]	44,525	19,818	903,182	390,832	610,087	264,008	2,288,404	1,034,186	3,846,198	1,708,844

r Revised.
[1] Bullion also moves in both directions between U.S. markets and foreign stocks on deposit in the Federal Reserve Bank. Excludes monetary gold.
[2] Includes gold content of base metal ores, concentrates, and matte destined for refining.
[3] Data may not add to totals shown because of independent roundings.

Source: Bureau of the Census.

Table 15.—U.S. imports for consumption of gold, by country[1]

Year and country	Ore and concentrates[2]		Waste and scrap		Doré and precipitates		Refined bullion		Total[3]	
	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)
1983	239,146	$94,919	146,164	$51,516	608,458	$255,113	3,599,188	$1,575,570	4,592,956	$1,977,118
1984	202,787	69,061	357,119	122,483	1,277,146	461,763	6,031,550	2,293,606	7,868,602	2,946,914
1985	37,067	11,628	366,887	107,147	1,461,068	468,227	6,360,977	2,109,475	8,225,999	2,696,478
1986	37,618	13,094	520,317	159,786	1,391,061	504,457	13,800,451	5,016,558	15,749,447	5,693,896
1987:										
Australia	51	22	--	--	35	11	14,460	6,358	14,546	6,391
Bolivia	--	--	183,537	71,163	--	--	1,085	413	184,622	71,576
Brazil	--	--	257	74	3	1	5,012	2,187	5,272	2,262
Canada	3,622	1,499	84,875	26,819	649,072	284,842	1,235,308	554,246	1,972,877	867,405
Costa Rica	--	--	18,655	7,648	--	--	--	--	18,655	7,648
Chile	72	31	3,465	1,592	6,077	3,195	250,009	109,513	259,623	114,331
Colombia	--	--	4,935	1,904	13	7	23	8	4,971	1,919
Dominican Republic	5	2	37,778	9,665	235,331	99,515	23,750	9,501	296,864	118,683
Ecuador	--	--	9,807	3,193	2,208	567	874	347	12,889	4,107
Finland	--	--	--	--	--	--	11,931	2,904	11,931	2,904
Germany, Federal Republic of	138	48	338	45	4,389	1,999	5,737	2,372	10,602	4,465
Guyana	8,784	3,512	3,260	1,282	223	96	8,234	2,631	20,501	7,521
Honduras	2,179	716	2,418	988	7	3	--	--	4,604	1,707
Ivory Coast	1,433	572	--	--	441	182	2,980	1,389	4,854	2,144
Japan	3,859	1,695	270	62	984	163	964	384	6,077	2,303
Mexico	11,109	4,208	11,749	3,346	330	85	20,042	8,787	43,230	16,426
Panama	--	--	5,866	2,363	--	--	2,107	974	7,973	3,336
Switzerland	122	48	8,593	3,753	120	70	50,835	23,572	59,670	27,444
Togo	12,799	5,003	--	--	--	--	398	167	13,197	5,171
United Kingdom	--	--	297	129	21,798	9,482	403,279	160,781	425,374	170,392
Uruguay	--	--	5,874	2,740	--	--	319,303	137,305	325,177	140,045
Venezuela	--	--	52,926	18,062	393	167	1,167	405	54,486	18,634
Yugoslavia	--	--	--	--	3,230	1,306	56,857	24,900	60,087	26,206
Other	1,758	570	13,757	5,244	958	334	8,698	3,795	25,171	9,944
Total[3]	45,931	17,926	448,657	160,073	925,612	402,026	2,423,053	1,052,941	3,843,253	1,632,966

[1]Bullion also moves in both directions between U.S. markets and foreign stocks on deposit in the Federal Reserve Bank. Excludes monetary gold
[2]Includes gold content of base metal ores, concentrates, and matte imported for refining.
[3]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

WORLD REVIEW

World demand for gold, including scrap gold for use in fabricated products, declined by 5%, reflecting in part the absence from the market of the Japanese Hirohito coin program of 1986.

According to Consolidated Gold Field's 22d annual review and summary,[11] the total supply of gold to the world's market economy countries remained steady at 64.6 million ounces. Increased mine production in the market economy countries was more than offset by lower sales from the centrally planned economy countries, principally the U.S.S.R., at 9.7 million ounces in 1987 compared with 12.9 million in 1986. Net purchases from the market by the official sector's central banks totaled about 2.2 million ounces, down from 4.6 million ounces in 1986. Karat jewelry manufacture absorbed about 36.6 million ounces, up from about 35.5 million ounces in 1986. Gold used in the minting of official coins fell from the record-high level of about 10.2 million ounces minted in 1986 to about 6.6 million ounces in 1987. The total gold used in industrial applications, including electronics, dentistry, and other uses, remained nearly unchanged at 7.8 million ounces. Identified hoarding of gold bars for investment or asset-fixing, outside of Europe and North America, increased by 25% from nearly 7.1 million ounces in 1986 to over 8.8 million ounces. Generally the volume of gold trading on the major futures and options exchanges around the world rose substantially. Finally, the supply of new gold and gold contained in scrap, exceeded the demand for use in fabricated products by 4.6 million ounces compared with a surplus of about 4.1 million ounces during 1986. However, the firmness of the price throughout 1987 suggests that this surplus of supply over identifiable demand was easily absorbed by investors in Europe and North America.

In April, the South Korean Government began minting gold and silver coins to commemorate the 1988 Olympics to be held in Seoul. Four series of six coins each were to be produced.

In October, the Royal Mint of the United Kingdom announced the issue of its new Britannia gold coin, thereby entering the competitive world gold bullion coin market, currently dominated by the recently issued American Eagle and the Canadian Maple Leaf, as well as by several other gold bullion coins. The new legal tender Britannia, 91.66%-pure gold, was being struck in four weights ranging from 1.0 ounce down to 0.10 ounce.

The year also witnessed the formation of the World Gold Council, an organization funded by world gold producers to promote investment in gold and to encourage gold jewelry sales.

A comprehensive review of gold's monetary and industrial roles and an analysis of the world gold mining industry with an outlook for production to the year 2000 was published in 1987.[12]

Australia.—Australia's gold production rose for the seventh successive year. In 1987, 26 new gold mines were commissioned with planned capacity ranging from less than 3,000 ounces per year at many small placer mines to large, mostly open pit, lode mines capable of producing up to nearly 300,000 ounces per year. The State of Western Australia was again the country's largest gold producer. As a consequence of continuing expansion in gold exploration activity, Australia's minable gold resources reportedly increased nearly 25% over 1986 levels. Australia's Bureau of Mineral Resources, Geology, and Geophysics forecast that production would reach nearly 4.2 million ounces in 1988, peak at nearly 4.5 million ounces by 1991, and decline to about 3.9 million ounces by 1992. An increase in the capacity of the country's domestic precious metals refining industry was expected.

Global sales of the new Standard (nonproof) Australian Gold Nugget coin series began in April. Goldcorp Australia, the Government's sales corporation, reportedly initiated sales through distributors in seven countries. The 99%-pure coins, Australia's first bullion coins minted as legal tender, range in weight from 0.10 to 1.0 ounce. During the first 2 months of trading, nearly 250,000 ounces of coins were sold—nearly twice the original sales target of 130,000 ounces. Goldcorp reportedly sold over 350,000 ounces during the year. Its original 3-year global sales target reportedly was about 400,000 ounces.

At the new open pit Kidston Mine, Queensland's largest and Australia's second largest gold mine, opened in 1985, Placer Pacific Ltd. reported recovering nearly

230,000 ounces at a cash cost of $142 per ounce. Placer continued exploration at its Mount Rawdon gold property in Queensland, a potential open pit operation, and at prospects in the Cooper Range area of the State. BMG of Houston, TX, dedicated its new 60,000-ounce-per-year open pit gold mine, which was south of Charters Towers in northern Queensland. The new mine, known as the Pajingo Mine, also was expected to produce about 200,000 ounces of silver per year. Cash production costs over the life of the mine were expected to average $141 per equivalent gold ounce (with byproduct silver converted to equivalent ounces of gold). In April, Pan Australian Mining Ltd. officially opened its new Mount Leyshon gold mine also near Charters Towers. The new open pit heap-leaching operation began leaching in late 1986. It was designed to produce about 45,000 ounces per year during its first 3 years of operation.

Sedimentary Holdings Ltd. and its partners poured their first gold at the Cracow Mining Venture in March. The new mine was expected to produce about 40,000 ounces during the 1987 financial year. Additions to the mill, commissioned in midyear, were expected to raise the milling capacity by nearly 80% to about 250,000 tons per year. Sixty miles south of Townsville, Carpentaria Gold Pty. Ltd., a subsidiary of MIM Holdings Ltd., poured its first gold in December at its new Ravenswood Mine. The new open pit and heap-leaching operation was expected to produce at a rate of about 15,000 ounces per year. In November, Central Coast Exploration NL began mining its Croyden deposit in the Croyden Goldfield of northern Queensland. Annual production was expected to be about 37,000 ounces per year. In southeastern Queensland, Astrik Resources NL started mining at its open pit Agricola deposit. The new mine, using carbon-in-pulp recovery, was expected to yield about 30,000 ounces per year.

Some other Queensland properties moving toward production in 1988 included the 100,000-ounce-per-year Selwyn (Starra) Mine owned by Cyprus Minerals Australia Co. and its partners; Diversified Mineral Resources Ltd. NL's 30,000-ounce-per-year Clocurry property; and Australian Consolidated Minerals Ltd.'s Wirralee Mine in northern Queensland, due on-stream at the rate of 50,000 ounces per year by mid-1988.

Preliminary mining was begun near yearend at the Sheahan-Grants Mine, 20 miles south of Orange in the State of New South Wales, by Cyprus and its partner Climax Mining Ltd. Metal production began in January and should amount to nearly 30,000 ounces per year during the expected 4-year life of the mine. Paragon Resources NL's wholly owned Temora Mine at Wagga Wagga was commissioned in May to begin production at an annual rate of 35,000 ounces. At BHP Gold Mines Ltd.'s wholly owned Brown's Creek open pit property at Blaney, the existing treatment plant was undergoing modification to raise the annual production rate to about 20,000 ounces. Plans called for increasing later production to about 27,000 ounces per year.

In the State of Victoria, the Sandhurst Gold Joint Venture completed a pilot plant run to test a new gold recovery process. The new coal-oil agglomeration process, developed and patented by one of the partners, BP Australia Gold Pty. Ltd., uses a noncyanide technology that is reportedly economical and harmless to the environment. Bendigo Gold Associates Pty. Ltd., Victoria's second largest gold producer, also was recovering gold from Bendigo-area tailings dumps. Also at Bendigo, Western Mining Corp. Holdings Ltd. (WMCH) began preparation for further underground exploration and bulk sampling at the Old Williams United shaft, and Bendigo Mining NL began dewatering at the old Deborah Mine prior to beginning underground exploration. Near Heathcote in central Victoria, Australian Gold Development NL reportedly was planning to rehabilitate the Costerfield gold mine and had begun rehabilitation and dewatering at the old Brunswick Mine.

In Tasmania, Aberfoyle Ltd. and its partners started mining at their Hellyer polymetallic deposit, made viable primarily by its gold content. In eastern Tasmania, Australian Consolidated and its partner Allstate Exploration NL reportedly began clearing the shaft and dewatering the old Beaconsfield gold mine.

In South Australia, the Olympic Dam project at Roxby Downs moved toward a mid-1988 startup. The owners of the huge copper-uranium-gold project, WMCH and BP Australia Ltd., expect to recover more than 90,000 ounces of gold per year in addition to considerable values of copper and uranium.

In July, Dominion Mining Ltd. officially opened its new Cosmo Howley gold mine in the Darwin region of the Northern Territory. Mining at the 40,000-ounce-per-year open pit heap-leaching operation had begun in late 1986, and the first gold was poured in January. In the south Alligator River area, BHP Gold and its partners, Noranda Australia Ltd. and NBHC Ltd., continued exploration at the Coronation Hill property, where high-grade gold discoveries also reportedly contained associated platinum and palladium values. Cyprus continued development of its Moline Mine, due to begin production in late 1988 at a rate of about 12,000 ounces per year. Producing at a rate of over 60,000 ounces per year, the Granites Mine of North Flinders Mines Ltd. became the Territories' largest producer during the year.

In Western Australia in response to increasing output of Australian gold mines, the State government's Perth Mint announced that it would expand its gold-refining capacity by building two new refineries: One in Perth with a planned capacity of about 3.5 million ounces per year and one at Kalgoorlie capable of refining nearly 1.0 million ounces per year. Both refineries were to replace the existing Perth facility, which has an annual capacity of about 240,000 ounces. Australia's largest gold-producing mine, the Telfer open pit east of Nullagine, commissioned its mill expansion project designed to provide flotation facilities for the treatment of gold-copper sulfide ores. The mine was owned by Newmont Australia Ltd. (70%) and BHP Gold (30%). To the south, between Kalgoorie and Boulder, Newmont began metal production in December at its jointly held New Celebration Mine. Mining begun the previous year was from three open pits, where 500,000 tons of ore per year are now selectively mined and carefully blended to achieve maximum recovery at an expected annual rate of about 40,000 ounces of gold per year. The New Celebration mill was being expanded to handle 1.5 million tons of ore per year.

In December, Gold Mines of Kalgoorlie Ltd. (GMK), announced a proposal, subject to regulatory approval, to acquire all of Kalgoorlie Lake View Pty. Ltd.'s holdings in the Golden Mile area of Kalgoorlie. This acquisition would result in the consolidation of most of the gold mining operations at Kalgoorlie. Control of the Kalgoorlie mines under a single ownership would reportedly result in the formation of the largest gold mining operation in the world outside of the Republic of South Africa.

During its financial year ending in June, Western Mining Corp. and its affiliates' gold mines produced nearly 654,623 ounces, compared with 556,000 ounces during the comparable 1986 period. The Western Mining Group, the dominant gold producer, conducts gold mining operations in the area around Norseman, Kambalda, Kalgoorlie-Boulder, and to the north near Agnew.

Production began in July at an initial rate of 225,000 ounces per year at the Boddington Mine, 70 miles southeast of Perth. Boddington is a joint venture managed by Worsley Alumina Pty. Ltd. on behalf of Reynolds Australia Alumina Ltd. (40%), the Shell Co. of Australia Ltd. (30%), BHP Minerals Ltd. (20%), and Kobe Alumina Associates (Australia) Ltd. (10%). The gold at Boddington occurs in an unusual association with bauxite. Following up on the characteristics of this unusual occurrence, Alcoa of Australia discovered gold in a similar geological environment on its bauxite leases near the Boddington Mine. Reportedly it planned to begin recovering gold in 1988.

Other Western Australia gold mines reportedly beginning production during 1987 included Julia Mines NL's Goongarrie Mine at about 12,000 ounces per year. Nord Resources (Pacific) Pty. Ltd.'s 38,000-ounce-per-year Kurara Mine, formerly known as Reedy's North, began in June. Aberfoyle Exploration Pty. Ltd.'s Bardoc property, expected to produce 38,000 ounces per year, began production in January. The Gabanintha Mine near Meekatharra began production in October at an expected initial rate of about 25,000 ounces per year. Gabanintha was owned by Dominion Mining Ltd., Black Swan Gold Mines Ltd., and Southern Ventures NL. Near Leonora, Hunter Resources and its partners commissioned their 40,000-ounce-per-year Mertondale Mine in February. East Murchison Mining Pty. Ltd. and partners reopened the Gidgee deposit in July. Eastmet Ltd.'s open pit Youanmi Mine poured its first gold in January and was expected to produce at a rate of about 35,000 ounces per year when fully operational.

Kalgoorlie Resources NL commissioned its Premier Mine in August. Queen Margaret Gold Mines NL and Spargo Exploration commissioned their Bellevue Mine in October. Production was expected to reach about 55,000 ounces per year when fully operational. The Mount Fisher Mine, 60 miles east of Wiluna, also began production in October. The owners, Sundowner Minerals NL, expect to produce about 35,000 ounces per year. Freeport-McMoRan Australia Ltd. continued construction on its open pit Karonie project 65 miles east of Kalgoorlie, where initial gold production began in November.

Brazil.—To encourage Brazil's mining industry, the Government of Brazil reportedly adopted a number of fiscal and financial incentives including low-interest loans for equipment and a 10-year corporate tax holiday for projects in the Amazon Basin. To discourage smuggling of gold to other countries, the Brazilian Central Bank reportedly continued its practice of paying a premium for gold. Smuggling, however, remained a problem as production from numerous unregulated, independent miners or "garimpeiros" continued to elude detection as it moved to markets outside of the country.

In the State of Minas Gerais, gold production was begun at yearend at General Mining Union Corp. Ltd.'s (Gencor) 58,000-ounce-per-year underground São Bento Mine. At Nova Lima, in Minas Gerais, Mineração Morro Velho S.A. (MMV), a 70%-owned subsidiary of Anglo-American Corp., operated Brazil's largest gold mine, the Morro Velho Mine, a deep underground operation dating back to the early 1800's. MMV's annual production from its mines in the State of Minas Gerais, the Morro Velho and the Raposos-Cuiaba, and its Jacobina Mine in the State of Bahía was reportedly about 354,000 ounces. Near Paracatu, Rio Paracatu Mineração S.A. poured the first bar of gold at its new 100,000-ounce-per-year Morro do Ouro Mine. The company is a joint venture between Rio Tinto Zinc do Brazil and Autram Mineração e Participações S.A., a consortium of U.S. and Canadian companies.

In the State of Goiás, MMV and its partner Inco Gold Co. continued with the development of their 120,000-ounce-per-year Crixas property, scheduled for production in late 1989. BP Mineração and its partners began production at a rate of about 60,000 ounces per year at the Cabacal Mine in the State of Mato Grosso. At the Fazenda Brasileiro gold mine in the State of Bahía, Brazil's first open pit and heap-leaching mine, the Cia. Vale do Rio Doce (CVRD) continued development of its underground mine and associated milling facilities. A mid-1988 startup was planned. Another CVRD project in Bahía, the open pit Antas Mine, reportedly moved toward a 1989 startup.

Garimpeiros continued to pursue surface and placer deposits mainly in the States of Amazonas, Mato Grosso, and Pará. In the latter State, garimpeiros continued to work the large gold deposit at Serra Pelada. However, production from this huge hand-dug pit continued to decline as physical factors and a lack of planning further limited the amount of ore available to the miners' primitive methods.

Canada.—The intense gold exploration activity that began several years ago continued in 1987. Much of the heightened activity, especially by junior exploration firms, has been attributed to the Flow-Through Share Program, instituted by the Government in 1983. It enabled companies to issue shares for specific projects and pass the allowable exploration expenses on the project through to the investor, who can in turn deduct the expenses from taxable income earned from other sources. A survey of junior mining companies conducted by the Prospectors and Developers Association reportedly demonstrated that 75% of those firms participating in the survey had used the flow-through program. In June 1987, in an effort to slow down the rapid growth of the program, the Government, as part of the sweeping changes made to the Canadian tax system, introduced changes that affected the Canadian mining industry. Included in the tax reforms scheduled to take effect with the 1988 tax year were changes in the mechanism governing the flow-through program as well as modifications to other tax benefits previously enjoyed by the industry. For example, the earned depletion allowance will be gradually phased out and disappear entirely on July 1, 1989, and the tax writeoff allowable for flow-through share investments will decline from the current level of 133% on selected exploration costs to 100% during the same period.

With the exception of Prince Edward Island, there was at least one gold mine operation in every Canadian Province. Five Provinces lacked gold operations in 1986. Details of developments in Canadian gold mining were summarized in a report prepared by the Canadian Department of Energy, Mines, and Resources.[13]

The amalgamation of several large Canadian gold mining companies during 1987 resulted in the formation of Placer Dome, the largest gold mining company outside of the Republic of South Africa. The companies involved were Placer Development Ltd., Dome Mines Ltd., and Campbell Red Lake Mines Ltd. Formation of another large company, Hemlo, resulted from the merger of Noranda Inc., Hemlo Inc., Goliath Gold Mines Ltd., and Golden Sceptre Resources Ltd. Inco Ltd., primarily a nickel producer, spunoff its gold assets into a new company concerned solely with gold, Inco Gold.

With 1987 production at about 1,740,000 ounces, Ontario was again Canada's largest gold-producing Province. Increased production at some mines reflected better ore grades and improved recovery. Several new mines began production during the year, including the Golden Rose of Emerald Lake Resources Inc. at Sturgeon Falls and the Bell Creek Mine of Canamax Resources Inc. at Timmons. The estimated annual production expected from these new mines was about 39,000 ounces and 26,000 ounces, respectively. Placer Dome and Amoco Canada Petroleum Co. Ltd. switched from open pit mining to underground at their Detour Lake property, and production in 1988 was expected to exceed 96,000 ounces. At about $96 per ounce, the Golden Giant's production costs were reportedly the lowest in Canada in 1987. The legal dispute that arose during 1986 between Lac Minerals Ltd., owners of the Page-Williams Mine, and International Corona Resources Ltd., joint partners in the David Bell Mine, continued during 1987. In 1986 an Ontario Supreme Court ruled in favor of International Corona, but in late 1987, the Supreme Court of Canada granted Lac Minerals the right to appeal the lower court decision, which had awarded the Page-Williams Mine to International Corona.

Gold mines under development in Ontario during the year included Cameron Lake, Duport (Shoal Lake), Dona Lake, Golden Patricia, Mishibishu Lake, Kremzer, Davidson Tisdale, Diepdaume, Clavos Project, St. Andrews, and Holt-McDermitt. Lac Minerals' Lake Shore gold mine reportedly was closed owing to exhaustion of its ore body.

The Province of Quebec produced 940,000 ounces of gold in 1987, a slight increase over 1986 production. The increased exploration and development activity of 1986 in the Casa Berardi area of northwestern Quebec continued during 1987. The Golden Pond property, a joint venture between Inco Gold and Golden Knight Resources Inc., continued under development toward its scheduled opening in August 1988. The Golden Pond East deposit, scheduled to produce about 60,000 ounces per year, was to be the first of three ore bodies to be developed. Eighteen miles to the east, evaluation continued on the Estrades deposit of Teck Corp. and Golden Hope Resources Inc. In the Rouyn-Val d'Or area, the Province's principal gold-producing area with nine operating mines, Lac Minerals announced a $45 million development plan for its Bousquet No. 2 Mine deposit discovered in 1986. The mine was expected to start at 1,000 tons of ore per day and go to full commercial production at the rate of 2,000 tons per day by 1990, producing 140,000 ounces of gold per year. Agnico-Eagle Mines Ltd. was expected to have its Dumagami Mine and mill, which lies beside Bosquet No. 2, operating by June 1988, producing at a rate of about 64,000 ounces per year. Construction of the Sleeping Giant Mine of Perron Gold Mines Ltd. was completed. The mine was due to begin producing in early 1988 at a rate of about 61,000 ounces per year. An affiliated company, D'Or Val Mines, began production at its Beacon Mine in early 1987.

During the year, the Murray Brook property in New Brunswick and the Tangiers and Cochrane Hills properties in Nova Scotia reached the development stage. In August, Hope Brook Gold Inc., a subsidiary of BP Resources Canada Ltd., began heap leaching at its Hope Brook gold mine on the southwest coast of Newfoundland. The first 17-month mining phase will treat ore mined from an open pit for a recovery of about 17,000 ounces. Phase 2 calls for construction of a 3,000-ton-per-day plant and underground mine to be completed in late 1988. Mining during phase 2 will produce 126,000 ounces per year.

In Nova Scotia, Seabright Resources Inc. modified the old Gays River lead and zinc mill to treat gold ore from its nearby Forest Hill Mine, due to begin operating in 1988. Seabright's nearby Beaver Dam deposit was being developed underground, although two other deposits, the Caribou and Moose River, were less advanced. In the Province of New Brunswick at the Cape Spencer Mine, Gordex Minerals Ltd. planned to convert its heap-leaching recovery system to vat leaching to permit gold recovery year-round. Gordex estimated 1987 production to be about 7,500 ounces.

Granger Exploration Ltd. and the Abermin Corp. began production in May at their Tartan Lake Mine near Flin Flon, Manitoba. Production during 1987 was expected to be 40,000 to 45,000 ounces, rising to 100,000 ounces in 1988. Also in Manitoba, Pioneer expected to begin production at its New Puffy Lake Mine at an annual rate of about

40,000 ounces.

Gold production resumed in the Province of Saskatchewan following a 50-year hiatus. The Star Lake Mine owned by Saskatchewan Mining and Development Corp., Uranertz Exploration and Mining Ltd., and Starrex Mining Corp. began production in early 1987. Several other properties reportedly were also under investigation in the La Ronge region of the Province.

In the Yukon Territory, Canamax Resources and Pacific Trans-Ocean Resources Ltd. began construction at their Ketza River project due to start up in 1988. Borealis Exploration Ltd. reportedly poured its first gold at its underground Fat Lake deposit in the Keewatin District of the Northwest Territories in October. Also in the Northwest Territories, the old Ptarmagan Mine reportedly was nearing an early 1988 startup under new ownership by Treminco Resources Ltd. Also in the Northwest Territories, Getty Resources Ltd. and Noranda Exploration reportedly were developing their Courageous Lake property.

With 38,000 ounces, the Province of British Columbia was Canada's third largest gold producer, with production from three mines: the Cassiar, Blackdome, and Nickel Plate. The open pit Nickel Plate Mine at Hedley, owned by Mascot Gold Mines Ltd., was reopened in midyear and was expected to produce nearly 120,000 ounces per year. Properties under development during the year included the Cinola, Golden Bear, Lawyers, and Reg.

Caribbean Basin.—Because of worldwide interest in exploring high-tonnage, low-grade epithermal gold deposits along crustal plate boundaries, several companies began to focus their attention on the Caribbean crustal plate. The theoretical boundaries of this plate extend from mid-Guatemala south to Panama, east through Guyana, north along the east side of the Lesser Antilles, then westward between Haiti and Cuba, and back to Guatemala. Many geological and mineralogical characteristics associated with the recent significant gold discoveries around the Pacific Rim and in particular in Papua New Guinea have been recognized at some gold deposits around the Caribbean Plate. Countries in the region where gold has been produced include the Dominican Republic, where Rosario Dominicana S.A. has been mining gold at its Pueblo Viejo gold mine for many years. Pueblo Viejo is the largest open pit primary gold mine in the Western Hemisphere. Other producers include Costa Rica, Guyana, Honduras, and Nicaragua, where numerous small mines were producing gold in 1987. They also include El Salvador, Panama, and Puerto Rico, where gold has been produced for years on an intermittent basis.

In addition to the ongoing United Nations Department of Technical Cooperation's exploration work at several gold deposits in Haiti, companies known to be exploring for gold in the Caribbean include Canyon Resources Corp., Antilles Resources Ltd., Cyprus Gold Co., Homestake, Chevron Resources, and Freeport Minerals Co. These companies and others from Australia, Japan, and Panama reportedly have been especially attracted to the Dominican Republic following a 1987 decree that opened heretofore unexplored areas of the island previously ruled to be off limits to commercial development.

The Nicaraguan Ministry of Mines reported that the La India Mine, 25 miles northeast of León, was scheduled for rehabilitation through a joint U.S.S.R.-Nicaragua effort. At one time, the mine produced about 30,000 ounces of gold and 40,000 ounces of silver per year. Several other mines, including the La Liberdad, Siuna, and the El Limón Mines were reported to have been producing gold in 1987. Several others reportedly were being reactivated. Despite efforts by the Government to encourage increased production, widespread smuggling of gold to other countries occurred in response to the Government's policy of paying only $50 per ounce for domestic gold. Reportedly, this smuggling resulted in a loss of up to 75% of the estimated total production. Attacks by anti-Government forces on mining towns reportedly have also interrupted production.

Ecuador.—The large changes to earlier published estimates of Ecuadorean gold production shown in table 16 reflect recent data reported by the Government of Ecuador. Minera Nambija, a joint Government- and cooperative-owned gold mining company, reportedly was considering applications from nine companies to operate a new automated plant at the Nambija Mine in southern Ecuador. In addition to Nambija, the country's major lode gold mining areas include Portovelo, Ponce Enriquez, and Zaruma. Other areas known to be rich in gold include Paccha and Piñas. Many of Ecuador's river systems reportedly contain rich deposits of placer gold.

Government mining officials in Ecuador

were predicting that large increases in future gold production would accrue from ongoing Government efforts to encourage more domestic mining. This activity would reportedly help to offset foreign exchange losses incurred as a result of declining world oil prices. New mining laws decreed in 1985 and 1988 set forth a number of incentives for foreign investment, including various tax breaks and exemptions from import duties, streamlined permitting and speedier resolution of judicial disputes, and reduced royalty and prospecting fees.

Europe.—Limassol S.A. of Greece reportedly began experimental mining of a gold property on the island of Cyprus. The Hellenic Industrial & Mining Investment Co. of Greece contracted for a basic engineering study aimed at recovering gold from an arseniferous pyrite concentrate produced at the Olympias Mine in northern Greece.

In the Huelva Province of southwestern Spain, Thorco Resources Inc. of Toronto, Canada, reportedly was preparing for a 1988 startup of its developing Tharsis gold and silver heap-leaching project. The project will reportedly be the only heap-leaching operation in Europe. Spain's Instituto Nacional de Industria reportedly was also planning to restart a gold mining operation at Rodalguilar in Almería Province.

Reports of gold exploration and/or work directed toward reopening long-closed gold mines came from the Federal Republic of Germany and Yugoslavia.

On March 12, Belgium became the first European Economic Community (EEC) country to mint European Currency Unit (ECU) coins as legal tender. The gold and silver coins were minted to mark the 30th anniversary of the Treaty of Rome. The ECU, an artificial currency created in 1979, is based on the combined value of 10 of the 12 EEC currencies. The number of coins to be minted under the program has not been decided. Near yearend more than 500,000 gold ECU's reportedly had been sold.

The U.S.S.R. was estimated to be the world's second largest gold producer, behind the Republic of South Africa. However, since 1933, gold production data have been a state secret.

At least one new Soviet gold mine, the new open pit Kirgiz gold mining complex in Kirgizia in southern Russia reportedly was scheduled for completion during the 1986-90 5-year planning period.

Ireland and Scotland.—Ennex International PLC reported that permission was received to proceed with its plan to go underground at its Curraghinalt property in County Tyrone, Northern Ireland. If the results of this work are positive, Ennex will seek approval to commission a mining operation at a rate of about 30,000 ounces per year starting in 1989. Ennex also reported that exploration nearby, as well as in the Dooros area of Connemara, had uncovered gold mineralization. The company was also exploring and planning the development of a gold-silver prospect at Cononish, Scotland, reportedly the first substantial discovery of gold or silver in that country.

Ennex's success in Ireland has stimulated a number of other companies to explore there for gold. Nearly 800 mineral exploration licenses reportedly were either in effect, approved, or pending approval by Government authorities.

Oceania.—Indonesia lies in an area believed to be influenced geologically by the convergence of four major crustal plates: the Eurasian, Indo-Australian, Pacific, and Philippine Plates. In recent years, discoveries of epithermal gold deposits have been largely along the southern rim of the Pacific Plate from Indonesia east and south to New Zealand. Exploration companies, recognizing the potential for further discoveries in Indonesia, have intensified their work in that country. According to news media reports released near yearend, foreign firms intent on gold exploration had signed 32 contracts with the Government during the first 10 months of 1987 and a further 28 were expected before yearend. About 600 companies reportedly were waiting for their contract applications to be processed. Most of the companies so far have been Australian. However, a growing number was from nations in the Northern Hemisphere. As was the case earlier in Brazil and later in the Philippines, the growing wave of officially sanctioned exploration has increasingly brought the mining companies into potential conflict with timbering companies and illegal miners operating in remote areas of the vast island archipelago. A number of mines, including Freeport Indonesia Inc.'s Ertzberg copper-gold-silver mine in West Irian, have been in operation for years. The major areas of active gold mining include the southern Provinces of Kalimantan, Maluku, Sulawesi, Sumatra, West and East Nusa Tenggara, and West Irian.

The mining industry in Papua New Guinea is the single most important element of the nation's economy. Five new mines, reportedly representing a potential investment of $1.35 billion, will soon begin production in that nation. They are Lihir, Misima, Porgera, Uramit, and Wapulu.

The nation's largest existing gold mine, the giant Ok Tedi Mine in the Star Mountains, reportedly produced nearly 600,000 ounces of gold in 1987. Ownership of the mine, in addition to the Government's 20% stake, was vested in a consortium of international mining companies. With a midyear shipment of copper concentrates to Japan, Ok Tedi officially entered its planned copper-producing phase, during which both gold and copper will be principal products. Papua New Guinea's second largest gold producer was Bougainville Copper Ltd.'s mine on Bougainville Island. Gold production, a byproduct of copper mining, amounted to nearly 500,000 ounces during 1987.

CRA Ltd. of Australia reported that drilling at its Hidden Valley project in the Wau-Bulolo region of Morobe Province of Papua New Guinea had returned promising results. At Wau, New Guinea Goldfields Ltd., controlled by Renison Goldfields Consolidated Ltd., reported producing nearly 21,000 ounces of gold from its Wau mines. The large increase over the previous year's production of 5,700 ounces largely reflected the efficiency of its new mill and carbon-in-pulp plant. Renison reportedly entered into an agreement with City Resources Ltd. to explore the placer gold potential of Renison's holdings in the Bulolo goldfield. Dredging in the area from 1931 to 1967 reportedly did not fully exploit the potential of the field.

In late 1987, Niugini Mining Ltd. announced that production had begun at its 100%-owned Mount Victor Mine near Kainantu in Papua New Guinea's Eastern Highlands Province. Annual gold production from the open pit operation was estimated to be 12,000 to 15,000 ounces. A unique feature of the mine's plant including housing, workshops, and powerplant, was that it is fully self-contained and portable. When mining is completed in 2 or 3 years, the entire plant can be moved intact to the next minesite. Niugini also holds a 25% interest in the recently discovered Lihir gold deposit, one of the largest outside of the Republic of South Africa. Ore reserve data compiled during 1987 indicated a minable reserve in excess of 18 million ounces of gold. The company's partner in the project, situated on Lihir Island east of the island of New Ireland, is Kennecott Explorations (Australia) Ltd. Niugini announced at year-end that a third area of gold mineralization, the Kapit Ore Zone, had been discovered near the two known principal ore bodies. The company was also exploring recent discoveries in the Tabar Islands group northwest of Lihir. Drilling and sampling were proceeding at 12 prospects scattered between the islands of Simberi, Tabar, and Tatu. Other companies, too numerous to mention here, were exploring gold prospects on other Papuan islands including New Britain, Fergusson, Woodlark, and the Tanga and Feni Islands. Toward the southeast, other companies were exploring in Vanuatu, the Solomon Islands, Fiji, and New Zealand.

In the Solomon Islands, the placer mine of Zanex Ltd. and Mavu Gold Development at Mavu on Guadalcanal Island, resumed production after having been closed in late 1986 owing to the destruction of its recovery plant during a typhoon. Annual gold capacity at the site, the Solomon's only large gold mine, was 13,000 ounces. If two nearby deposits prove to be economic, the capacity may be expanded to 50,000 ounces per year. Cyprus Minerals Co.'s Gold Ridge property on Guadalcanal reportedly was in an advanced stage of exploration.

At the Emperor gold mine on the island of Viti Levu in Fiji, the Vatukoula Joint Venture, 80%-owned by Emperor Gold Mining Co. Ltd. and 20% by Western Mining Corp. Holdings (Fiji) Pty. Ltd. produced nearly 102,000 ounces during the fiscal year, compared with 76,297 in the previous year. Production was derived from both open pit and underground sources. Production was begun at the nearby Tavua Basin Joint Venture in which Western Mining holds a 50% interest. During the year, exploration on the island of Vanu Levu by United Resources (Fiji) Ltd., a subsidiary of City Resources, reportedly resulted in the discovery of gold values associated with an identified epithermal system.

New Zealand has been a small gold producer for many years. Combined with the recognition of the epithermal origin of some known deposits, this fact has spurred an interest in more exploration. Some of the companies currently exploring for or developing gold deposits in New Zealand include Homestake, BP Minerals, AMAX Exploration (New Zealand) Inc., Australian Consolidated, and BHP Gold. Some of the properties undergoing examination or development on North Island include Karangahke, Golden Cross, Martha Hill, and Waihi. Properties on South Island include Sam Creek, Macraes Flat, and various placer goldfields such as those at Otago.

The search for gold in the South Pacific spilled over in 1987 into heretofore relatively unexplored regions. The rediscovery of gold at Rois Malk in the State of Airai in Palau and the recognition of the epithermal origins of the prospect by the U.S Geological Survey in 1985 apparently served as a catalyst for at least one company to explore the potential there and to expand the scope of its search to other targets in the South Pacific region. Micronesian Mineral Resource Co. Ltd. of Vancouver, Canada, in partnership with Nord Australia conducted a detailed study of the Rois Malk area in 1986. In 1987, the partners reportedly expanded their search toward the east and northeast for other areas where epithermal systems may occur. Their exploration reportedly was conducted in the Caroline Islands group of Micronesia, then in the Northern Mariana Islands. The islands of Kosrae (Kusaie), Ponape, and Yap (Pohnpei), and later the island of Saipan were the principal points of investigation. Work was planned for the islands of Guam and Truk in 1988.

Responding to the widespread interest in gold exploration in the Pacific Rim, the Queensland, Australia, State government, and four major corporate sponsors hosted an international congress in Queensland on the geology, structure, mineralization, and economics of the Pacific Rim. The conference was convened from August 26 to 29 under the auspices of the Australasian Institute of Mining and Metallurgy.

Peru.—In an effort to stimulate greater domestic gold production, the Government of Peru reopened the San Antonio de Poto Goldfield in Puno in the high Andes Mountains of southeastern Peru near the Bolivian border. The remote and isolated area was considered by the Government to be Peru's most important gold mining area. Empresa Minero Perú S.A. (Minero Perú) the Government company that operates several small placer mines in the Ananea section of the goldfield, invited local and foreign companies to participate in financing or in joint ventures with Minero Perú to establish mining in the Ananea area. Nearly 36 international companies reportedly purchased bidding instruction packages.

In early 1987, Peru announced the discovery of important gold placer deposits near the Cordillera del Condor, close to the Ecuadorean border. Gold reserves were estimated at over 3.2 million ounces. Plans for the project, called CHINCORCO, include more exploration and the installation of a small pilot plant. Operations in the region were expected to be complex and to pose difficulties because of the rugged terrain. The announcement aroused a long-standing conflict between Ecuador and Peru because the discovery area lies in territory of disputed national ownership.

Philippines.—The gold rush that began several years earlier on the island of Mindanao continued to mature. Centered around the Gulf of Davao from Compostela eastward to Pantukan and Mount Dewalwal, an estimated 200,000 people were engaged in mining, processing, and refining gold as well as providing services to the largely artisan industry. Most of the processing reportedly was centered around the village of Tagum, where up to 1,600 ounces of gold or more were produced in the area per day.

In the Camarines Norte Province of southern Luzon, Benguet Corp. reportedly began production at its Paracale gold project. Production at the new facility was expected to amount to about 22,000 ounces of gold and 49,000 ounces of silver per year. Benguet also continued to rehabilitate the La Suerte Mine, a former gold producer. Benguet was the largest gold producer in the Philippines, with overall gold production in 1987 amounting to nearly 250,000 ounces. Benguet Exploration Inc.'s King King gold mine in Davao del Norte Province reportedly came into production during the year following the completion of three heap-leaching pads and an associated recovery plant. Construction of an additional recovery plant and nine new pads was also reportedly nearing completion.

Gold production at Atlas Consolidated Mining & Development Corp.'s heap-leaching operation on Masbate Island amounted to about 63,000 ounces in 1987. Five 75,000-square-foot asphalt leaching pads were employed. Gold production from Atlas Consolidated's gold-copper operations on Cebu Island reportedly totaled 78,500 ounces. Development continued on new underground gold mines, the Bin Star and the Dabu-Pinigue, with startup scheduled for early 1988. Two others, the Colorado Mine and IXL Mine, were due to begin underground production later that year.

City Resources (Asia) Ltd. a Hong Kong-based firm, reportedly purchased a controlling interest in Manhattan Mining Corp. of the Philippines for the purpose of exploring leases held by Manhattan.

Paragon of Australia reportedly was exploring claims held by its partner, Philippine Eagle Mines. Paragon's interest was apparently focused on reserves remaining at the old Philippine Eagle Mine at Longos in southern Luzon. Kenmare Resources, based in Dublin, Ireland, reportedly initiated an agreement with the Philippine National Oil Co. to explore for epithermal gold on concessions held by the oil company on southern Luzon and the islands of Leyte and Negros. On the island of Lahuy, 200 miles southeast of Manila, Genoa Resources and Investment Ltd. reportedly was searching for evidence of epithermal systems at the old underground Treasure Island Mine. Finally, Galactic Resources of Vancouver, Canada, reportedly signed a joint-venture agreement with Lepanto Consolidated Mining Co. Inc., to develop a major gold-copper-porphyry discovery at Mankayan in Benguet Province. The deposit, known as the Far South East Porphyry Project, reportedly was thought to contain 12 million ounces of gold and 4.5 billion pounds of copper.

South Africa, Republic of.—Despite continuing labor strikes and unrest, continuing currency inflation, and declining ore grades, the Republic of South Africa remained the world's largest gold-producing nation, with 37% of world mine production in 1987.

Of the 19.2 million ounces of gold produced in the Republic of South Africa during the year, 18.4 million ounces was produced by the 30 mines that together represent the membership of the Chamber of Mines of South Africa. The remainder was recovered by small independent gold producers or as a byproduct of other mining sectors. Overall, 46 gold mines and 16 retreatment plants were producing gold in 1987. The total ore milled by Chamber members, including ore milled by producers of byproduct and coproduct uranium, amounted to 118.6 million tons, averaging 0.17 ounce of gold per ton. In 1986, 118.7 million tons, averaging 0.18 ounce per ton was milled. Working costs for South African gold mines in 1987 averaged $276.05 per ounce and ranged from $139.69 per ounce at the Kloof Mine to $585.30 per ounce at East Rand Proprietary.[14] Production by the six major mining groups was as follows, in millions of ounces: Anglo American Corp. of South Africa Ltd. (AAC), 7.1; Gold Fields of South Africa Ltd., 4.1; Gencor, 2.9; Rand Mines Ltd., 1.8; Anglovaal Ltd. (AVL) 1.3; and Johannesburg Consolidated Investment Co. Ltd. (JCI), 1.2.

In terms of individual mine output, the largest South African gold mines, in millions of ounces of production, were AAC's new Freegold Mine with 3.2, Vaal Reefs North and South lease areas with 2.3, Driefontein Consolidated with 2.1, Western Deeps with 1.1, Hartebeestfontein with 1.0, and Kloof with just under 1.0.

The National Union of Mineworkers (NUM) represent primarily black miners and have an estimated paidup membership of 200,000 workers out of a total mine work force of about 800,000. In August, NUM went on strike at operations held by the major mining groups. AAC and Gencor operations witnessed the most strike activity. The primary issue was NUM's negotiation of a 30% increase in basic wages plus certain fringe benefits. Stockpiling of run-of-mine ore prior to the strike and immediate transfer of office personnel to production lines served to lessen the impact of the strike on gold production. The strike ended after 3 weeks.

In late 1987, Gencor announced plans to develop its new Oryx Mine alongside its existing Beisa property south of the town of Welkom in the Orange Free State. The Beisa, a gold and uranium producer, had been closed since 1985. Initial production from the Oryx will begin in mid-1988 and will employ some of the surface and underground facilities of Beisa, while building by 1994 to an annual capacity of about 2.9 million tons of ore per year, containing 480,000 ounces of gold. Following a 10-year research program, Gencor's new bacterial oxidation demonstration plant completed its first full year of operation in October; it is the world's first full-scale integrated gold recovery plant designed and built specifically to incorporate a proprietary biological preleaching circuit. The plant, at the company's Fairview gold mine in the eastern Transvaal was used to pretreat the mine's refractory ores. Owing to the presence of certain mineral constituents, these ores are difficult and expensive to treat using conventional techniques. Gencor claimed that a 95% gold recovery had been achieved with the aid of the new process.

The consistently high gold prices in terms of rands over the past several years has encouraged the formation of an increasing number of small gold mining establishments. Consequently, plans to construct several small gold mining operations have been announced that are scheduled to begin production before 1990 and be at full capacity by 1995. These include the Osprey and Southgo Mines due in late 1987, the Eersteling and Sub-Nigel Mines due in 1988, and several others including the old Roodepoort underground mine west of Johannesburg that was reopened in August 1987. Owned by Roodepoort Gold Holdings (Pty.) Ltd., the mine was expected to produce about 4.2 million ounces during an anticipated mine life of 14 years. Gold recovery was to be through a new 20,000-ton-per-month carbon-in-pulp plant.

Rand Mines and AAC decided to develop a new gold mine in the Barberton area of the eastern Transvaal. The new mine will be developed by Barbrook Mining and Exploration Co. with each of the two mining groups holding an equal interest. Commissioning was expected during the third quarter of 1989 with full production of about 33,000 ounces per year expected by early 1990.

The Drylands Mine, the nation's first heap-leaching operation to treat only primary gold ore, reportedly was started up during the year. Production was expected to amount to about 64,000 ounces over a 4-year period. In October, East Rand Gold and Uranium Co.'s (Ergo) new Daggafontein recovery plant was commissioned. The new plant, Ergo's third such plant, will process old gold mine tailings for an annual recovery of about 96,000 ounces of gold. It has been estimated that tailings accumulated in the various Witwatersrand goldfields may contain as much as 42 million ounces of gold. Ergo, owned by AAC, is the largest of the companies formed to process gold-bearing tailings. Other such producers include the Joint Metallurgical Scheme, the Rand Mines Milling and Mining Co., on the Central Rand, and Gencor's Chemwes plant, in the Klerksdorp area.

Potchefstroom Gold Areas, an independent mining firm, confirmed the presence of a gold-bearing reef in the Potchefstroom Gap area in the western Transvaal. The reef, known as the Bird Reef, was believed by some geologists to correlate with the extremely rich Vaal Reef. The drill intersection, at a depth of 12,600 feet, indicated grades of 0.5 ounce per ton over a width of nearly 2.5 feet. Two other intersections nearby, however, indicated much lower values. The discovery was considered by some to be the most significant since the establishment of the Evander Field almost 30 years ago. Although the country may be on the brink of establishing a new gold mining area, some less confident observers pointed out that the cost of establishing new gold mines in the area would be extremely high as a result of the depth of the reef and the small width of the gold-bearing seam.

Rhombus Mining and Exploration Co. Ltd., also an independent company, announced that drilling had intersected rocks of the lower Witwatersrand system at a depth of 7,200 feet at a site about 60 miles south of Beatrix in the Orange Free State. The discovery was significant in that some geologists have theorized for years about the possibility of the Witwatersrand Basin extending into the southern Orange Free State. It was believed that additional carefully placed drill holes will intersect the overlying gold-bearing upper Witwatersrand system. In addition to the two areas above, exploration by the major mining groups and an increasing number of independent mining and exploration companies was being concentrated north of Evander on the East Rand, south of the Western Areas gold mine in the Western Transvaal, south of Klerksdorp in the far western Transvaal, the Bothaville Gap area, and south of the Free State Mine in the Orange Free State. Oil rigs capable of drilling to great depth were being used by some firms in their exploration work.

Mining research was conducted by the South African Chamber of Mines and the individual mining groups. New mining methods, including improved mine support systems, more rapid and efficient ore removal systems, improvements in underground safety and working environments, and the greater use of computers to streamline various operational tests were some of the benefits developed and operational.

Plans were announced by Rand Refinery Ltd. during the year to construct a new gold-refining facility. The existing refinery, where all of South Africa's gold is refined, processes about 50% of the gold produced in the market economy countries. The new refinery was to have an annual input capacity of about 26 million ounces of raw gold, generally containing 84% gold, 11% silver, and 5% base metals. Construction was scheduled to begin in early 1988 and the refinery was expected to be in operation in about 2 years. The new plant was to be at the same site as the existing refinery.

Table 16.—Gold: World mine production, by country[1]

(Troy ounces)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Argentina	24,660	22,120	28,357	30,350	30,000
Australia	983,522	[3]1,295,963	[4]1,881,491	2,413,842	3,472,000
Bolivia	49,217	40,827	[e]30,000	24,531	39,000
Brazil[e, 5]	[r]1,850,000	[r]1,900,000	[r]2,200,000	[r]2,300,000	2,300,000
Burkina Faso[e]	--	500	50,000	80,000	80,000
Burundi	272	1,115	829	980	1,000
Cameroon	261	[e]250	215	248	250
Canada	2,363,411	2,682,786	2,815,118	[e]3,364,700	3,788,000
Central African Republic	2,492	6,953	6,033	[e]6,000	6,000
Chile	[r]570,964	[r]541,064	554,278	576,719	530,000
China[e]	1,850,000	1,900,000	1,950,000	2,100,000	2,300,000
Colombia	[r]426,517	[r]730,670	1,142,385	1,285,878	[6]850,711
Congo	267	101	515	[e]500	500
Costa Rica[e]	30,000	35,000	[6]15,997	11,600	13,000
Dominican Republic	354,023	338,272	328,046	[e]282,990	246,000
Ecuador	[r]67,800	280,000	300,000	317,327	320,000
El Salvador	650	285	--	--	--
Ethiopia[e]	14,000	15,000	15,000	15,000	15,000
Fiji	40,124	48,515	60,707	94,902	85,000
Finland	25,206	28,067	19,130	37,680	60,000
France	71,659	70,279	90,021	75,618	64,000
French Guiana	8,038	10,127	8,005	10,481	11,000
Gabon	[e]550	1,325	1,608	2,000	2,000
Germany, Federal Republic of[e]	1,900	1,500	1,200	1,200	850
Ghana	276,000	287,000	299,363	287,127	[6]328,000
Guyana	4,607	11,131	10,323	14,035	15,000
Honduras	2,151	2,784	5,023	2,018	2,500
Hungary[e]	30,000	20,000	20,000	18,000	18,000
India[7]	70,158	65,234	58,771	60,250	58,000
Indonesia[8]	76,888	78,677	83,688	102,942	114,500
Japan	100,921	103,519	170,525	330,515	[6]276,432
Kenya	100	600	442	2,339	2,500
Korea, North[e]	160,000	160,000	160,000	160,000	160,000
Korea, Republic of[7]	72,083	79,156	77,258	149,436	150,000
Liberia[e, 9]	15,400	10,500	4,900	[r]20,100	15,000
Madagascar[e]	110	130	130	130	130
Malaysia	84,496	89,527	90,304	88,385	109,000
Mali	[e]13,000	16,075	16,075	[r, e]19,500	22,500
Mexico	198,177	270,998	265,693	250,615	250,000
Namibia	7,459	6,302	6,237	[r, e]6,400	6,400
New Zealand	9,667	21,605	45,011	[e]46,000	45,000
Nicaragua	46,428	25,316	24,491	28,664	[6]31,628
Papua New Guinea	579,407	[e]835,000	1,186,618	1,127,686	[6]1,069,011
Peru	168,534	187,406	212,870	215,862	215,000
Philippines	816,536	827,149	1,062,997	1,296,400	1,071,300
Portugal	[r]16,398	6,205	9,259	6,173	5,000
Romania[e]	65,000	65,000	65,000	60,000	60,000
Rwanda	623	240	238	208	200
Sierra Leone[10]	12,000	[r]18,223	19,004	12,000	15,000
Solomon Islands	[e]1,100	2,572	2,100	3,150	4,000
South Africa, Republic of	21,847,310	21,860,933	21,565,230	20,513,665	[6]19,227,887
Spain	162,296	123,330	185,524	167,184	148,000
Sudan[e]	500	1,500	1,500	1,600	1,600
Suriname	482	322	[e]500	[e]600	700
Sweden	[r]108,300	[r]141,600	148,900	[r, e]130,000	150,000
Taiwan[7]	52,361	37,794	30,633	29,270	27,000
Tanzania	[e]800	2,680	1,776	2,735	3,000
U.S.S.R.[e]	8,600,000	8,650,000	8,700,000	8,850,000	8,850,000
United States	2,002,526	2,084,615	2,427,232	3,739,015	[6]4,966,382
Venezuela	[e]33,200	[e]50,885	74,180	[e]82,800	86,000
Yugoslavia	[r]136,250	125,130	[r, e]110,000	[r, e]115,000	115,000
Zaire	192,930	117,115	63,022	167,827	160,000
Zambia	10,160	12,185	7,909	1,865	1,800
Zimbabwe	453,373	[r]478,307	472,327	477,535	485,000
Total	[r]45,163,264	[r]46,827,464	49,183,988	51,619,577	52,480,781

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

[1]Table includes data available through June 10, 1988.

[2]Gold is also produced in Bulgaria, Burma, Cuba, Czechoslovakia, the German Democratic Republic, Guinea, Norway, Poland, Senegal, Thailand, and several other countries. However, available data are insufficient to make reliable output estimates.

[3]Excludes gold in bismuth concentrate.

[4]Excludes gold in gold ore and concentrate from South Australia.

[5]Officially reported figures are as follows, in troy ounces: Major mines: 1983—199,206; 1984—213,963; 1985—244,249; 1986—300,545; and 1987—300,000 (estimated). Small mines (garimpos): 1983—1,526,775; 1984—982,623; 1985—709,760; 1986—475,059; and 1987—500,000 (estimated).

[6]Reported figure.

[7]Refinery output.

[8]Excludes production from so-called people's mines, estimated at 482,000 troy ounces per year during 1986 and 1987, but includes gold recovered as byproduct of copper mining.

[9]These figures are based on gold taxed for export and include gold entering Liberia undocumented from Guinea and Sierra Leone.

[10]Data are based on official exports and do not reflect gold moved through undocumented channels.

TECHNOLOGY

The Bureau published a report to aid the Minerals Management Service in designating specific offshore areas for consideration of near-term lease offerings. Three selected placer areas, one each for chromium, gold, and titanium, were investigated and evaluated using engineering cost models. The gold placer area was offshore Nome, AK. Sensitivity analyses were then performed on major physical and engineering parameters affecting the economic viability of mineral resources from these three locations.[15] The Bureau examined aggregate trends in foreign direct investment in the U.S. mining and mineral industries between 1977 and 1984. It provided an analysis of foreign investment in several major mineral commodity industries including the gold industry. In 1985, the proportion of the U.S. gold mining capacity held by foreign investors amounted to 44%. The motivation behind the growth in foreign investment and an examination of U.S. policies toward this investment and the issues raised were addressed.[16] A method of estimating capital and operating costs associated with the exploration, mining, and processing of placer deposits was published by the Bureau. Operational parameters for placering equipment and basic principles of placer mining techniques were detailed in a manner to ensure representative cost estimates.[17] The Bureau published an inventory of potential mineral supplies in the United States, including gold. Availability curves depicting how much gold can be recovered as a function of the cost of production were prepared. The chapter on gold identified the mines and processing plants evaluated and provided information on the engineering aspects of these operations. Geology and resources, historic production and current capacities, and mining and processing technologies were presented.[18]

The current and future uses of gold in combating cancer, lessening the pain of arthritis, and other current and future applications of gold were presented at the first International Conference of Gold and Silver in Medicine held in Bethesda, MD, May 13-15, 1988. The conference was sponsored by the Gold and the Silver Institutes, both in Washington, DC.[19]

The Governor of South Dakota awarded $71,800 to the South Dakota School of Mines and Technology to study chlorination extraction for processing metallic ores. The process may prove to be an economic alternative to cyanide extraction. The money was part of a recently established employer's Investment in South Dakota's Future Fund, which uses residual funds from the State's Unemployment Insurance Funds. The study was to include acquisition of ore samples from the Black Hills and other western gold-producing localities. The samples then were to be tested for their amenability to the process. Economic feasibility of the concept was to be assessed on selected gold and silver ores, and a commercial reactor for chlorination processing was to be designed.[20]

A new gold alloy, called 990 Gold, composed of 99% gold and 1% titanium, was developed and patented by the World Gold Council's Gold Information Center. The new alloy allows for the manufacture of almost pure gold articles with improved hardness and good wear properties. The alloy is manufactured by melting the constituents in a vacuum or in an argon atmosphere, followed by casting. By heat treatment at about 800° C and 500° C, the alloy can be obtained in its soft and hardened forms, respectively. The 990 Gold reportedly is easy to work in sheet, strip, or wire form but cannot be cast. Handy & Harman (New York) was licensed to manufacture and distribute 990 Gold stock.[21] A cupric chloride process that would retrieve gold from electronic devices, scrap metal, or discarded jewelry was developed by researchers at the University of Wisconsin.[22] A system, which recovers precious metals including gold from scrapped automobile catalytic converters, was being marketed by Mitsui & Co. (USA). The metals are dissolved in hydrochloric acid and then deposited electrolytically onto carbon particles. After redissolving in acid, the pure metals, including gold and silver, are selectively precipitated.[23] Pulse-plated gold deposits for aerospace components were reported superior to those produced using DC electrolytic plating processes. Pulse-plating yielded deposits with higher infrared reflectivity, decreased porosity and thermal emissivity, smoother and brighter surfaces, and greater density.[24]

A collection of papers addressing various aspects of heap-leach pad construction, monitoring and analysis of solution flow through the heap and its collection, and the design of construction pads was published as a reference for the development, design, and operation of heap-leaching projects.[25]

[1]Physical scientist, Branch of Nonferrous Metals.

[2]Ounce refers to troy ounce.

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Graphite

By Harold A. Taylor, Jr.[1]

Amorphous graphite was not mined domestically in 1987. All natural graphite supplies, particularly of fine crystalline flake, had a difficult time keeping abreast of industrial demand, which increased substantially over that of 1986. Prices of the major imported graphites generally increased over those of 1986, except for the price of Sri Lankan lump and chip graphite, which dropped significantly.

Production of synthetic graphite and graphite fibers increased 7% and 19%, respectively.

Domestic Data Coverage.—Domestic production data for synthetic graphite are developed by the Bureau of Mines from a voluntary survey of domestic producers, titled "Synthetic Graphite." Of the 36 operations to which a survey request was sent, 97% responded, representing 100% of the total production data shown in table 4.

Table 1.—Salient natural graphite statistics

	1983	1984	1985	1986	1987
United States:					
Production ---short tons--	W	W	--	--	--
Consumption, apparent ---do---	W	W	44,380	35,036	34,871
Exports ---do---	9,435	7,096	8,357	7,754	12,897
Value ---thousands--	$3,455	$2,807	$3,125	$3,416	$6,218
Imports for consumption ---short tons--	43,586	58,246	52,737	42,790	47,768
Value ---thousands--	$11,921	$14,579	$16,186	$15,758	$17,654
World: Production ---short tons--	[r]666,247	[r]691,988	687,640	[p]736,513	[e]694,167

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

Legislation and Government Programs.—There were no acquisitions or disposals of graphite from the strategic and critical materials stockpile in 1987.

Table 2.—U.S. Government stockpile goals and yearend stocks of natural graphite in 1987, by type

(Short tons)

Type	Goal	National stockpile inventory
Madagascar crystalline flake	20,000	17,826
Sri Lanka amorphous lump	6,300	5,444
Crystalline, other than Madagascar and Sri Lanka	2,800	1,933
Nonstockpile-grade, all types	--	932

Source: General Services Administration. Inventory of Stockpile Materials as of Dec. 31, 1987.

DOMESTIC PRODUCTION

United Minerals Co. did not operate its Townsend, MT, mine in 1987. Output of synthetic graphite increased 7% to about 225,000 short tons, at 33 plants, with a likelihood of some unreported production for in-house use. Production of all kinds of graphite fiber and cloth increased 19% to 2,000 tons.

Union Carbide Corp. closed its Puerto Rican graphite electrode plant in October after an earlier partial layoff in April. The company consolidated operations by transferring production to its plant in Clarksville, TN. The demand for graphite electrodes has been dropping in many countries, including Japan, for several years because of declines in the electrode-consuming steel industry and because of more efficient use made of the electrodes.

Akzo-Enka America Inc. bought the Fortafil Fiber Div. graphite fiber plant in Tennessee from Great Lakes Carbon Corp. It also owns a West German graphite fiber plant. Courtaulds Ltd. of the United Kingdom increased its share of ownership of Hysol Grafil Co. from 50% to 80%.

Table 3.—Principal producers of synthetic graphite in 1987

Company	Plant location	Product[1]
Airco Carbon, a division of Airco Inc	Niagara Falls, NY	Anodes, electrodes, crucibles, motor brushes, refractories, unmachined shapes, powder.
Do	St. Marys, PA	Do.
Do	Ridgeville, SC	Do.
Akzo-Enka America Inc., Fortafil Fiber Div.	Rockwood, TN	High-modulus fibers.
Amoco Performance Products	Greenville, SC	Cloth and high-modulus fibers.
Ashland Petroleum Co., Carbon Fibers Div	Ashland, KY	High-modulus fibers.
BASF Structural Materials Inc	Rock Hill, SC	Do.
Fiber Materials Inc	Biddeford, ME	High-modulus fibers and cloth.
Fiber Technology Corp	Provo, UT	
BF Goodrich Co., Engineered Systems Div., Super Temp Operation.	Santa Fe Springs, CA	Other.
Great Lakes Carbon Corp	Morganton, NC	Anodes, electrodes, motor brushes, unmachined shapes, other, powder.
Do	Niagara Falls, NY	Do.
Do	Ozark, AR	Do.
Hercules Inc	Salt Lake City, UT	High-modulus fibers.
HITCO Materials Group, British Petroleum Co. Ltd.	Gardena, CA	Cloth and high-modulus fibers.
Hysol Grafil Co	Sacramento, CA	High-modulus fibers.
North American Carbon Inc	Punxsutawney, PA	Other.
National Electrical Carbon Co	Fostoria, OH	Motor brushes, unmachined shapes, cloth.
Ohio Carbon Co	Cleveland, OH	Unmachined shapes.
Pfizer Minerals, Pigments & Metals Div	Easton, PA	Other.
Polycarbon Inc	North Hollywood, CA	Cloth.
Sigri Carbon Corp	Hickman, KY	Electrodes.
Stackpole Fibers Co. Inc	Lowell, MA	High-modulus fibers.
The Stackpole Corp., Carbon Div	St. Marys, PA	Motor brushes, unmachined shapes, powder.
Standard Oil Co., Specialty Graphite Metallics Div.	Sanborn, NY	Motor brushes, unmachined shapes, cloth.
Superior Graphite Co	Russellville, AR	Anodes, electrodes, other.
Do	Hopkinsville, KY	Do.
Textron Corp., Avco Specialty Materials Div.	Lowell, MA	High-modulus fibers.
Ultra Carbon	Bay City, MI	Powder and other.
Union Carbide Corp., Carbon Products Div	Clarksburg, WV	Anodes, electrodes, unmachined shapes, powder, other.
Do	Clarksville, TN	Do.
Do	Columbia, TN	Do.
Do	Yabucoa, PR	Do.

[1]Cloth includes low-modulus fibers; electric motor brushes include machined shapes; crucibles include vessels.

Table 4.—U.S. production of synthetic graphite, by use

Use	1986 Quantity (short tons)	1986 Value (thousands)	1987 Quantity (short tons)	1987 Value (thousands)
Products:				
Anodes	4,992	$14,463	3,388	$9,431
Cloth and fibers (low-modulus)	164	17,895	255	23,706
Crucibles, vessels, refractories	W	W	W	W
Electric motor brushes and machined shapes	W	W	W	W
Electrodes	139,926	302,160	153,847	312,907
Graphite articles[1]	--	32,351	--	30,084
High-modulus fibers	1,513	76,622	1,745	84,559
Unmachined graphite shapes	11,086	49,545	8,421	45,699
Other	r27,728	36,190	35,545	58,012
Total	r185,409	529,226	203,201	564,398
Powder and scrap	25,076	9,870	21,727	10,290
Grand total	r210,485	539,096	224,928	574,688

rRevised. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Includes all items for which no quantity data is available.

Table 5.—U.S. production of graphite fibers

Year	Cloth and low-modulus fibers: Quantity (short tons)	Cloth and low-modulus fibers: Value (thousands)	High-modulus fibers: Quantity (short tons)	High-modulus fibers: Value (thousands)	Total: Quantity (short tons)	Total: Value (thousands)
1977	136	$8,800	49	$4,330	185	$13,130
1978	141	8,720	149	11,804	290	20,524
1979	169	10,089	194	13,031	363	23,120
1980	169	11,254	306	17,379	475	28,633
1981	216	15,293	409	21,759	625	37,052
1982	212	17,706	605	30,091	817	47,797
1983	188	14,217	739	33,854	927	48,071
1984	223	17,979	1,160	56,436	1,383	74,415
1985	316	27,235	1,586	84,743	1,902	111,978
1986	164	17,895	1,513	76,622	1,677	94,517
1987	255	23,706	1,745	84,559	2,000	108,265

CONSUMPTION AND USES

Reported consumption of natural graphite increased slightly to about 32,200 tons. The three major uses of natural graphite were refractories, foundries, and lubricants, which accounted for 54% of reported consumption.

Table 6.—U.S. consumption of natural graphite, by use

Use	Crystalline: Quantity (short tons)	Crystalline: Value (thousands)	Amorphous[1]: Quantity (short tons)	Amorphous[1]: Value (thousands)	Total[2]: Quantity (short tons)	Total[2]: Value (thousands)
1986:						
Batteries	W	W	W	W	r1,302	r$1,824
Brake linings	1,453	$1,294	2,632	$2,112	4,085	3,406
Carbon products[3]	406	1,025	211	249	617	1,274
Crucibles, retorts, stoppers, sleeves, nozzles	1,516	1,333	14	15	1,530	1,348
Foundries[4]	553	356	3,916	1,279	4,469	1,635
Lubricants[5]	832	970	3,824	3,177	4,656	4,147
Pencils	1,740	2,334	286	213	2,026	2,547
Powdered metals	459	802	111	165	570	967
Refractories	W	W	W	W	8,020	3,790
Rubber	221	258	155	86	376	344
Steelmaking	131	70	1,546	607	1,677	677
Other[6]	94	212	2,049	2,298	2,143	2,510
Withheld uses	r6,499	r4,962	2,823	652	--	--
Total[2]	r13,904	r13,616	17,568	10,853	r31,472	r24,469

See footnotes at end of table.

Table 6.—U.S. consumption of natural graphite, by use —Continued

Use	Crystalline		Amorphous[1]		Total[2]	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1987:						
Batteries	W	W	W	W	1,102	$1,702
Brake linings	1,627	$1,408	2,643	$2,745	4,270	4,153
Carbon products[3]	361	868	219	270	580	1,138
Crucibles, retorts, stoppers, sleeves, nozzles	W	W	W	W	1,506	1,411
Foundries[4]	436	281	4,345	1,321	4,781	1,602
Lubricants[5]	805	789	3,606	2,296	4,411	3,085
Pencils	1,857	2,047	271	164	2,129	2,211
Powdered metals	461	848	121	190	582	1,038
Refractories	W	W	W	W	8,300	3,682
Rubber	130	152	279	141	409	293
Steelmaking	167	111	1,369	538	1,536	649
Other[6]	73	163	2,487	2,750	2,560	2,913
Withheld uses	6,559	5,828	4,348	967	--	--
Total[2]	12,475	12,494	19,690	11,383	32,165	23,876

[r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Withheld uses."
[1]Includes mixtures of natural and manufactured graphite.
[2]Data may not add to totals shown because of independent rounding.
[3]Includes bearings and carbon brushes.
[4]Includes foundry facings.
[5]Includes ammunition, packings, and seed coatings.
[6]Includes paint and polishes, antiknock and other compounds, soldering and/or welding, electrical and electronic products, mechanical products, magnetic tape, small packages, industrial diamonds, and drilling mud.

PRICES

Graphite prices are often negotiated between the buyer and seller and are based on purity and other criteria. Therefore, published price quotations are given as a range of prices. Another source of information for graphite prices is the average customs value per ton of the different imported classes. However, it should be noted that these mainly represent shipments of unprocessed graphite.

The prices of crystalline flake increased by 10% to $712 per ton: Mexican amorphous graphite rose by 6% to $52 per ton, all types of Sri Lankan lump graphite dropped by 13% to $811 per ton, and other natural graphite (mostly fine crystalline flake and dust) rose slightly to $547 per ton.

The price for crystalline graphite at the point of consumption (mostly crystalline flake, some crystalline dust, and a little lump graphite) was up slightly to $1,002 per ton, from $979 (revised) in 1986. The price for amorphous graphite (including small amounts of amorphous-synthetic graphite mixtures) dropped by 6% to $578 per ton.

Table 7.—Representative yearend graphite prices[1]

(Per short ton)

	1986	1987
Flake and crystalline graphite, bags:		
China	$54-$1,542	$54-$1,542
Madagascar	290- 998	290- 998
Sri Lanka	272- 1,361	272- 1,361
Amorphous, nonflake, cryptocrystalline graphite (80% to 85% carbon):		
Korea, Republic of (bags)	82- 113	82- 113
Mexico (bulk)	82- 109	82- 109

[1]F.o.b. foreign port or border.

Source: Engineering and Mining Journal. V. 187, No. 12, Dec. 1986, p. 19; and v. 188, No. 12, Dec. 1987, p. 11.

FOREIGN TRADE

Total exports of natural and artificial graphite increased by 7%. Exports of graphite electrodes totaled 65,987 tons valued at $119.7 million, of which 15,210 tons ($22.8 million) went to Japan, 7,610 tons ($23.1 million) to Canada, 6,655 tons ($10.4 million) to Venezuela, 4,161 tons ($7.8 million) to the U.S.S.R., 3,851 tons ($8.5 million) to the Federal Republic of Germany, 3,800 tons ($6.8 million) to Brazil, and the balance to other destinations.

Imports for consumption of natural graphite increased 12% from those of 1986. Imports of natural graphite from Canada, Madagascar, and Mexico rose substantially, in contrast to those of Sri Lanka, which dropped by about 33%.

Imports of all kinds of graphite fiber, including tows, yarns, textiles, preox fiber, and carbon fiber, but not precursor, were estimated to be 880 tons, worth about $45 million in 1987, compared with 730 tons, worth $39 million (revised) in 1986. Almost all of this was from Japan, but the United Kingdom, Israel, and the Netherlands (transshipments) supplied minor amounts.

Table 8.—U.S. exports of natural and artificial graphite, by country

Country	Natural[1]		Artificial		Total	
	Quantity (short tons)	Value	Quantity (short tons)	Value	Quantity (short tons)	Value
1986:						
Brazil	56	$23,760	266	$352,975	322	$376,735
Canada	3,678	1,427,685	6,808	546,429	10,486	1,974,114
Germany, Federal Republic of	57	21,574	7,633	2,344,940	7,690	2,366,514
Italy	804	101,859	174	81,071	978	182,930
Japan	495	534,388	2,530	1,376,583	3,025	1,910,971
Mexico	722	230,059	267	214,649	989	444,708
United Kingdom	391	146,876	915	522,532	1,306	669,408
Venezuela	116	92,571	31	46,712	147	139,283
Other	1,435	837,463	2,585	1,260,806	4,020	2,098,269
Total	7,754	3,416,235	21,209	6,746,697	28,963	10,162,932
1987:						
Brazil	12	83,880	67	55,762	79	139,642
Canada	7,672	2,384,595	8,693	523,209	16,365	2,907,804
Germany, Federal Republic of	--	--	1,211	560,386	1,211	560,386
Italy	166	72,201	256	109,363	422	181,564
Japan	1,677	1,875,353	2,795	1,580,820	4,472	3,456,173
Mexico	399	185,097	168	97,456	567	282,553
United Kingdom	1,289	621,874	554	455,489	1,843	1,077,363
Venezuela	194	123,492	1	1,605	195	125,097
Other	1,488	871,453	4,377	2,276,049	5,865	3,147,502
Total	12,897	6,217,945	18,122	5,660,139	31,019	11,878,084

[1]Amorphous, crystalline flake, lump or chip, and natural, not elsewhere classified.

Source: Bureau of the Census.

Table 9.—U.S. imports for consumption of natural graphite, by country

Country	Crystalline flake		Lump or chippy dust		Other natural crude and refined		Amorphous		Total[1]	
	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)
1985	5,899	$3,161	1,654	$1,307	18,743	$9,767	26,441	$1,952	[2]52,737	[2]$16,186
1986:										
Austria	--	--	--	--	46	27	--	--	46	27
Belgium-Luxembourg	--	--	--	--	39	64	--	--	39	64
Brazil	1,452	887	--	--	3,246	1,784	--	--	4,698	2,671
Canada	124	96	--	--	89	77	--	--	213	173
China	1,612	646	--	--	9,231	3,820	212	15	11,055	4,481
Colombia	--	--	--	--	33	42	--	--	33	42
France	181	123	--	--	224	164	--	--	405	287
Germany, Federal Republic of	73	94	--	--	854	1,392	--	--	927	1,486
Greece	--	--	--	--	([3])	4	--	--	([3])	4
Hong Kong	--	--	--	--	--	--	531	75	531	75
India	22	10	--	--	318	248	--	--	340	258
Ireland	--	--	--	--	1	5	--	--	1	5
Ivory Coast	--	--	--	--	483	44	--	--	483	44
Japan	170	447	--	--	95	266	--	--	265	713
Madagascar	1,043	702	--	--	1,798	890	--	--	2,841	1,592
Mexico	20	17	--	--	833	427	17,057	836	17,910	1,280
Montserrat	--	--	--	--	60	44	--	--	60	44
Morocco	61	52	--	--	--	--	--	--	61	52
Mozambique	--	--	--	--	54	2	--	--	54	2
Netherlands	61	44	--	--	10	3	--	--	71	47
Norway	--	--	--	--	19	9	--	--	19	9
South Africa, Republic of	--	--	--	--	81	43	--	--	81	43
Sri Lanka	--	--	2,054	1,914	--	--	--	--	2,054	1,914
Sweden	2	1	--	--	--	--	--	--	2	1
Switzerland	--	--	--	--	264	105	--	--	264	105
Taiwan	([3])	4	--	--	--	--	--	--	([3])	4
United Kingdom	--	--	--	--	26	29	--	--	26	29
Venezuela	--	--	--	--	314	307	--	--	314	307
Total[1]	4,821	3,122	2,054	1,914	18,115	9,796	17,800	925	[2]42,790	[2]15,758
1987:										
Austria	--	--	--	--	--	--	82	37	82	37
Belgium-Luxembourg	--	--	--	--	37	13	--	--	37	13
Brazil	1,019	622	--	--	4,763	2,754	--	--	5,782	3,376
Canada	977	554	--	--	1,152	548	--	--	2,129	1,102
China	1,827	963	--	--	9,096	3,222	741	80	11,664	4,265
France	--	--	--	--	108	163	--	--	108	163
Germany, Federal Republic of	22	99	--	--	269	761	--	--	291	860
Hong Kong	--	--	--	--	--	--	59	8	59	8
India	39	15	--	--	348	284	--	--	387	299
Japan	83	295	--	--	403	780	--	--	486	1,075
Madagascar	2,519	2,086	--	--	1,325	975	--	--	3,844	3,061
Mexico	--	--	--	--	1,392	683	19,321	998	20,713	1,682
Netherlands	--	--	--	--	20	28	--	--	20	28
Seychelles	--	--	--	--	20	13	--	--	20	13
South Africa, Republic of	--	--	--	--	176	89	--	--	176	89
Sri Lanka	--	--	1,402	1,137	--	--	--	--	1,402	1,137
Sweden	--	--	--	--	([3])	3	--	--	([3])	3
Switerland	--	--	--	--	20	33	--	--	20	33
United Kingdom	8	9	--	--	244	262	--	--	252	271
Venezuela	--	--	--	--	44	16	--	--	44	16
Zimbabwe	--	--	--	--	172	84	--	--	172	84
Other	82	39	--	--	([3])	1	--	--	82	40
Total[1]	6,574	4,683	1,402	1,137	19,589	10,710	20,203	1,123	47,768	17,654

[1]Data may not add to totals shown because of independent rounding.
[2]Data do not include artificial graphite.
[3]Less than 1/2 unit.

Source: Bureau of the Census.

Table 10.—U.S. imports for consumption of artificial graphite and graphite electrodes, by country

Country	Artificial graphite Quantity (short tons)	Artificial graphite Value (thousands)	Graphite electrodes Quantity (short tons)	Graphite electrodes Value (thousands)
1986:				
Australia	2	$33	--	--
Austria	--	--	(1)	$11
Belgium	35	105	1,753	3,076
Canada	1,312	488	4,626	5,389
China	15	28	60	79
Denmark	--	--	(1)	5
France	504	1,075	4,723	6,869
Germany, Federal Republic of	1,055	3,642	8,560	12,268
Hong Kong	--	--	7	8
India	979	138	--	--
Italy	14	44	5,785	7,648
Japan	1,436	6,494	30,241	53,091
Korea, Republic of	--	--	71	214
Netherlands	--	--	6,184	7,890
Norway	--	--	199	64
Singapore	--	--	528	865
Spain	--	--	1,609	2,441
Sri Lanka	--	--	20	12
Sweden	20	26	(1)	20
Switzerland	4,210	6,222	11,789	4,353
Taiwan	--	--	37	34
United Kingdom	10	45	1,517	2,381
Total[2]	9,594	18,339	77,710	106,719
1987:				
Australia	4	47	--	--
Austria	--	--	(1)	6
Belgium	(1)	2	1,192	1,862
Brazil	--	--	130	35
Canada	1,492	767	5,828	7,161
China	75	18	48	71
Denmark	--	--	1	26
Finland	--	--	(1)	2
France	759	2,523	4,124	4,990
Germany, Federal Republic of	967	2,426	2,176	4,296
Italy	239	308	5,557	7,214
Japan	1,017	6,175	26,574	38,623
Korea, Republic of	--	--	139	551
Netherlands	6	47	1,459	1,269
Norway	--	--	(1)	65
Spain	--	--	2,005	2,922
South Africa, Republic of	--	--	(1)	2
Sweden	(1)	3	(1)	135
Switzerland	4,547	9,603	102	159
Taiwan	--	--	213	213
United Kingdom	4	8	986	1,020
Other	61	56	1	3
Total[2]	9,170	21,983	50,535	70,625

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

Source: Bureau of the Census.

WORLD REVIEW

World demand was steady, but world supply dropped slightly, tightening markets and drawing down stocks.

Canada.—Cal Graphite Corp. became the second firm to schedule a crystalline flake graphite deposit in Ontario for mining in late 1988. The firm estimated that proven reserves total 29.5 million tons of ore averaging 4% graphite at its Graphite Lake, Butt Township, property. Construction was scheduled to begin in the spring of 1988 on the mine, which will run 25 years with presently known reserves, and on a mill designed to produce 22,000 tons of medium flake product containing 97.5% carbon per year.

Japan.—A shrinking Japanese steel industry resulted in reduced domestic demand for graphite electrodes. Exports of electrodes also declined because of the strong yen, compounding the problem. Officials of the Ministry of International Trade and Industry expect to see some plant closings and purchases of some smaller firms. For example, Kiowa Carbon Co. Ltd. was bought out by Toyo Carbon Co. Ltd. The firms are likely to convert some of the excess electrode capacity to produce other graphite shapes, particularly specialty products such as electrodes for spark discharge machines and graphite hot zone heaters for production of single crystal silicon and optical fiber.

The Japanese graphite fiber industry also reached overcapacity. As of late 1987, there were 23 companies producing or seeking to begin production of graphite fiber, most of them petroleum or energy-related firms. These potential producers, most with small pilot plants in operation, were sending out samples for evaluation and otherwise developing markets. The overcapacity is likely to be short term, unlike that for electrodes. The firms were planning to look at a variety of uses, but of most interest are those in construction. New types of graphite fibers with the same physical properties as presently available fibers, but at much lower prices, were being introduced. In addition, other fibers priced at current levels with much better properties, often tailored to customer requirements, were being scheduled for introduction in a short time. Production of carbon-carbon composites has been greatly expanded.

Many of the firms planned to market their graphite fiber to reinforce concrete, potentially a very high-volume market in Japan. Lightweight graphite-fiber-reinforced concrete building panels have been used to make all the concrete parts of a Tokyo highrise. The applications of lightweight concrete panels are expected to be concentrated in interior floors and walls and not in other parts of the building in the near term. Graphite fiber also has been placed in concrete road slabs on the surface to conduct away the galvanic electric currents that cause the steel reinforcing rods to corrode. A graphite fiber composite rod was proposed to reinforce concrete bridge deck slabs and graphite fiber to reinforce concrete in contact with acid waters.

In Japan, graphite fiber has been proposed for use in the structural components of X-ray machines, in robots and machine tools, and in electromagnetic shielding in buildings. Intercalated graphite fiber was proposed for use as a conductor and a high-temperature lubricant. High-performance fiber could be used in leaf springs and in automobile frames. High-modulus and ultrahigh-modulus fibers are being investigated for use in engine parts, such as pistons, valves, and connecting rods. The extent of graphite fiber applications will depend on lowering manufacturing costs, and on improving some physical properties.

The Japanese Government began to publish statistics on graphite fiber in 1987 when production was 3,490 tons. Production for the producing firm's own use was 315 tons and exports were 2,020 tons. Stocks usually average about 540 tons at the end of each month.

Korea, Republic of.—Korea Steel Chemical Co. brought on-stream a 132-ton-capacity polyacrylonitrile precursor-based graphite fiber plant at Pohang. The plant also makes chopped fiber and preoxidized fiber. Most of the sales will be to the domestic fishing rod industry.

The United Nations Industrial Development Organization signed an agreement with the Korean Government to develop a production process for pitch-based graphite fiber.

Han Kuk Fiber Glass Co. Ltd. planned to rapidly increase the size of its graphite fiber prepreg plant to consume 200 tons of fiber annually. The company's major market was sports equipment, particularly tennis rackets, but it also began to sell fiber prepreg to the Korean aircraft industry.

Le Carbone-Lorraine S.A., a subsidiary of Pechiney, constructed a graphite fiber composite plant for electrical, mechanical, and refractory applications in a suburb of Seoul.

Mexico.—The Sonoran amorphous graphite district had about 10 mining operations in 1987. Many new deposits of various sizes have recently been found near the Mar de Cortes (the southern Sonoran seacoast). The major producer, Grafitos Mexicanos S.A., operated eight mines, including new ones near Navojoa and Alamos, and produced about 32,600 tons in 1986. The firm was planning to begin making graphite briquets.

Table 11.—Graphite: World production, by country[1]

(Short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Argentina	22	16	[e]20	[e]17	17
Austria	44,553	48,269	33,911	39,867	38,600
Brazil (marketable)[3]	30,463	36,023	48,131	[e]40,800	44,000
Burma[4]	220	258	258	796	550
China[e]	204,000	204,000	204,000	204,000	204,000
Czechoslovakia[e]	55,000	55,000	65,000	65,000	61,000
Germany, Federal Republic of	[r]13,241	[r]13,620	14,107	14,587	13,000
India (mine)[5]	43,615	42,975	30,134	42,342	22,000
Italy	2,534	--	--	--	--
Korea, North[e]	28,000	28,000	28,000	28,000	28,000
Korea, Republic of:					
Amorphous	35,903	62,014	77,026	106,458	88,000
Crystalline flake	766	2,541	1,766	707	1,100
Madagascar	14,944	15,403	15,400	17,843	18,000
Mexico:					
Amorphous	47,034	43,923	36,892	39,619	39,000
Crystalline flake	1,828	1,855	2,105	2,026	2,000
Norway	8,888	11,097	[e]2,500	--	--
Romania[e]	13,900	13,700	13,200	13,200	13,200
Sri Lanka	6,094	6,198	8,171	8,216	7,700
Thailand	95	--	--	--	--
Turkey[e]	[6]5,297	5,500	5,500	5,500	5,500
U.S.S.R.[e]	88,000	88,000	90,000	91,000	92,000
United States	W	W	--	--	--
Zimbabwe	21,850	13,596	11,519	16,535	16,500
Total	[r]666,247	[r]691,988	687,640	736,513	694,167

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Table includes data available through May 20, 1988.

[2]In addition to the countries listed, Namibia may have produced graphite during the period covered by this table, but output is unreported, and available general information is inadequate for formulation of reliable estimates of output levels.

[3]Does not include the following quantities sold directly without beneficiation, in short tons: 1983—12,278; 1984—2,902; 1985—3,300 (estimated); 1986—4,400 (estimated); and 1987—not available.

[4]Data are for fiscal year beginning Apr. 1 of that stated.

[5]Indian marketable production is 10%-20% of mine production.

[6]Reported figure.

TECHNOLOGY

The Bureau of Mines investigated possible substitutes for imported crystalline flake graphite used in dolomite-carbon refractories. Fundamental engineering properties, such as the oxidation resistance, hot strength, and deformation under load, were determined for different kinds and mixes of crystalline flake graphite with dolomite. Results indicated that an 85%-carbon-content graphite was just as good as a 95%-carbon-content graphite in a 10% by weight graphite-dolomite mix when tested for oxidation rate, hot strength, or deformation under load. Dolomite-carbon brick made with the 10% graphite-dolomite mix gave the optimum hot strength and deformation under load. Use of a boron-treated graphite gave significantly higher strength and lower deformation under load at high temperatures than the untreated material.[2]

The Bureau of Mines initiated a research project to establish the feasibility of producing flake graphite from the steelmaking waste called kish. Kish is graphitic material that separates from the carbon-containing molten steel and ultimately is associated with the slag or is collected in the baghouse. The Bureau researchers estimated that domestic availability of kish was quite large, probably large enough to supply the entire U.S. demand for flake graphite, freeing the United States from its 100% import dependency.

A new technique for carefully controlled precision stirring a molten mixture of metal and graphite fiber kept the fiber evenly dispersed. The new technique produced a cast metal-matrix composite item with good properties. This could bring metal-matrix composites into large commercial production and greatly cut composite production costs by improving ease of handling, allowing production of composite ingots for later use, and by allowing the equivalent of dilution of the composite ingot when remelted for the casting.[3]

[1]Physical scientist, Branch of Industrial Minerals.

[2]Bennett, J. P. The Effect of Different Natural Flake Graphite Additions on the High-Temperature Properties of a Dolomite-Carbon Refractory. BuMines RI 9111, 1987, 12 pp.

[3]Bittence, J. C. Advanced Metal Composites on the Move. Adv. Mater. & Processes, v. 132, No. 1, July 1987, pp. 45-49.

Gypsum

By Lawrence L. Davis[1]

Demand for gypsum products remained strong in 1987. New public and private housing unit starts, a major indicator of gypsum product demand, decreased 10% to 1.6 million units. The decrease was sharpest in the fourth quarter, but did not significantly affect the overall 1987 gypsum product demand. The gypsum industry set new record-high levels for crude gypsum mined, calcined gypsum production, and shipments of prefabricated wallboard products.

Sales of gypsum products increased 6% to 27 million tons, but value decreased 9% to $2.3 billion. This was a result of increased competition and cost reduction measures put into effect by most companies.

Imports for consumption of crude gypsum increased slightly to 9.7 million tons. Total value of gypsum product exports increased 11% to $32 million.

Domestic Data Coverage.—Domestic production data for gypsum are developed by the Bureau of Mines from a survey of U.S. gypsum operations. Of the 129 operations to which the annual survey request was sent, 127 responded, representing 99% of the total production shown in tables 1 and 2.

Table 1.—Salient gypsum statistics

(Thousand short tons and thousand dollars)

	1983	1984	1985	1986	1987
United States:					
Active mines and plants[1]	111	113	116	113	109
Crude:					
Mined	12,884	14,319	[r]14,414	[r]15,403	15,612
Value	$101,361	$113,671	[r]$111,785	[r]$99,570	$106,977
Imports for consumption	8,031	8,904	9,922	9,559	9,717
Byproduct gypsum sales	760	780	779	653	688
Calcined:					
Produced	13,902	15,450	15,982	17,061	17,592
Value	$270,136	$320,518	$366,581	$310,353	$321,645
Products sold (value)	$1,605,605	$2,274,261	$2,418,296	$2,514,432	$2,282,845
Exports (value)	$32,088	$29,852	$26,419	$28,805	$32,061
Imports for consumption (value)	$87,880	$169,667	$155,422	$181,168	$163,581
World: Production	[r]88,907	[r]93,751	94,307	[p]95,360	[e]98,897

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

[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 remained the world's leading producer of gypsum, accounting for 16% of the total world output.

Crude gypsum was mined by 34 companies at 61 mines in 21 States. Production increased slightly. Leading producing States, in descending order, were Michigan, Iowa, Texas, Oklahoma, California, Nevada, and Indiana. These seven States produced more than 1 million tons each and together accounted for 74% of total domestic production. Stocks of crude ore at mines and plants at yearend were 3.0 million tons.

Leading companies were USG Corp., 11

mines; National Gypsum Co., 7 mines; Georgia-Pacific Corp., 6 mines; Celotex Corp. (a subsidiary of Jim Walter Corp.) and Domtar Inc., 3 mines each; and Weyerhaeuser Co., 1 mine. These 6 companies, operating 31 mines, produced 75% of the total crude gypsum.

Leading individual mines, in descending order of production, were USG's Plaster City Mine, Imperial County, CA; USG's Alabaster Mine, Iosco County, MI; USG's Shoals Mine, Martin County, IN; National Gypsum's Tawas Mine, Iosco County, MI; USG's Sweetwater Mine, Nolan County, TX; Temple-Eastex Inc.'s, Fletcher Mine, Comanche County, OK; Weyerhaeuser's Briar Mine, Howard County, AR; National Gypsum's Sun City Mine, Barber County, KS; National Gypsum's Shoals Mine, Martin County, IN; and USG's Sperry Mine, Des Moines County, IA. These 10 mines accounted for 41% of the national total. Average output for the 61 mines increased slightly to 256,000 tons.

Gypsum was calcined by 14 companies at 72 plants in 29 States, principally for the manufacture of gypsum wallboard and plaster. Calcined output increased 3% in tonnage and 4% in value. Leading States, in descending order, were California, Texas, Florida, Iowa, and Nevada. These 5 States, with 24 plants, accounted for 40% of the national output.

Leading companies were USG, 21 plants; National Gypsum, 18 plants; Georgia-Pacific, 9 plants; Domtar, 8 plants; and Celotex, 4 plants. These 5 companies, operating 60 plants, accounted for 84% of the national output.

Leading individual plants were, in descending order of production, USG's Plaster City plant, Imperial County, CA; USG's Jacksonville plant, Duval County, FL; Weyerhaeuser's Briar plant, Howard County, AR; USG's Sweetwater plant, Nolan County, TX; USG's Baltimore plant, Baltimore County, MD; National Gypsum's Tampa plant, Hillsborough County, FL; Temple-Eastex's West Memphis plant, Crittenden County, AR; USG's Shoals plant, Martin County, IN; USG's Stony Point plant, Rockland County, NY; and Republic Gypsum Co.'s Duke plant, Jackson County, OK. These 10 plants accounted for 28% of the national production. Average calcine production for the 72 U.S. plants was 244,300 tons, a 3% increase.

The following companies sold a total of 688,000 tons of byproduct gypsum, valued at $8.5 million, principally for agricultural use, but some for gypsum wallboard manufacturing: General Chemical Corp. and J. R. Simplot Co., both in California; Occidental Petroleum Corp. in Florida; Kemira Inc. in Georgia; SCM Pigments Div. of SCM Corp. in Maryland; Texasgulf Inc. in North Carolina; and Texas Utilities Co. in Texas. Approximately 55% was of nonphosphogypsum origin, compared with 39% in 1986. Some byproduct gypsum obtained from SCM Corp.'s SCM Pigments Div.'s plant in Baltimore, MD, was mixed with natural gypsum and commercially used in the manufacture of wallboard at USG's Baltimore plant. Byproduct gypsum from the Texas Utilities powerplant at Tatum, TX, was used exclusively as feed to Windsor Gypsum Co.'s new plant.

Gypsum wallboard plant capacity increased 7% to 25.11 billion square feet. Total wallboard shipments were 20.6 billion square feet, 82% of capacity. Both shipments and capacity were at record-high levels.

USG closed its wallboard plant at Heath, MT, and its gypsum mine at Shoemaker, MT, in January, citing high cost of operation and long distances to major markets as the reasons. Western Gypsum Co. ceased operations at its Rosario Mine and wallboard plant near Santa Fe, NM, in August.

USG completed expansions to its wallboard plants at Stony Point, NY, and Fort Dodge, IA, and began expansion to double the capacity of its wallboard plant at Sperry, IA. The $30 million expansion at Sperry was scheduled for completion in 1989.

Georgia-Pacific was preparing to begin operation of a new gypsum mine and wallboard plant at Las Vegas, NV. The company also announced plans for a 270-million-square-foot wallboard plant at Paradise, KY. The $20 million plant, using feed from a nearby Tennessee Valley Authority (TVA) powerplant, was scheduled for completion in late 1989.

Domtar completed acquisition of the mines and wallboard plants formerly owned by Genstar Gypsum Products Co. Objections by the U.S. Department of Justice to the acquisition were overcome when Domtar agreed to sell a mine and wallboard plant at Las Vegas, NV, within 6 months. Domtar also announced plans to build a $30 million wallboard plant in Newington, NH, using crude gypsum from Nova Scotia.

James Hardie Gypsum Co., a new subsidiary of James Hardie Industries Ltd. of

Australia, entered the domestic gypsum industry by purchasing the Las Vegas, NV, facilities that Domtar was required to sell and by purchasing Norwest Gypsum Co. of Seattle, WA, a wallboard manufacturer. Another new company, Standard Gypsum Co., entered the market by purchasing a wallboard plant at McQueeney, TX, from Windsor Gypsum. Standard announced plans to increase the plant's annual capacity to 300 million square feet. They also purchased a mine at Fredericksburg, TX. Windsor Gypsum began operations at its new plant at Tatum, TX, using synthetic gypsum from nearby Texas Utilities powerplants. Construction of Atlantic Gypsum Co.'s new wallboard plant at Port Newark, NJ, continued. The $34 million facility was expected to begin operating in June 1988.

Colorado Lien Co. reactivated its Munroe Mine in Larimer County, CO. Several mines were idle throughout the year: Quad-Honstein Joint Venture's Woodham Mine in Larimer County, CO; Southwestern Portland Cement Co.'s Finlay Mine in Hudspeth County, TX; and Thomas J. Peck & Sons Inc.'s Nephi Mine in Juab County, UT. Cox Enterprises Inc.'s Levan Mine in Sanpete County, UT, was inactive, but crude gypsum was shipped from stocks. Winn Rock Inc.'s Winnfield Mine in Winn Parish, LA, the only anhydrite mine in the United States, produced rock mainly for road construction.

Table 2.—Crude gypsum mined in the United States, by State

State	1986			1987		
	Active mines	Quantity (thousand short tons)	Value (thousands)	Active mines	Quantity (thousand short tons)	Value (thousands)
Arizona and New Mexico	7	615	$3,246	7	582	$3,001
Arkansas, Kansas, Louisiana	4	1,474	8,166	5	1,655	9,462
California	7	1,378	10,777	7	1,468	11,719
Colorado, Montana, South Dakota, Washington, Wyoming	10	r836	r4,711	9	671	5,095
Indiana, New York, Ohio, Virginia	5	1,960	12,479	5	2,241	14,750
Iowa	6	1,826	12,602	6	1,874	12,887
Michigan	5	1,979	11,052	5	1,977	12,190
Nevada and Utah[1]	8	1,520	10,699	6	1,444	10,285
Oklahoma	5	1,683	9,855	5	1,828	13,336
Texas	6	2,131	14,982	6	1,874	14,254
Total[2]	63	r15,403	r99,570	61	15,612	106,977

rRevised.
[1]Utah includes revisions in 1986.
[2]Data may not add to totals shown because of independent rounding.

Table 3.—Calcined gypsum produced in the United States, by State

State	1986			1987		
	Active plants	Quantity (thousand short tons)	Value (thousands)	Active plants	Quantity (thousand short tons)	Value (thousands)
Arizona and New Mexico	3	426	$5,786	3	376	$4,796
Arkansas, Louisiana, Oklahoma	7	1,831	29,209	7	1,896	32,465
California	6	1,695	33,495	6	1,924	39,364
Colorado and Utah	3	388	7,027	3	409	7,334
Delaware, Maryland, North Carolina, Virginia	6	1,543	28,980	6	1,690	31,269
Florida	3	1,309	25,158	3	1,308	27,362
Georgia	3	768	17,001	3	753	15,606
Illinois, Indiana, Kansas	6	1,533	25,664	6	1,529	25,573
Iowa	5	1,220	21,963	5	1,247	20,925
Massachusetts, New Hampshire, New Jersey, Pennsylvania	5	885	18,577	5	911	17,959
Michigan	4	618	10,923	4	673	11,438
Montana,[1] Washington, Wyoming	5	778	16,451	4	723	14,977
Nevada	3	950	16,198	3	1,071	18,045
New York	4	1,047	18,940	4	1,057	18,946
Ohio	3	479	9,659	3	460	10,868
Texas	6	1,590	25,323	7	1,562	24,718
Total[2]	72	17,061	310,353	72	17,592	321,645

[1]1986 only.
[2]Data may not add to totals shown because of independent rounding.

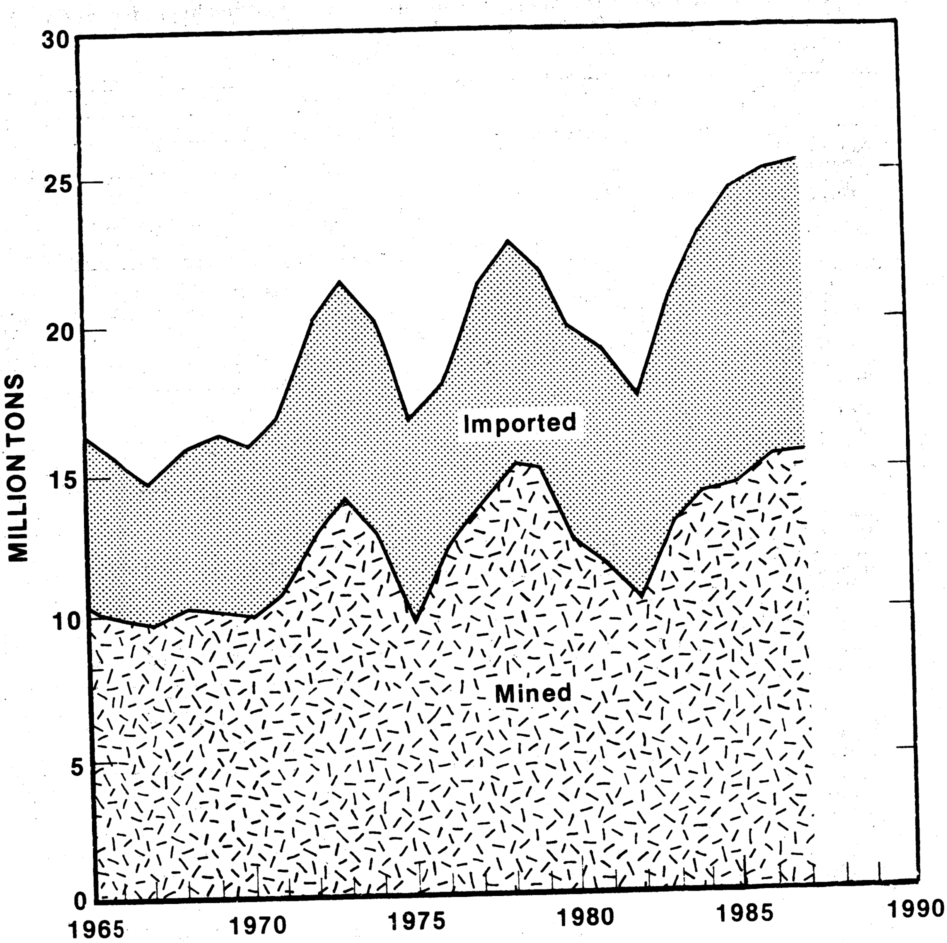

Figure 1.—Supply of crude gypsum in the United States.

CONSUMPTION AND USES

Apparent consumption, defined as production plus net imports plus industry stock changes, of crude gypsum, including by-product gypsum, increased slightly to 26.4 million tons. Net imports provided 37% of the crude gypsum consumed. Apparent consumption of calcined gypsum increased slightly to 17.6 million tons.

Yearend stocks of crude gypsum at mines and calcining plants were 3.0 million tons. Of this, 53% was at calcining plants in coastal States.

Of the total gypsum products sold or used, 6.3 million tons or 24% was uncalcined. Of the total uncalcined gypsum, 79% was used for portland cement manufacture, and 16% was used in agriculture. Of the total calcined gypsum, 96% was used for prefabricated products and 4% for industrial and building plasters. Of the prefabricated products, based on surface square feet, 68% was regular wallboard, 22% was fire-resistant type X wallboard, 3% was water- and/or moisture-resistant board, and 3% was 5/16-inch mobile home board. Lath, veneer base, sheathing, predecorated, and other types made up the balance. Of the regular wallboard, 82% was 1/2 inch and 11% was 5/8 inch. In descending order, the leading sales regions for prefabricated products were the South Atlantic, Pacific, and East North-Central; together, they accounted for 54% of the total.

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	1986 Quantity	1986 Value	1987 Quantity	1987 Value
Uncalcined:				
Portland cement	4,296	40,328	4,994	53,024
Agriculture[1]	943	13,517	1,028	17,145
Fillers and miscellaneous	93	7,868	301	10,798
Total[2]	5,331	61,712	6,324	80,967
Calcined:				
Building plaster:				
Regular base coat	133	14,888	136	15,261
Poured gypsum cement and concrete	2	139	3	248
Veneer plaster	107	16,412	114	17,882
Gauging plaster and Keene's cement	29	3,705	27	3,473
Other	7	1,224	--	--
Total[2]	278	36,367	280	36,865
Industrial plaster	476	54,126	496	58,627
Prefabricated products[3]	19,048	2,362,225	19,441	2,106,386
Total calcined[2]	19,802	2,452,719	20,218	2,201,878
Grand total[2]	25,133	2,514,432	26,541	2,282,845

[1]Includes most of 652,562 tons of byproduct gypsum in 1986 and most of 688,246 tons in 1987.
[2]Data may not add to totals shown because of independent rounding.
[3]Includes weight of paper, metal, or other materials, and some byproduct gypsum.

Table 5.—Prefabricated gypsum products sold or used in the United States

Product	1986 Thousand square feet	1986 Thousand short tons[1]	1986 Value (thousands)	1987 Thousand square feet	1987 Thousand short tons[1]	1987 Value (thousands)
Lath:						
3/8 inch	23,460	17	$3,980	20,500	16	$3,484
1/2 inch	1,000	1	159	700	1	121
Other	--	--	--	2,000	1	328
Total[2]	24,460	18	4,139	23,200	18	3,933
Veneer base	453,770	456	61,793	479,310	484	53,893
Sheathing	337,890	316	54,531	312,690	300	46,513
Regular gypsumboard:						
3/8 inch	433,450	324	51,724	612,980	462	63,361
1/2 inch	11,493,000	10,136	1,188,138	11,455,627	10,265	1,024,974
5/8 inch	1,578,700	1,442	195,767	1,523,720	1,456	164,776
1 inch	84,500	148	20,646	85,050	149	20,074
Other[3]	227,620	143	25,230	242,730	154	17,824
Total[2]	13,817,270	12,193	1,481,506	13,920,107	12,486	1,291,009
Type X gypsumboard	4,357,990	4,935	563,985	4,488,857	4,945	505,042
Predecorated wallboard	132,200	124	42,833	127,760	122	42,489
5/16-inch mobile home board	570,770	433	54,932	597,780	466	56,463
Water/moisture-resistant board	521,980	485	79,485	556,930	523	85,310
Other	84,800	87	19,020	97,280	98	21,734
Grand total[2]	20,301,130	19,048	2,362,225	20,603,914	19,441	2,106,386

[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-, 7/16-, and 3/4-inch gypsumboard.

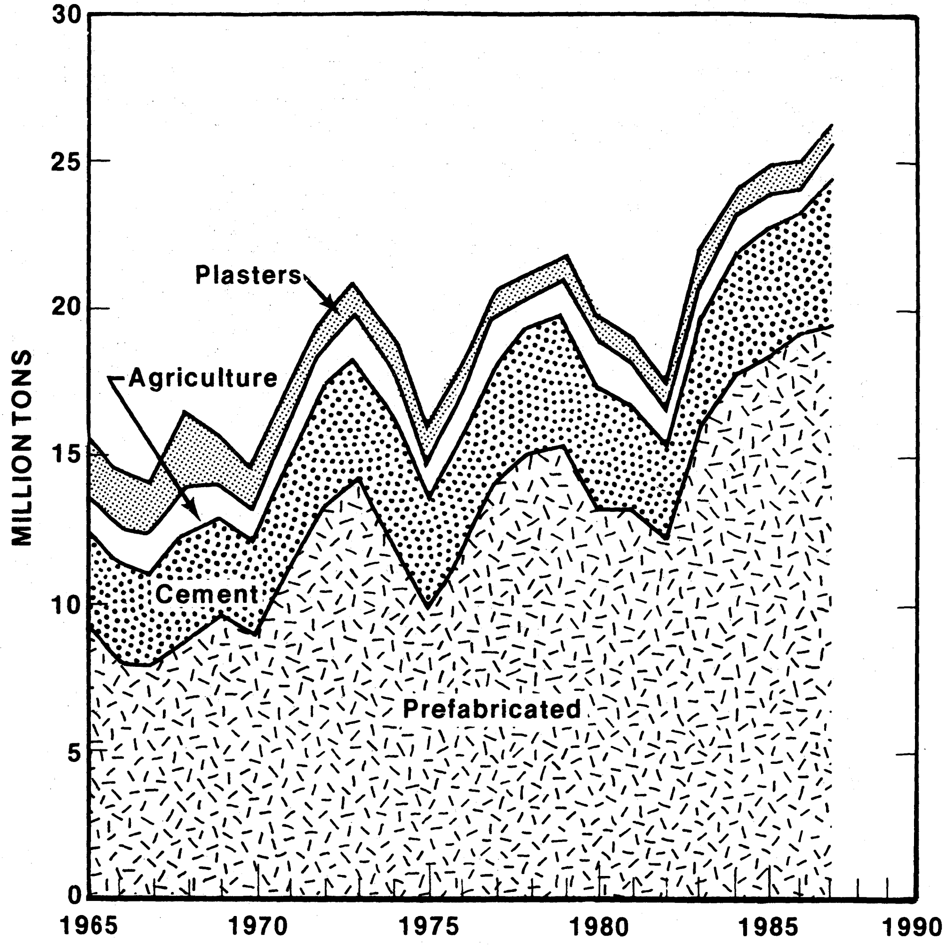

Figure 2.—Sales of gypsum products, by use.

PRICES

On an average value-per-ton basis, crude gypsum increased 6% to $6.85, calcined gypsum increased slightly to $18.28, and byproduct gypsum increased 73% to $12.32.

The average value of gypsum products sold or used decreased 14% to $86.01 per ton. Prefabricated products were valued at $108.35 per ton, industrial plasters at $118.20 per ton, building plasters at $131.66 per ton, and uncalcined products at $12.80 per ton.

Quoted prices for gypsum products were published monthly in Engineering News-Record. Prices in December, based on truck lots delivered to the job, showed a wide range. Regular 1/2-inch wallboard prices ranged from $76 per thousand square feet at Dallas to $240 at New York. The average price in December for 20 cities was $162 per thousand square feet, with some minor discounts for prompt payment. This represented a 8% decrease compared with that of December 1986.

FOREIGN TRADE

Imports for consumption of crude gypsum, which increased slightly to 9.7 million tons, represented 37% of apparent consumption. Crude gypsum from Canada and Mexico was used mainly to feed wallboard plants in coastal cities. Imports from Spain, the other major source of imported gypsum, were used mostly for portland cement manufacture. Gypsum wallboard imports, principally from Canada, 99%, were 762 million square feet, a 9% decrease.

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.[1] (value)	Total value
	Quantity	Value		
1985	83	13,021	13,398	26,419
1986	155	15,481	13,324	28,805
1987	127	15,629	16,432	32,061

[1]Includes gypsum or plaster building boards and lath (TSUS 245.7000) and articles, n.s.p.f., of plaster of paris (TSUS 512.4500).

Source: Bureau of the Census.

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)	Plasterboard[2] (value)	Other manufactures, n.s.p.f.[3] (value)	Total value
	Quantity	Value	Quantity	Value				
1985	9,922	64,089	2	242	5,173	80,119	5,799	155,422
1986	9,559	64,996	3	436	6,817	99,089	9,829	[4]181,168
1987	9,717	59,171	2	384	6,080	82,220	15,726	163,581

[1]Includes imports of jet manufactures, which are believed to be negligible.
[2]Includes gypsum or plaster building boards and lath (TSUS 245.7000).
[3]Includes statues and articles, n.s.p.f., of plaster of paris (TSUS 512.4100 and 512.4400) and gypsum cement (TSUS 512.3100 and 512.3500).
[4]Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

Table 8.—U.S. imports for consumption of crude gypsum, by country

(Thousand short tons and thousand dollars)

Country	1986		1987	
	Quantity	Value	Quantity	Value
Australia	--	--	58	370
Bahamas	18	75	--	--
Canada[1]	6,252	44,511	6,166	38,486
China	--	--	233	1,234
Greece	--	--	67	1,254
Hong Kong	20	129	--	--
Jamaica	23	135	23	117
Mexico	2,040	9,455	2,022	10,931
Spain	1,200	10,502	1,135	6,662
Other	6	189	12	118
Total[2]	9,559	64,996	9,717	59,171

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

Source: Bureau of the Census.

WORLD REVIEW

Estimated world production of crude gypsum increased 4% to 9.9 million tons. Total world production figures are probably somewhat low because, in some countries, significant production was consumed captively and not reported. Also, production from small deposits in developing countries was intermittent and often unreported.

Australia.—The gypsum industry in Australia is dominated by two companies: Boral Ltd. and CSR Ltd. The two companies compete with one another in the manufacture and marketing of gypsum products, but share mining and transportation of crude gypsum through a joint venture company, Gypsum Resources Australia Pty. Ltd. CSR commissioned a new plaster mill and wallboard plant at Sydney and a new plaster mill at Perth.[2]

Canada.—Canada remained the world's second largest producer of crude gypsum, accounting for 10% of the world total. Production remained about the same at 9.7 million tons, 68% of which came from Nova Scotia. Ontario accounted for 16% of total production, and the remaining production came from British Columbia, Manitoba, and Newfoundland.

Domtar completed its acquisition of the Genstar Gypsum Ltd. wallboard plants in Edmonton, Alberta, and Saskatoon, Saskatchewan, and a gypsum quarry at Flat Bay, Newfoundland. The Flat Bay quarry was closed in December. Domtar was developing a new underground mine at Caledonia, Ontario, to supply its nearby wallboard plant. The mine was expected to be operational in 1990 and to tap reserves expected to last 75 years at present demand levels.[3]

The Gypsum Association in the United States, of which all Canadian gypsum wallboard manufacturers were members, announced that yearend Canadian wallboard capacity was 3.87 billion square feet, a 4% increase.

China.—A contract for the construction of a gypsum plaster plant was awarded to a French firm. The plant was to be built in Shandong Province and to have a capacity of 33,000 tons per year.[4]

U.S.S.R.—An open pit mine was commissioned in eastern Siberia, near Noril'sk. Production was expected to be 55,000 to 65,000 tons annually, and reserves were estimated to last for 50 years at that rate of production.[5]

United Kingdom.—Redland PLC of the United Kingdom and CSR Ltd. of Australia announced the formation of a joint venture called Redland Plasterboard Ltd., which planned to enter the United Kingdom wallboard market beginning in 1988 by importing wallboard from a Norwegian firm. Plans also included the construction of two plants. The first would be in operation by 1991, near Bristol, using imported gypsum from Spain.[6]

Eternit TAC of Belgium announced plans to begin importing wallboard into the United Kingdom from Belgium and to open a domestic plant sometime in the future.[7]

Knauf GmbH of the Federal Republic of Germany announced that it was planning a wallboard plant at Sittingbourne, Kent. Until the plant is built, Knauf planned to enter the market with imported wallboard.[8]

Table 9.—Gypsum: World production, by country[1]

(Thousand short tons)

Country	1983	1984	1985	1986[p]	1987[e]
Afghanistan[e]	3	3	3	3	3
Algeria[e]	275	275	275	303	303
Angola[e]	22	22	22	22	22
Argentina	637	625	508	509	507
Australia	1,664	[r]2,129	1,923	1,730	1,760
Austria[2]	828	816	765	773	770
Bolivia[e]	1	1	1	1	1
Brazil	613	544	617	777	960
Bulgaria	425	433	428	435	435
Burma[3]	38	30	43	43	44
Canada (shipments)[2]	8,275	8,550	9,311	9,704	[4]9,712
Chile	73	185	216	213	[4]258
China[e]	4,700	5,300	6,300	7,200	7,900
Colombia	262	287	276	325	330
Cuba[e]	145	145	145	145	145
Cyprus	35	24	18	33	33
Czechoslovakia	935	928	[r] [e]940	[e]940	940

See footnotes at end of table.

Table 9.—Gypsum: World production, by country[1] —Continued

(Thousand short tons)

Country	1983	1984	1985	1986[p]	1987[e]
Dominican Republic	[e]230	[e]230	342	146	[4]65
Ecuador[e]	2	2	2	2	2
Egypt	795	[e]800	927	[e]1,000	990
El Salvador[e]	5	5	4	4	4
Ethiopia[e]	5	5	5	5	[4]1
France[2]	6,111	5,954	[e]6,000	4,833	[4]4,969
German Democratic Republic[e]	397	397	397	375	375
Germany, Federal Republic of (marketable)[2]	2,739	2,493	2,609	2,090	2,100
Greece[e]	[4]711	720	720	720	720
Guatemala	43	28	19	31	[4]26
Honduras[e]	25	25	25	25	25
Hungary[e 2]	31	33	33	33	33
India	1,145	1,519	1,389	1,707	[4]2,051
Iran	9,521	10,655	9,242	[r e]9,300	9,300
Iraq[e]	190	330	330	330	390
Ireland	388	358	335	318	330
Israel	46	51	[e]50	[e]50	50
Italy	1,530	1,393	1,390	1,373	1,360
Jamaica	119	199	197	129	165
Japan[e 5]	[4]6,443	6,700	6,900	7,000	7,200
Jordan	45	[r]123	101	77	77
Kenya[2]	1	[e]2	[e]2	12	12
Korea, Republic of[5]	586	558	873	([6])	--
Laos[e]	80	[4]90	120	140	155
Lebanon	[4]6	6	3	3	3
Libya[e]	[r]200	[r]200	[r]200	[r]200	200
Luxembourg[e]	([7])	([4 7])	([7])	([7])	([7])
Mauritania[e]	4	1	6	6	6
Mexico	3,261	[r]3,247	2,608	2,894	[4]2,708
Mongolia[e]	35	35	35	35	35
Morocco[e]	485	500	500	500	500
Nicaragua	13	[e]10	9	[e]9	9
Niger[e]	3	3	3	3	--
Pakistan	351	413	451	411	500
Paraguay	4	7	3	3	3
Peru	85	74	32	190	165
Philippines[5]	122	124	[e]124	[e]124	124
Poland[e 2]	[r]1,020	[r]1,300	[r]1,070	[r]1,100	1,200
Portugal	275	251	[e]275	[e]250	265
Romania[e]	1,800	[r]1,820	[r]1,790	[r]1,760	1,750
Saudi Arabia	342	[r]406	451	411	411
Sierra Leone	4	4	[e]4	[e]4	--
South Africa, Republic of	571	590	505	446	[4]385
Spain	6,195	5,914	6,090	[e]6,060	6,100
Sudan[e 2]	9	[4]9	[4]7	8	8
Switzerland[e]	200	240	240	220	230
Syria	[r]87	[r]88	177	[r e]176	176
Taiwan[5]	3	2	2	2	[4]2
Tanzania[e]	13	13	[4]16	[r]16	16
Thailand	838	1,224	1,404	1,836	[4]3,340
Tunisia[e]	88	95	100	110	110
Turkey	83	64	86	141	[4]333
U.S.S.R.[e 5]	5,400	5,400	5,400	5,500	5,500
United Kingdom[2]	3,271	3,459	3,515	[e]3,530	3,530
United States[8]	12,884	14,319	14,414	15,403	[4]15,612
Uruguay	167	82	[e]110	[e]110	110
Venezuela	226	158	147	[e]275	275
Vietnam[e]	30	30	30	30	30
Yemen Arab Republic	26	27	[e]27	58	58
Yugoslavia	687	669	[r e]670	[r e]680	680
Total	[r]88,907	[r]93,751	94,307	95,360	98,897

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through July 8, 1988.
[2]Includes anhydrite.
[3]Data are for year beginning Apr. 1 of that stated.
[4]Reported figure.
[5]Includes byproduct gypsum. (In the case of Japan, byproduct gypsum was virtually all the gypsum consumed during 1983-87.)
[6]Revised to zero.
[7]Less than 1/2 unit.
[8]Excludes byproduct gypsum.

TECHNOLOGY

Use of synthetic gypsum produced during flue gas desulfurization continued to attract interest. Windsor Gypsum's wallboard plant in Tatum, TX, became fully operational using synthetic gypsum from the Texas Utilities powerplants as the sole source of gypsum. Georgia-Pacific announced plans to construct a 270-million-square-foot-per-year wallboard plant in Kentucky using synthetic gypsum from the TVA's Paradise powerplant.[9] C-E Raymond Combustion Engineering Inc. announced that it had developed a process for using synthetic gypsum to manufacture high-quality wallboard.[10]

The Oak Ridge National Laboratory reported the results of tests to determine formaldehyde sorption and desorption characteristics of gypsum wallboard. Gypsum board was of interest as an indoor sink for pollutants, such as formaldehyde, because of its typically large surface area and water content. Gypsum wallboard was found to have substantial storage capacity for formaldehyde, which provides a time-dependent buffer to changes in formaldehyde concentration surrounding the board, but does not provide a permanent loss mechanism.[11]

The Bureau of Mines conducted pull tests on resin-grouted roof bolts in a number of underground evaporite mines. Pull-test data were shown to be helpful in establishing resin column-length criteria for roof bolts in evaporite mines.[12]

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[1]Physical scientist, Branch of Industrial Minerals.

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[3]Vagt, O. Gypsum and Anhydrite. Can. Miner. Yearbook 1987, pp. 33.1-33.8.

[4]Industrial Minerals (London). No. 245, Feb. 1988, p. 9.

[5]Levine, R. M. Eastern Europe. Min. Annu. Rev., June 1987, pp. 463-464.

[6]Benbow, J. World Gypsum—A Review. Ind. Miner. (London), No. 247, Apr. 1988, pp. 57-79.

[7]Industrial Minerals (London). No. 243, Dec. 1987, p. 16.

[8]———. No. 244, Jan. 1988, p. 11.

[9]Page 12 of work cited in footnote 7.

[10]Pit & Quarry. May 1987, pp. 16-17.

[11]Matthews, T. G., A. R. Hawthorne, and C. V. Thompson. Formaldehyde Sorption and Desorption Characteristics of Gypsum Wallboard. Environ. Sci. Technol., v. 21, No. 7, 1987, pp. 629-634.

[12]Smith, W. C., and R. M. Stateham. Column Length Criteria for Resin Bolting in Evaporites. BuMines RI 9121, 1987, 20 pp.

Helium

By William D. Leachman[1]

Grade-A helium (99.995% or better) sales volume in the United States by private industry and the Bureau of Mines was 1,736 million cubic feet (MMcf) in 1987.[2] Grade-A helium exports by private producers were 494 MMcf, for total sales of 2,230 MMcf of U.S. helium. The price of Grade-A helium, f.o.b. plant, was about $37.50 per thousand cubic feet (Mcf) for both the Bureau and private industry. The Bureau's price for bulk liquid helium was $45.00 per Mcf with additional costs for container services and rent. Private industry's liquid helium price was also about $45 per Mcf with some producers posting surcharges to this price.

Domestic Data Coverage.—Domestic production data for helium are developed by the Bureau of Mines from records of its own operations as well as the "High-Purity Helium" survey, a single, voluntary canvass of private U.S. operations. Of the seven operations to which a survey request was sent, all responded. Those data plus data from the Bureau's operations represent 100% of the total production shown in table 2.

Legislation and Government Programs.—The Government's program for storage of private crude helium in the Government's helium storage facilities at the Cliffside Field near Amarillo, TX, once again was vital in supplying helium for the private helium market. During the winter months, private industry produces crude helium from natural gas supplying the fuel market. The volume of crude helium produced is usually greater than needed to supply the helium market. The Government stores this privately owned excess crude helium production under contract in its Cliffside helium storage reservoir. During periods of insufficient crude helium production (usually the summer months), the stored private helium is returned to provide that part of private demand that cannot be supplied from current production. Privatization of all the Government's helium program, except the conservation storage operation, is currently under consideration.

DOMESTIC PRODUCTION

In 1987, 12 privately owned domestic helium plants were operated by 9 companies. Eight privately owned plants and one Bureau of Mines plant extracted helium from natural gas. Both private and Bureau plants use cryogenic extraction processes. Pressure-swing adsorption is used for helium purification at three of the newer private helium plants and at the Bureau's plant. Cryogenic purification is used by other producers. The Bureau and all seven private plants that produce Grade-A helium also liquefy helium. They are Air Products and Chemicals Inc., Hansford County, TX; Navajo Refined Helium Co., Shiprock, NM; Kansas Refined Helium Co., Otis, KS; Exxon Co. U.S.A., Shute Creek, WY; and Union Carbide Corp., Linde Div., Bushton, Elkhart, and Ulysses, KS.

The volume of helium recovered from natural gas increased considerably in 1987. Even though one of private industry's larger crude helium purification plants was shut down for modification in April 1987, all crude helium extraction plants remained in operation. All of the natural gas processed for helium extraction came from gasfields in Kansas, New Mexico, Oklahoma, Texas, and Wyoming. After the initial shakedown operations, Exxon was able to maintain operations near capacity for all of 1987. The facility is composed of two parallel plants, each of which has the capacity to process 240 million cubic feet per day (MMcf/d) of Riley Ridge gas, purify 1.5 MMcf/d of helium, and liquefy about 2,500 liters per hour of liquid helium.

Table 1.—Ownership and location of helium extraction plants in the United States in 1987

Category and owner or operator	Location	Product purity
Government-owned:		
Bureau of Mines	Masterson, TX	Crude and Grade-A helium.[1]
Private industry:		
Air Products and Chemicals Inc	Hansford County, TX	Grade-A helium.[1]
Exxon Co. U.S.A	Shute Creek, WY	Do.[1 2]
Kansas Refined Helium Co	Otis, KS	Do.[1]
Navajo Refined Helium Co	Shiprock, NM	Do.
Northern Helex Co	Bushton, KS	Crude helium.
OXY Cities Service Cryogenics Inc	Scott City, KS	Do.[3]
OXY Cities Service Helex Inc	Ulysses, KS	Crude helium.
Phillips Petroleum Co	Dumas, TX	Do.
Do	Hansford County, TX	Do.
Union Carbide Corp., Linde Div	Bushton, KS	Grade-A helium.[1]
Do	Elkhart, KS	Do.
Do	Ulysses, KS	Do.

[1]Including liquefaction.
[2]Initial production began Oct. 1986.
[3]Output is piped to Ulysses, KS, for purification.

Table 2.—Helium recovery in the United States[1]

(Thousand cubic feet)

	1983	1984	1985	1986	1987
Crude helium:					
Bureau of Mines:					
Total storage	-275,714	-314,969	-411,681	-379,827	-289,085
Private industry:					
Stored by Bureau of Mines	282,018	506,092	487,576	431,917	730,360
Withdrawn	-729,134	-605,935	-956,462	-980,209	-219,594
Total private industry storage	-447,116	-99,843	-468,886	-548,292	+510,766
Total crude helium	-722,830	-414,812	-880,567	-928,119	+221,681
Stored private crude helium withdrawn from storage and purified by the Bureau of Mines for redelivery to industry	-65,015	-49,057	-5,339	-18,658	-6,765
Grade-A helium:					
Bureau of Mines sold	241,733	294,460	397,446	333,447	266,594
Private industry sold	1,120,955	1,342,961	1,485,662	1,607,963	1,963,750
Total sold	1,362,688	1,637,421	1,883,108	1,941,410	2,230,344
Total stored	-787,845	-463,869	-885,906	-946,777	+214,916
Grand total recovery	574,843	1,173,552	997,202	994,633	2,445,260

[1]Negative numbers denote net withdrawal from the Government's underground helium storage facility, a partially depleted natural gas reservoir in Cliffside Field near Amarillo, TX.

Table 3.—Summary of Bureau of Mines helium plant operations

(Thousand cubic feet)

	1985	1986	1987
Grade-A supply:			
Inventory at beginning of period[1]	18,163	3,173	17,784
Helium recovered: Exell plant[2]	387,795	366,716	294,474
Total	405,958	369,889	312,258
Grade-A disposal:			
Sales	397,446	333,447	266,594
Redelivered to private producers	5,339	18,658	6,765
Inventory at end of period[1]	3,173	17,784	38,899
Total	405,958	369,889	312,258

[1]At Amarillo and Exell helium plants.
[2]Includes 5,339 Mcf purified for private industry in 1985, 18,658 Mcf in 1986, and 6,765 in 1987.

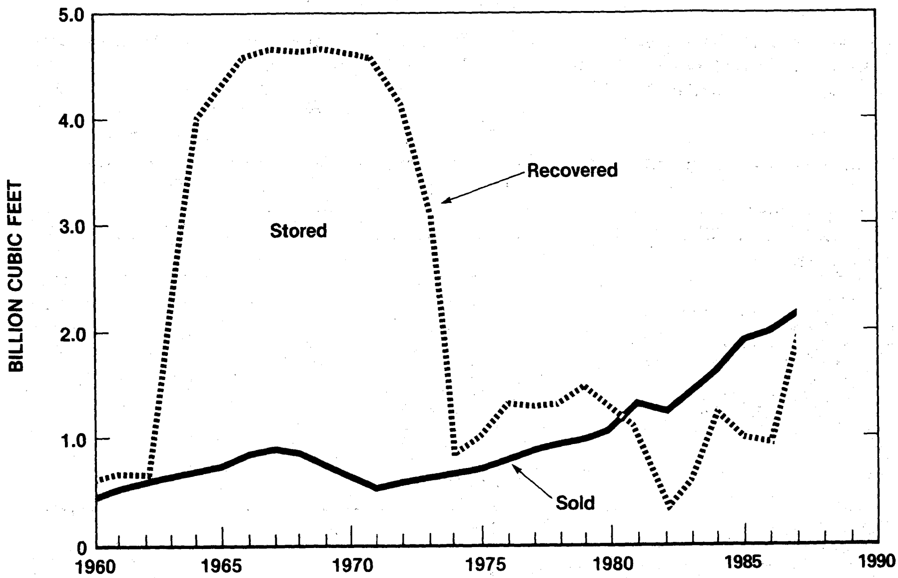

Figure 1.—Helium recovery in the United States, 1960-87.

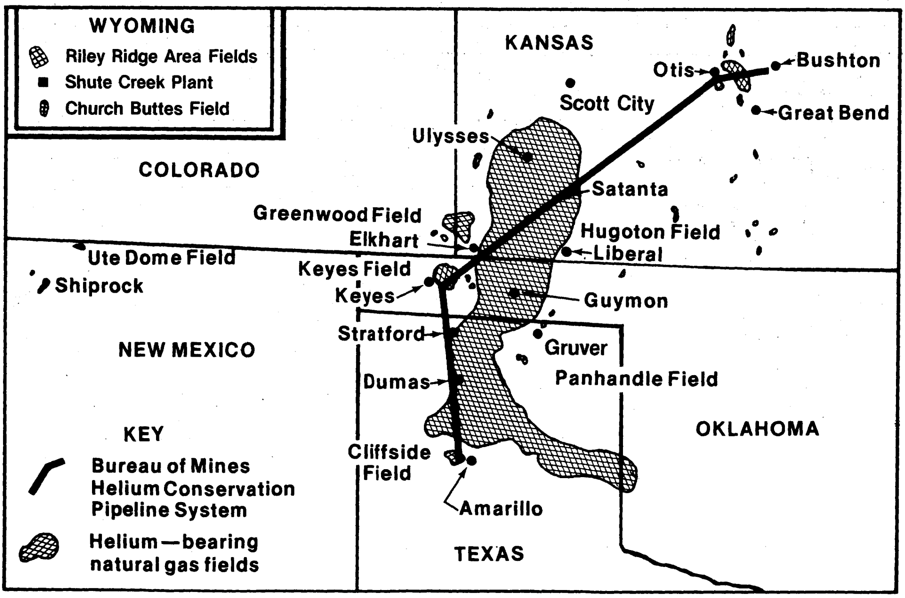

Figure 2.—Major U.S. helium-bearing natural gas fields.

CONSUMPTION AND USES

The major domestic end uses of helium were cryogenics, welding, and pressurizing and purging. Minor uses included synthetic breathing mixtures, chromatography, leak detection, lifting gas, heat transfer, and controlled atmospheres. The Pacific and Gulf Coast States were the principal areas of helium consumption.

Bureau of Mines sales to Federal agencies and their contractors totaled 267 MMcf in 1987, which is a decrease of about 20% compared with 1986 sales. This decrease was due primarily to slowdowns and changes being made in programs that require helium by the National Aeronautics and Space Administration (NASA), the U.S. Department of Energy (DOE), and the U.S. Department of Defense.

The Federal agencies purchase their major helium requirements from the Bureau of Mines. Direct helium purchases by DOE, the Department of Defense, NASA, and the National Weather Service constituted most of the Bureau's Grade-A helium sales. All of the remaining helium sales to Federal agencies were through Bureau contract distributors, who purchased equivalent volumes of Bureau helium under contracts described in the Code of Federal Regulations (30 CFR 602). Some of the contract distributors also have General Services Administration helium supply contracts. These contracts make relatively small volumes of helium readily available to Federal installations at lower freight charges by using the contractors' existing distribution systems.

Table 4.—Total sales of Grade-A helium in the United States

(Million cubic feet)

Year	Volume
1983	995
1984	1,245
1985	1,444
1986	1,509
1987	1,736

Table 5.—Bureau of Mines sales of Grade-A helium, by purchaser[1]

(Thousand cubic feet)

	1985	1986	1987
Federal agencies:			
Department of Defense	120,225	95,444	95,386
Department of Energy	37,731	41,275	27,497
National Aeronautics and Space Administration	103,144	45,684	17,504
National Weather Service	909	729	766
Other	7,604	4,827	7,223
Total	269,613	187,959	148,376
Federal agency sales supplied by private contract helium distributors[2]	124,299	140,071	117,052
Commercial sales	3,534	5,417	1,166
Grand total	397,446	333,447	266,594

[1]Table identifies Federal purchaser, who may redistribute the helium to another Federal helium user.

[2]Purchased from the Bureau of Mines by commercial firms and redistributed to Federal installations under contract authority of 30 CFR 602.

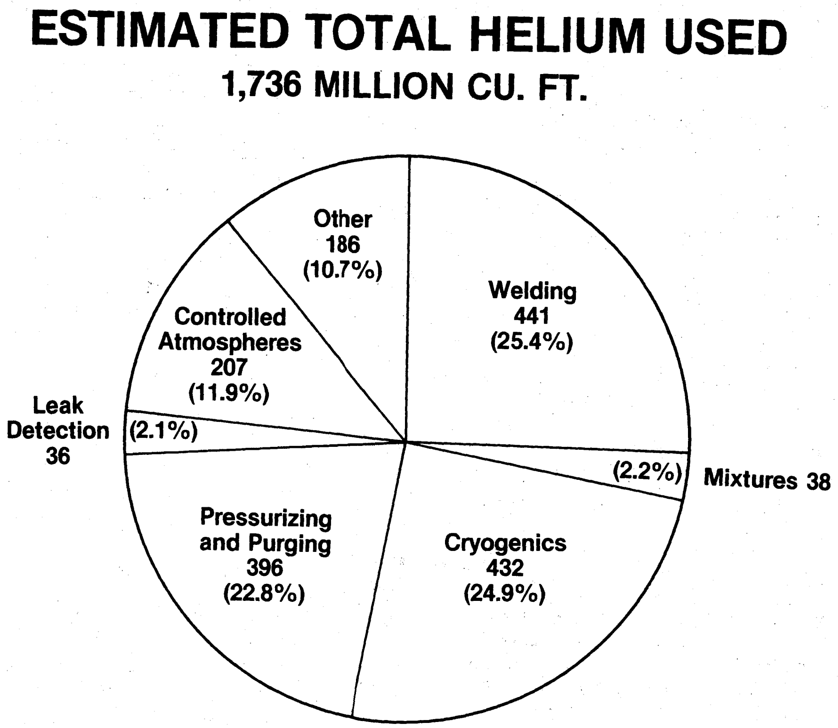

Figure 3.—Estimated helium consumption in the United States in 1987, by end use (million cubic feet).

STOCKS

The volume of helium stored for future use in the Bureau of Mines helium conservation storage system, which includes the conservation pipeline network and the Cliffside Field near Amarillo, TX, totaled 35.9 billion cubic feet (Bcf) at yearend. The conservation storage system contains crude helium purchased by the Bureau under contract, Bureau helium extracted in excess of sales, and privately owned helium stored under contract. During 1987, 730 MMcf of private helium was delivered to the Bureau's helium conservation storage system, and 704 MMcf was withdrawn, for a net increase of 26 MMcf of private helium in storage.

Table 6.—Summary of Bureau of Mines helium conservation storage system[1] operations

(Thousand cubic feet)

	1985	1986	1987
Helium in conservation storage system at beginning of period:			
Stored under Bureau of Mines conservation program	35,196,692	34,784,996	34,405,169
Stored for private producers under contract	2,814,605	2,340,395	1,773,445
Total	38,011,297	37,125,391	36,178,614
Input to system:			
Net deliveries from Bureau of Mines plants[2]	-411,681	-379,827	-289,085
Stored for private producers under contract	487,576	431,917	730,360
Total	75,895	52,090	441,275
Redelivery of helium stored for private producers under contract[2]	-961,801	-998,867	-704,031
Net addition to system[2]	-885,906	-946,777	-262,756
Helium in conservation storage system at end of period:			
Stored under Bureau of Mines conservation program	34,784,996	34,405,169	34,116,084
Stored for private producers under contract	2,340,395	1,773,446	1,799,774
Total	37,125,391	36,178,614	35,915,858

[1]Crude helium is injected into or withdrawn (-) from the Government's underground helium storage facility, a partially depleted natural gas reservoir in Cliffside Field near Amarillo, TX.
[2]Negative numbers denote net withdrawal from storage.

RESOURCES

Domestic measured and indicated helium resources as of January 1, 1987 (the latest figures available), were estimated to be 496 Bcf. The total identified helium resources was about 43 Bcf less than reported in 1986. The decrease was due primarily to changes in the estimate of probable natural gas resources made by the Potential Gas Committee reevaluation of the average helium contents and helium loss due to natural gas production. The resources included measured reserves and indicated resources estimated at 229 and 29 Bcf, respectively, in natural gas with a minimum helium content of 0.3%. The measured reserves included 36 Bcf stored by the Bureau of Mines in the helium conservation storage system. Measured helium resources in natural gas with a helium content of less than 0.3% are estimated to be 38 Bcf. Indicated helium resources in natural gas with a helium content of less than 0.3% are estimated to be 200 Bcf. Approximately 139 Bcf, or 91%, of the domestic helium resources under Federal ownership are in the Riley Ridge area and the Church Buttes Field in Wyoming, and in the Cliffside Field in Texas.

Most of the domestic helium resources are in the midcontinent and Rocky Mountain regions of the United States. The measured helium reserves are in approximately 97 gasfields in 12 States. About 90% of these reserves are contained in the Hugoton Field in Kansas, Oklahoma, and Texas; the Keyes Field in Oklahoma; Cliffside and Panhandle Fields in Texas; and the Riley Ridge area in Wyoming. The Bureau of Mines analyzed a total of 224 natural gas samples from 22 States and one foreign country during 1987 in conjunction with a program to survey and identify possible new sources of helium.

TRANSPORTATION

All Grade-A gaseous helium sold by the Bureau of Mines was shipped in cylinders, special railway tank cars, or highway tube semitrailers. Liquid helium was shipped in dewars and semitrailers from the Exell helium plant. Private industrial gas distributors shipped helium as gas or liquid. Much of the private helium was transported in liquid form by semitrailers to distribution centers, where most of it was gasified and compressed into trailers and small cylinders for delivery to the end user.

PRICES

The Bureau of Mines price, f.o.b. plant, for Grade-A helium has been maintained at $37.50 per Mcf since October 1, 1982, when it was raised from the $35 per Mcf price established in 1961. The price for Grade-A helium from private producers is about $37 per Mcf, which is approximately the same as the Government price. The Bureau's trailer-load liquid helium price was $45 per Mcf during all of 1987 with additional charges for container services and rent. The typical private industry price for liquid helium was also $45 per Mcf gaseous equivalent plus surcharges.

FOREIGN TRADE

Exports of Grade-A helium, all by private industry, increased by 14% in 1987 to 494 MMcf (table 7). Over 53% of the exported helium was shipped to Europe. Belgium-Luxembourg, France, and the United Kingdom, collectively, received more than 96% of the European helium imports. About 33% of the U.S. helium exports went to Asia; almost 4% each to North and South America; 3% to Australia and New Zealand; 1% each to Africa, Central America, and the Middle East; and less than 0.5% to the Caribbean. The shipments of large volumes of helium to Western Europe were attributed to the use of helium in cryogenic research and superconducting equipment. Significant volumes are also being used in breathing mixtures for diving, welding, and as a lifting gas. Although no helium was imported in 1987, import tariffs on helium decreased 0.2% on January 1, 1987, to 3.7%. No further decreases in import tariffs are currently scheduled.

Table 7.—U.S. exports of Grade-A helium

(Million cubic feet)

Year	Volume
1983	368
1984	392
1985	439
1986	432
1987	494

Source: Bureau of the Census.

WORLD REVIEW

World production of helium, excluding the United States, was estimated to be 125 MMcf, most of which was extracted in Poland. The remainder was attributed to centrally planned economy countries, China, and India, which began producing helium in a small plant during 1986.

TECHNOLOGY

Until recently, all superconductors required liquid helium (-452° F) to reach superconducting temperatures. Current research on superconductors has resulted in the discovery of superconducting materials that operate above liquid nitrogen temperatures (-320° F). These new superconductors have physical limitations such as brittleness and poor current-carrying capacity, which has limited their use in various superconducting applications. When these problems are solved, the new materials could replace liquid-helium-cooled superconductors and adversely affect the liquid helium market. Most helium suppliers estimate it will be 5 to 10 years before the new materials affect liquid helium demand.

Meanwhile, technology that utilizes liquid helium to produce superconducting temperatures continues to be developed and operated. Liquid helium continues to be used at Fermi National Accelerator Laboratory for Tevatron/Tevatron 1, which is the world's first superconducting particle accelerator. The liquid-helium-cooled superconducting magnets used in this accelerator provide an intense and extremely steady magnetic field with only a fraction of the energy required by conventional electromagnets. The Tevatron is the highest energy particle accelerator in the world (1.6 trillion electron volts). In addition, DOE has already selected the magnets they propose to use in the superconducting supercollider (SSC). These magnets will be similar to those used at Fermi, which are liquid helium cooled, because they have been proven and tested in operation. When completed, the SSC will have about 10 times the power of the Tevatron (20 trillion electron volts).

After a year of preliminary testing, researchers working at Oak Ridge National Laboratory attained full-current simultaneous operation of the six liquid-helium-cooled electromagnets supplied for the Large Coil Task. These six magnets each incorporate a slightly different design, which is being tested to determine the best configuration for the confinement of fusion systems for the production of clean nuclear energy. Although these magnets are the largest ever tested (8 tesla, or 160,000 times as strong as the Earth's magnetic field), they are only one-third to one-half the size of those needed for proposed fusion reactors.

The use of liquid helium in magnetic resonance imaging (MRI) continues to increase as the medical profession accepts and develops new uses for the equipment. This equipment is providing accurate diagnosis of problems where exploratory surgery has previously been required to determine problems. Another medical application being developed uses MRI to determine by blood analysis if a patient has any form of cancer.

Lifting gas applications are increasing. Many companies, in addition to Goodyear, are now using "blimps" for advertising. The Navy and Air Force are investigating the use of airships to provide early warning systems to detect low-flying cruise missiles. The Drug Enforcement Agency is using radar-equipped blimps to detect drug smugglers along the southern border of the United States. In addition, NASA is currently using helium-filled balloons to sample the atmosphere in Antarctica to determine what is depleting the ozone layer, which protects Earth from harmful ultraviolet radiation.

Helium is used in several Strategic Defense Initiative applications such as the antisatellite (ASAT) rocket, chemical laser, and rail gun. The ASAT rocket uses liquid-helium-cooled infrared sensors for target location and guidance. Gaseous helium is used in the lasing gas mixture of the chemical laser, and liquid helium is used to provide cooling for the tracking telescope used by this weapon. The telescope is used to locate the target and thus focus the laser beam on the objective. High-pressure gaseous helium is used to provide the initial push that starts the projectile moving into the bore of the rail gun at a velocity of about 1,100 miles per hour. Electromagnetic energy applied along the bore of the rail gun accelerates the projectile to a final velocity of about 9,000 miles per hour. Superconducting magnetic energy storage (SMES) is also being investigated to provide power for laser systems. SMES allows the accumulation and storage of electrical energy over the long term (hours) and discharges it in minutes.

Other technologies that are evolving and require helium's unique properties are (1) metastable helium, which involves raising helium electrons to an excited state where energy is stored and then stabilizing the molecule in that state, (2) fiber-optic production, (3) helium-filled pillows used to simulate a precursor wave from a nuclear blast, (4) helium ions for tumor treatment, (5) liquid-helium-cooled microswitches called Josephson junctions, which are much faster than conventional semiconductors and use less power, (6) "aneutronic" nuclear fusion, where nuclear energy is produced from the reaction of deuterium with helium-3, producing few or no neutrons, is being investigated, and (7) new helium-breathing mixtures are being developed that enable deep-sea divers to reach depths below 1,700 feet.

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[1]Chemical engineer, Helium Field Operations, Amarillo, TX.

[2]All helium volumes herein reported at 14.7 pounds per square inch absolute and 70° F.

Iodine

By Phyllis Lyday[1]

Three producers of crude iodine supplied less than one-half of domestic demand; the remainder was imported.

Domestic Data Coverage.—Domestic production data for iodine are developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the three operations to which a survey request was sent, two responded, representing an estimated 97% of the total production. Production data are withheld to avoid disclosing company proprietary data. Reported consumption of iodine decreased, and the number of plants reporting decreased from 24 to 22 plants.

Legislation and Government Programs.—The National Defense Stockpile (NDS) contained 6.6 million pounds of crude iodine valued at $53 million in inventory at yearend. The stockpile goal remained at 5.8 million pounds.

The National Defense Authorization Act, 1987 (Public Law 99-661), which included policy changes affecting the NDS, was signed into law by the President in November 1986. Among the law's mandates was the requirement that a new position of NDS Stockpile Manager be created in early 1987. NDS disposals were to be contingent on purchases, requiring incoming and outgoing transactions to balance. The law authorized disposal of 800,000 pounds of iodine, which was completed by April 30, 1987, at a value of $4.9 million. A report describing total mobilization of the U.S. economy for a conventional global war of 3 years' duration was to be prepared by the Secretary of Defense no later than January 31, 1987.

The Food and Drug Administration continued to list Red No. 3 dye, erythrosine, on the provisional list of color additives. Red No. 3 contains 58% iodine by weight and has a grapelike color used in carbonated soft drinks, powdered drinks, gelatin desserts, icings, and pet foods.

DOMESTIC PRODUCTION

IoChem Corp. announced in June the purchase of 4,000 acres of leases in Dewey County, OK. About 2,800 acres of the leases were purchased from Ethyl Corp. of Richmond, VA. On October 1, 1987, IoChem opened an iodine plant with nameplate capacity of 1 million pounds per year 2 miles east of Vici, OK, and began production by the blowing-out process. The source of iodine was underground brines of the Morrowan Formation of Pennsylvanian Age, 10,000 feet beneath the surface. The plant employed 25 people, 20 of whom were hired locally. IoChem markets the iodine to Schering AG, Federal Republic of Germany, for use in radiopaque media.

North American Brine Resources operated two miniplants at Dover and Hennessey in Kingfisher County, OK. The plants were at oilfield reinjection disposal sites where iodine concentrations ranged up to 1,200 parts per million (ppm). Iodine of 95% purity was produced. North American was a joint venture among Beard Oil Co., 40%; Godoe USA Inc., a wholly owned subsidiary of United Resources Industry Co., 50%; and Inorgchem Development Inc., a wholly owned subsidiary of Mitsui & Co. Ltd. (United States), 10%.

Woodward Iodine Corp., a subsidiary of Asahi Glass Co. of Japan, produced iodine from brines using the blowing-out process.

Production of iodine was from underground brines at Woodard, OK, from the Morrowan Formation, 7,500 feet beneath the surface. The iodine concentration averaged 300 ppm. Plant capacity was reported at 2 million pounds per year of iodine of greater than 99.8% purity.

CONSUMPTION AND USES

Uses of iodine were in animal feed supplements, catalysts, inks and colorants, pharmaceuticals, photographic equipment, sanitary and industrial disinfectants, stabilizers, and other uses. Other uses included production of high-purity metals, motor fuels, iodized salt, smog inhibitors, and lubricants. Iodine also had application in cloud seeding and radiopaque diagnosis in medicine.

The Food and Drug Administration Compliance Policy Guides, chapter 25, on animal drugs, recommended limits for iodine. Ethylenediamine dihydroiodide incorporated into animal feeds was limited to 10 milligrams per head per day.

The U.S. International Trade Commission (ITC) publication, "Synthetic Organic Chemicals, 1986" reported that roentgenographic contrast media, sodium diatrizoate and meglumine iothalamate, were produced and contained between 47% and 60% iodine by weight.

The ITC reported in "Synthetic Organic Chemicals, 1986" that 304,000 pounds of Red No. 3 dye was sold at a value of $4.5 million. The four companies reporting production were H. Kohnstamm & Co. Inc., McCormick & Co. Inc., Sterling Drug Inc., and Warner-Jenkinson Co.

Domestic demand for hydriodic acid was about 400,000 pounds per year, of which approximately 70% was used in sanitizers and disinfectants. Between 10% and 15% of consumption was used in pharmaceuticals.

Ethyl Corp. was the first domestic producer of synthetic alcohols for detergents using the modified Ziegler process, which uses an iodine catalyst. This process allows Ethyl to produce those alcohols where market demand is greatest. The alcohols are useful for solid and liquid detergents for household and industrial applications.[2]

Table 1.—U.S. consumption of crude iodine, by product

Product	1986 Number of plants	1986 Consumption (thousand pounds)	1987 Number of plants	1987 Consumption (thousand pounds)
Conumption, reported:				
Resublimed iodine	6	154	5	104
Potassium iodide	7	1,046	6	573
Sodium iodide	7	136	6	342
Other inorganic compounds	17	1,245	9	927
Ethylenediamine dihydroiodide	4	1,016	3	472
Other organic compounds	15	1,538	13	1,590
Total	[1]24	[2]5,136	[1]22	4,008
Consumption, apparent	XX	W	XX	W

W Withheld to avoid disclosing company proprietary data. XX Not applicable.
[1]Nonadditive total because some plants produce more than one product.
[2]Data do not add to total shown because of independent rounding.

PRICES

The average declared c.i.f. value for imported crude iodine was $6.92 per pound. The average declared c.i.f. value for imported crude iodine from Japan averaged $7.08 per pound. The average declared c.i.f. value for iodine imported from Chile was $6.80 per pound. General Services Administration releases of iodine during the year had an average value of $6.14 per pound.

Quoted yearend U.S. prices for iodine and its primary compounds were as follows:

Table 2.—Yearend 1987 published prices of elemental iodine and selected compounds

	Per pound[1]
Calcium iodate, FCC drums, f.o.b. works	$5.50
Calcium iodide, 50-kilogram drums, f.o.b. works	$10.73- 11.63
Iodine, crude, drums	7.94- 8.16
Iodoform, N.F., 300-pound drums, f.o.b. works	24.00
Potassium iodide, U.S.P., drums, 5,000-pound lots, delivered	9.15
Resublimed iodine, U.S.P., granular, 100-pound drums, works	14.21- 14.59
Sodium iodide, U.S.P., crystals, 5,000 pound lots, drums, freight equalized	10.15

[1]Conditions of final preparation, transportation, quantities, and qualities not stated are subject to negotiations and/or somewhat different price quotations.

Source: Chemical Marketing Reporter. V. 232, No. 26, Dec. 25, 1987, pp. 29-35.

FOREIGN TRADE

The U.S. Department of the Treasury continued charging duty on iodine of 99.9% or greater purity, which included resublimed iodine and some iodine classified as crude before 1984. The duty for resublimed iodine was 6 cents per pound. The U.S. Government anticipated adoption of the Harmonized Commodity Description and Coding System (Harmonized System) as the basis for its export and import tariff and statistical classification systems. The system is intended for multinational use as a basis for classifying commodities in international trade for tariff, statistical, and transportation purposes. The Harmonized System as proposed includes resublimed and crude iodine under the same code, and the duty rate is free.

Table 3.—U.S. imports for consumption of crude iodine, by type and country

(Thousand pounds and thousand dollars)

Type and country	1986		1987	
	Quantity	Value[1]	Quantity	Value[1]
Iodine, crude:				
Canada	--	--	(2)	5
Chile	1,383	7,622	1,423	9,669
Japan	1,645	9,576	1,119	7,921
Total[3]	3,028	17,199	2,542	17,595
Iodine, potassium:				
Belgium	(2)	3	5	16
Brazil	2	10	--	--
Canada	6	37	--	--
Germany, Federal Republic of	(2)	3	50	29
India	50	279	76	496
Italy	4	5	--	--
Japan	17	111	2	18
Switzerland	(2)	1	--	--
United Kingdom	2	42	2	56
Total[3]	82	492	135	615
Iodine, resublimed:				
Finland	--	--	(2)	1
Germany, Federal Republic of	(2)	8	--	--
Japan	2,654	15,530	4,388	30,992
Sweden	2	24	(2)	1
Total	2,656	15,562	4,388	30,994
Grand total	5,766	33,253	7,065	49,204

[1]Declared c.i.f. valuation.
[2]Less than 1/2 unit.
[3]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

WORLD REVIEW

Chile.—Sociedad Química y Minera de Chile (SOQUIMICH), the only producer of iodine in Chile, was created in 1968; 62.5% of its capital came from the Anglo Lautara Nitrate Co., with the remaining 37.5% share belonging to Corporación de Fomento de la Producción (CORFO), a Government-owned corporation. In 1971, CORFO became the sole owner of SOQUIMICH. In 1983, CORFO began selling SOQUIMICH shares to the private sector; by September 30, 1987, CORFO had reduced its ownership to 18% of the company.

The Maria Elena and Pedro de Valdivia plants produced sodium nitrate, potassium nitrate, sodium sulfate, and iodine. From each 2,000 pounds of caliche ore mined, 75 pounds of crude iodine was produced. The company anticipated increasing exports of iodine by 33% over the next year. Chile produces more than 6.6 million pounds of crude iodine each year with a minimum purity of 99.5% iodine.[3]

Indonesia.—State enterprises, Indonesian private enterprises, and cooperatives, as well as private Indonesian citizens, can mine vital minerals, which include iodine. Foreign firms may only participate in mining these minerals as a contractor to the Government or as a minority participant in a domestic company. Foreign companies can engage in exploration activities through private Indonesian permit holders.[4] The only producer of crude iodine was the state-owned pharmaceutical firm, P. T. Kimia Farma at Watudakon near Mojokerto, East Java. Iodine occurs with trace amounts of bromine in brines associated with oil.

Japan.—Production of iodine was from subterranean brines from various strata buried with natural gas. Japan led the world in the production of iodine in 1987. Production was 76% of capacity during 1986.

Nihon Tennen Gas Kogyo Co. Ltd. produced iodine from underground brine on the Boso Peninsula, Chiba. Iodine occurs in concentrations of approximately 100 ppm at depths between 2,300 and 6,600 feet in the Kuzusa Group. Nihon was the pioneer in 1963 of the ion-exchange resin process for extracting iodine. Current recovery is more than 90% of contained iodine using sulfurous acid as the eluant. Iodine is produced at three locations by the sloping-fluidized-bed method. There are two sets of beds at the Koji factory, three sets of beds at the Kokoshiba factory, and one set of beds at the Narashino factory. Ten sets of fixed-bed absorbers are at the Chiba factory with the elusion and refining equipment. The fixed-bed reactor requires filtration before absorption, high pumping rates, and more workers to operate it. The sloping fluidized bed does not require filtration before adsorption, is easily scaled up, and requires less employees and electric power consumption. The ion-exchange process can maintain good economics at rates of 1 million gallons per day. The blowing-out process is economical at rates of 5 million gallons or higher per day.

U.S.S.R.—At the Neftechala iodine-bromine plant in Azerbaidzhan, construction was reported completed of the first stage of renovation. At the Nebit-Dag iodine-bromine plant in Turkmens S.S.R. (Turkmenistan), an experimental facility was planned from 1986 through 1990 to study the extraction of coproducts of boron, calcium, magnesium, and sodium from the brines. It was reported that the brines contain 250 ppm of these various elements.

Table 4.—Crude iodine: World production, by country[1]

(Thousand pounds)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Chile	6,158	5,866	6,658	6,781	6,600
China[e]	1,000	1,000	1,000	1,000	1,000
Indonesia	55	55	29	13	13
Japan	16,034	16,098	15,986	16,290	15,900
U.S.S.R.[e]	4,400	4,400	4,400	4,400	4,400
United States	W	W	W	W	W
Total[3]	27,647	27,419	28,073	28,484	27,913

[e]Estimated. [p]Preliminary. W Withheld to avoid disclosing company proprietary data.
[1]Table includes data available through June 17, 1988.
[2]In addition to the countries listed, New Zealand also produces elemental iodine, but production data are not available, and available information is inadequate to make reliable estimates of output levels.
[3]Excludes U.S. production.

TECHNOLOGY

Iodine at low concentrations leaches gold. Although an expensive element, iodine can be regenerated by a simple ion-exchange technique after leaching gold. Iodine penetrates rock particles, does not complex iron, and attacks sulfides weakly. Used for gold dissolution, iodine forms the most stable gold complexes of all the halogens.[5]

Polyacetylene with iodine has conductivities approaching those of metals. After modification of the catalyst, conductivities better than copper or silver were obtained on a weight basis. Electrically conductive polymers in rechargeable polymer batteries were first demonstrated in 1986 by Badische Anilin & Soda-Fabrik AG (BASF), Federal Republic of Germany. Conductive polymers could be used as magnetic screening to protect from radiation. The polypyrrole electrodes have an advantage in that they can be formed in a variety of shapes, making possible the development of novel types of batteries for electronics. The capacities of these systems are equivalent to nickel-cadmium batteries. Advantages of these new iodine-containing materials over conventional materials are that they are not affected by superficial mechanical damage, offer resistance in corrosive and abrasive environments, and can be miniaturized.[6]

Chlorine and iodine were investigated as useful pathfinders for mineralization. The results of published case studies indicate that these halogens form broad dispersion patterns in rocks and soils around many types of mineral deposits. Cold water extraction of chlorine and iodine concentrations were used to detect anomalies associated with mineralization.[7]

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[1]Physical scientist, Branch of Industrial Minerals.

[2]Weismantel, G. The Soap and Detergent Industry is the Universal Chemical. Market Place for Both Organic and Inorganic Compounds. Chem. Week, Spec. Adver. Sec., v. 138, No. 4, 1986, 14 pp.

[3]Chemical Marketing Reporter. Chilean Nitrate Foresees Easing in Tight Iodine Mart. V. 233, No. 16, 1988, pp. 5, 28.

[4]U.S. Embassy, Jakarta, Indonesia. Indonesia's Non-Oil Mineral Sector. State Dep. Airgram A-006, Feb. 4, 1988, 52 pp.

[5]von Michaelis, H. The Prospects for Alternative Leach Reagents—Can Precious Metals Producers Get Along Without Cyanide? Min. Eng., v. 188, No. 6, 1987, p. 47.

[6]European Chemical News Specialty Chemical Supplement. Electrically Conductive Polymers Poised for Market Debut. Jan. 1988, pp. 32, 35-36.

[7]Fuge, R., M. J. Andrews, and C. C. Johnson. Chlorine and Iodine, Potential Pathfinder Elements in Exploration Geochemistry. Appl. Geochem., v. 1, 1986, pp. 111-116.

Iron Ore

By Peter H. Kuck[1]

The fortunes of the domestic iron ore industry made a turn for the better in 1987. First, USX Corp. and the United Steelworkers of America (USWA) settled their 184-day labor dispute in February. Second, there was a growth in overall demand for steel products during the fall. Mine shipments of agglomerates and ore rose to 47 million tons[2] from a depressed level of 39 million tons in 1986. Yearend stocks of ore and agglomerates at U.S. furnace yards were at their lowest levels in more than three decades. The restructuring and recapitalization of the iron ore industry in the United States and Canada, begun in 1986, continued. For the first time in 9 years, the U.S. industry did not close or indefinitely idle any of its pelletizing operations. Installed pelletizing capacity was 75 million tons, down from 90 million tons in 1980—a pivotal year for the industry.

Significant strides were made in lowering operating costs and improving productivity. New labor contracts were signed at most of the mining complexes in the Lake Superior district. The USWA agreed to wage freezes or cuts in exchange for increased job security and participation in future profit sharing. Improved demand led to increased utilization of effective pelletizing capacity, which also helped to lower unit costs. Several pelletizing plants began producing fluxed pellets in addition to the traditional acid pellets. Although more expensive to produce, the fluxed pellets help to reduce operating costs at the blast furnace by lowering coke consumption, increasing the rate of the smelting reaction, increasing the life of the refractory lining of the furnace, and improving the reliability and stability

Table 1.—Salient iron ore statistics

(Thousand long tons and thousand dollars unless otherwise specified)

	1983	1984	1985	1986	1987
United States:					
Iron ore (usable,[1] less than 5% manganese):					
Production	37,562	51,269	48,751	r38,862	46,817
Shipments	44,596	50,883	49,411	41,327	47,146
Value	$1,944,988	$2,247,686	$2,076,730	$1,472,511	$1,503,087
Average value at mines dollars per ton	$43.61	$44.17	$42.03	$35.63	$31.88
Exports	3,781	4,993	5,033	4,482	5,013
Value	$182,744	$239,257	$240,557	$204,738	$198,254
Imports for consumption	13,246	17,187	15,771	16,743	16,583
Value	$445,731	$529,065	$452,267	$460,643	$408,783
Consumption (iron ore and agglomerates)	70,629	72,514	70,575	61,116	66,698
Stocks, Dec. 31:					
At mines[2]	4,122	5,265	5,951	3,255	2,261
At consuming plants	25,494	24,017	21,290	17,163	16,304
At U.S. docks	3,174	2,942	2,404	1,987	2,024
Manganiferous iron ore (5% to 35% manganese): Shipments	30	79	18	13	W
World: Production	r728,247	r822,824	844,738	p854,726	e869,127

eEstimated. pPreliminary. rRevised. W Withheld to avoid disclosing company proprietary data.
[1]Direct-shipping ore, concentrates, agglomerates, and byproduct ore.
[2]Excludes byproduct ore. These stocks are not comparable to those of previous years owing to the reclassification of some stocks from the usable to the byproduct category.

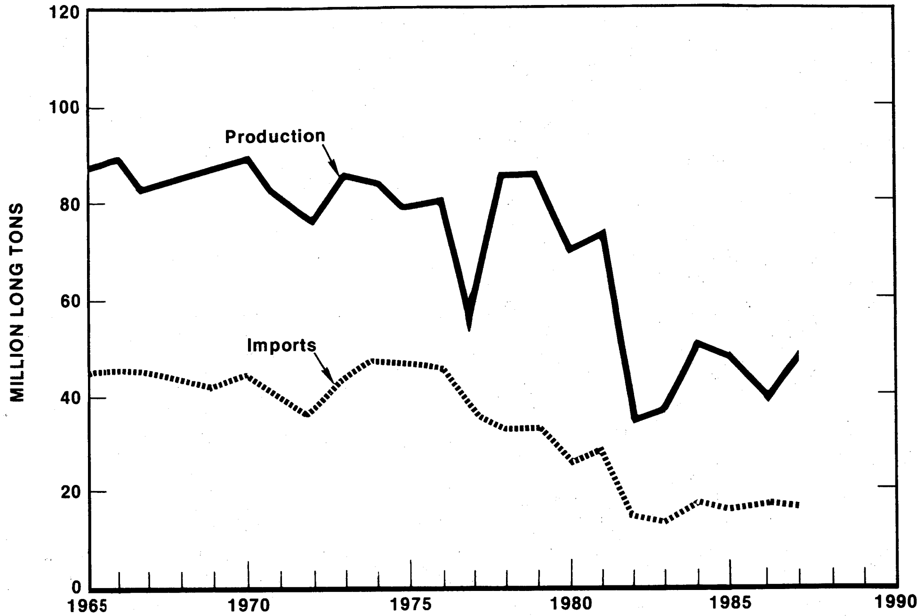

Figure 1.—U.S. iron ore production and imports for consumption.

of the furnace operation. The weakening of the U.S. dollar against the Japanese yen and several European currencies helped to improve pellet demand by slowing imports of finished steel into the United States and encouraged domestic hot metal production. The improvements in domestic mining and pelletizing productivity made it more difficult for foreign producers to sell pellets in the Great Lakes and Ohio River Valley regions. Because of reduced production costs, the U.S. Lower Lakes list price had dropped dramatically since 1984 and was much closer to the prevailing Rotterdam spot pellet price.

Consumption and trade of iron ore improved slightly in the rest of the world. Nonetheless, excess capacity to produce lump ore and sinter fines continued to overhang the international market. World prices for lump and fines continued their downward trend from 1982. Demand for pellets, in contrast, tightened somewhat. Cutbacks in demand for ore from Japan were offset by the expansion of hot-metal operations in Indonesia, the Republic of Korea, and other newly industrialized countries. Imports into the 12-member European Communities (EC) had been relatively constant since 1984 and totaled about 119 million tons in 1987. Ocean freight rates rose from the depressed levels of 1986, giving exporters like Brazil, with ports closer to Western Europe, an advantage over more distant exporters like Australia.

Domestic Data Coverage.—U.S. production data for iron ore are developed by the Bureau of Mines from three separate voluntary surveys of domestic operations. The annual "Iron Ore" survey (1066-A) provides the basic data used in this report. Of 33 addressees to whom the 1066-A form was sent, 32 responded, representing 99.98% of the total production shown in tables 1 through 4. Production for nonrespondents to the annual survey can be estimated from monthly surveys (1066-M), from railroad reports, or from reported production levels in prior years. This information may be supplemented by employment data, mine-inspection reports, and information from consumers. Consumption data were mostly provided by the annual "Blast Furnace and Steel Furnace" survey (1067-A). Data coverage for this survey is reported in the "Iron and Steel" chapter.

EMPLOYMENT

Statistics on employment and productivity in the U.S. iron ore industry in 1987, shown in table 2, were derived from quarterly employment data supplied by the Mine Safety and Health Administration (MSHA) of the U.S. Department of Labor and from production data derived from Bureau of Mines surveys. Both sets of data were obtained from producers' reports.

The statistics include production workers employed at mines, concentrators, and pelletizing plants, and in repair and maintenance shops, but do not include 693 persons engaged in management, research, or office work at mines and plants. Employees engaged in ore preparation, such as sintering, at blast furnace sites are not included. An additional 234 individuals were engaged in the secondary beneficiation of iron ore for heavy media and other nonsteel uses.

Because employment data reported to MSHA are primarily for safety analysis, hours spent by salaried employees in mines or plants may be included by operators in the total number of hours worked at individual mines or plants. This has resulted in understatement of calculated productivity by 10% to 25% for some operations, but its effect on others is not known. If company reporting practice is consistent, however, comparison of productivity from one year to the next should be reasonably valid.

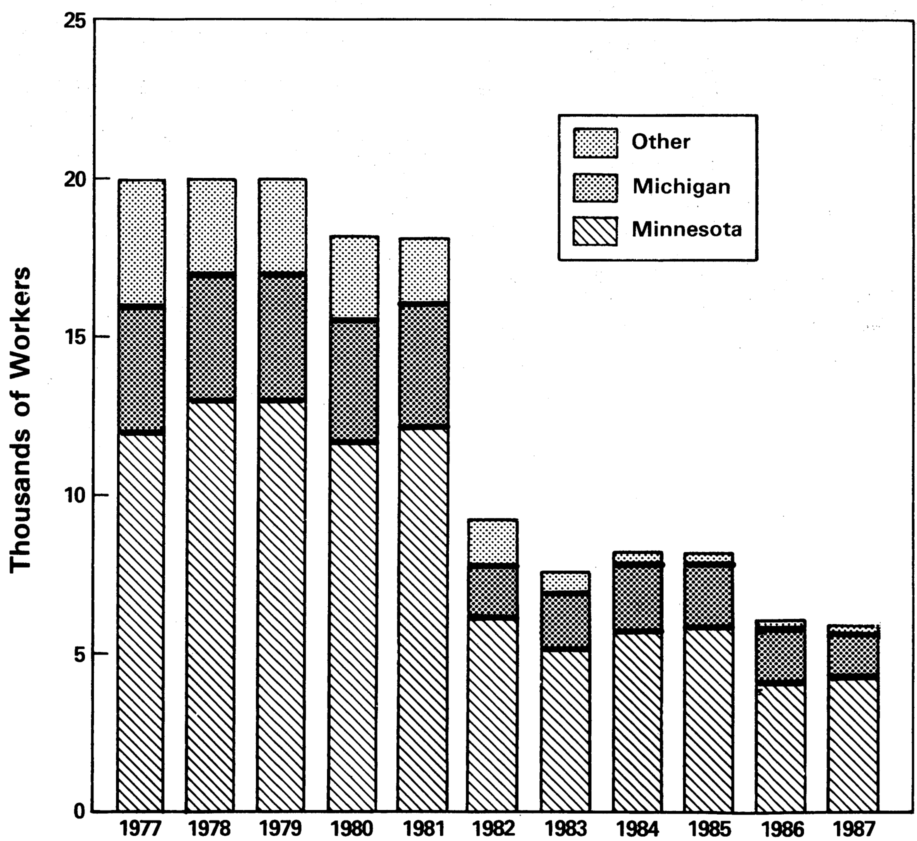

Figure 2.—Employment at iron mines and beneficiating plants.

Average quarterly employment was 4% lower than that of 1986, but total hours worked were slightly higher. At the same time, the output of usable ore jumped by 20% to meet increased pellet demand from domestic steel producers. The increase in demand enabled the iron ore industry to more fully utilize its effective pelletizing capacity and achieve economies of scale. The increase also came during a period when significant improvements were being made in productivity and cost reduction. In the Lake Superior district, which accounts for the bulk of U.S. output, average productivity for usable ore was 21% higher than that of 1986 and 86% higher than that of 1981. The significant gain since 1981 is primarily the result of drastic reductions in employment in 1982 and 1986 made by the principal producers, who were being battered by plummeting demand for domestic steel and a high level of steel imports. The two contractions have reduced installed pelletizing capacity by 19%. In 1987, pellet supply was more closely balanced with demand. For the first time in 9 years, the U.S. iron ore industry escaped permanently closing or indefinitely idling a pelletizing plant. As a result, U.S. production was concentrated in just eight large-scale taconite operations in the Lake Superior district.

The contraction of the iron mining and steel industries also led to an older work force, since younger workers traditionally have been laid off first. In the steel industry, the average age has edged up to about 44 from 40.6 in 1979.[3] In comparison, the average age of the employees at the revitalized Divrigi operations in Turkey is only 23.[4]

DOMESTIC PRODUCTION

The USX labor settlement and a strengthening of demand from the iron and steel industry were largely responsible for the 20% increase in iron ore production from the 1986 level of 38.86 million tons. The increase neutralized the downturn suffered by the domestic iron ore industry in 1986. Shipments of ore and agglomerates had dropped 16% between 1985 and 1986, putting several already financially troubled mine owners in a difficult position. Fortunately, the iron ore industry was able to turn around the situation in 1987 by reducing costs, recapitalizing, and improving pellet quality. A 12% increase in demand from Canada also helped. Total output of usable ore was equivalent to about 55% of installed production capacity on January 1.

An upturn in U.S. blast furnace activity during the fall offset a disappointing first quarter for the mine owners. Production of usable ore in the first half of the year was 10% lower than that in the comparable period of 1986. Similar declines occurred for mine shipments (14%) and pig iron production (10%). However, the monthly output of pig iron jumped from 2.74 to 3.47 million tons between February and March and kept growing for the rest of the year. In the end, 1987 pig iron production was 10% greater than that of 1986. The increase in pig iron output and the accompanying increase in demand for ore and agglomerates resulted from the resumption of iron and steelmaking by USX and the strengthening of overall demand for steel products in the fourth quarter. Secondary factors contributing to the turnaround were rising scrap prices; weakening of the U.S. dollar against the Japanese yen and major European currencies, which made the importation of some steels less attractive; rebuilding of inventories of finished steel that were depleted during the USX dispute; and increased exports of machinery and other goods fabricated from steel.

Iron ore was produced by 18 open pits and 1 underground mine. Twelve mines produced ore for the iron and steel industry, but only seven mines operated for the full 12 months. One taconite mine and its associated pelletizing plant remained idle throughout the year and another was being liquidated. Installed production capacity for usable ore at yearend was estimated at 84 million tons per year, including 75 million tons of capacity for pellets. Effective production capacity for pellets was at least 17 million tons less than installed capacity. Only four of the nine active pelletizing plants utilized more than 85% of their installed capacities.

An average of 3.1 tons of crude ore was mined in 1987 for each ton of usable ore produced. This ratio does not take into account the tonnage of waste rock or overburden removed. The ratio of total materials mined to usable ore produced was probably greater than 5 to 1. Low-grade ores of the taconite type mined in Michigan and Minnesota accounted for 99% of total crude ore production. U.S. production of pellets totaled 45.11 million tons, 96% of usable ore output. The average iron content of usable ore produced was 64.2%.

The iron ore industry of the United States and Canada underwent a major restructuring in 1986 aimed at lowering operating costs and improving competitiveness. Many of the organizational changes were still being implemented in 1987. A few companies, like Cleveland Cliffs Inc. (CCI), even initiated new restructuring and recapitalization programs. However, the bankruptcy filings of LTV Steel Co. Inc. and the Wheeling-Pittsburgh Steel Corp. made it difficult for their venture partners to refinance and modernize jointly owned operations.

CCI acquired its long-time competitor, Pickands Mather & Co., from Moore McCormack Resources Inc. on December 30, 1986. As a result of this acquisition, CCI is now responsible for more than 40% of pellet production capacity in North America. A new subsidiary, Cliffs Mining Co., was established to manage both Cleveland-Cliffs Iron Co. and Pickands Mather. At the beginning of 1987, CCI had equity in six iron mining operations, one of which was idle. The active operations included the Tilden Mining Co. (39%) and the Empire Iron Mining Partnership (5%), both of Michigan; the Hibbing Taconite Co. of Minnesota (15%); Wabush Mines of Labrador and Quebec (5.2%); and the Savage River Mines of Tasmania (36%). Pickands Mather also continued to manage the Erie Mining Co. of Minnesota for LTV Steel. The integration of Pickands Mather and the refocusing of CCI on its core iron ore business triggered a string of events that led to a restructuring and recapitalization of the amalgamated company. The management of CCI abandoned its earlier diversification strategy and began selling or spinning off its peripheral operations.

On April 17, Sharon Steel Corp. filed for protection under chapter 11 of the Federal Bankruptcy Code, adding to the complexity of the financial problems faced by CCI. Sharon Steel's filing put Tilden, which was operated and partly owned by Cleveland-Cliffs Iron, in a precarious situation. At the time of the filing, two of the four other partners in the Upper Peninsula venture—LTV Steel and Wheeling-Pittsburgh—were already involved in bankruptcy proceedings. Ownership in the mining complex was shared between Cleveland-Cliffs Iron, 39% equity; The Algoma Steel Corp. Ltd., 30%; LTV Steel, 12%; Stelco Inc., 10%; Sharon Steel, 5%; and Wheeling-Pittsburgh, 4%. However, Cleveland-Cliffs Iron had been absorbing the carrying cost of LTV Steel's interest since July 1986 when LTV Steel filed under chapter 11. Wheeling-Pittsburgh had been in technical default since April 1985.

On September 30, CCI bought back $126.4 million of Tilden long-term debt obligations from eight institutional lenders. The company purchased the notes for $106.0 million, a discount of $20.4 million, using $62.4 million obtained from the sale of 4 million shares of common stock and $43.6 million in cash. The transaction eliminated principal and interest payments of nearly $30 million per year for Cleveland-Cliffs Iron, and removed the threat of debt acceleration that was overhanging the Tilden partnership. As a result of the debt restructuring, CCI held a total of $52.6 million of Tilden notes backed by LTV Steel, Sharon Steel, and Wheeling-Pittsburgh.

The three solvent partners also began exploring ways of making Tilden more competitive. One proposal recommended that the beneficiation equipment at Tilden be converted to handle magnetite feed instead of hematite. The more easily processed magnetite ore would come from reserves at Schoolhouse Lake, just north of the existing pit. Magnetic separation techniques would drastically reduce the operation's concentrating costs, but the development of the new pit and conversion of the equipment would cost $25 million. A second proposal called for a 50% reduction in pellet production capacity from the existing 8.0 million tons per year. The partnership was still evaluating the two proposals at yearend, but was expected to approve both in early 1988.

On August 14, Cleveland-Cliffs Iron signed a letter of intent to sell its Presque Isle powerplant and related coal-handling facilities at Marquette, MI, to Wisconsin Electric Power Co. for $247.5 million. The 592-megawatt coal-fired plant supplied all of the electrical power required by both Empire and Tilden. At the time of the announcement, Cliffs had a 93% interest in the Upper Peninsula Generating Co., which in turn owned the plant. The remaining 7% was held by the Upper Peninsula Power Co. of Houghton, which operated the plant for the iron ore company. The sale of the Presque Isle plant to Wisconsin Electric was completed on December 30. The Milwaukee-based utility continued to serve the two taconite mines from Presque Isle under new long-term contracts, but could send any excess power through the existing grid to other customers. The transaction significantly reduced energy costs for the two mines.

On January 31, 46 of 47 locals of the USWA overwhelmingly ratified a new 4-year contract with USX. The vote ended a labor dispute that had shut down the company's entire USS Div. for 184 days. This was the longest work stoppage in the history of the domestic steel industry. Local 1938, made up of 1,300 workers at USX's Minntac Mine and pelletizing plant in Mountain Iron, MN, was the only bargaining unit to reject the agreement. The record-breaking labor dispute began August 1, 1986, when the previous contract expired and negotiators were unable to reach an agreement on either wages or the use of nonunion contractors. Analysts estimate that the work stoppage cost USX $3 billion in orders. The new contract permitted USX to eliminate 1,346 jobs through craft combinations and work-rule changes. The union also agreed to wage and benefit concessions that equated to at least a 7% savings for USX over the life of the contract.

Ratification enabled USX, the Nation's largest steelmaker, to proceed with its corporate restructuring program and to reduce its annual steelmaking capacity by about 27% to 19 million short tons. Management warned the USWA prior to the stoppage that USX was considering closing several facilities to increase its competitiveness. The restructuring led to the closure and eventual sale of the Geneva Works near Provo, UT. Two other steelmaking facilities were idled indefinitely, together with the sinter plant at Saxonburg, PA. The restructuring trimmed about 3,700 employees from the steel group's 22,000-plus payroll.

Operations were resumed at Minntac on May 17. However, USX management cut back the production rate to 9.2 million tons of pellets per year from the previous level of 12.5 million tons. The production cutback was dictated in part by the shutdown of Geneva. Geneva had been a major user of Minntac pellets since 1983 when the company closed its last western mine at Atlantic City, WY. Although the labor dispute was settled in January, USX management decided to keep the mining complex closed for an additional 3-1/2 months until excess pellet stocks at the remaining reopened blast furnaces were drawn down to satisfactory levels. Only four of the grate-kiln lines at the Minntac pelletizing plant were restarted. The facility has a total of 7 grate-kiln lines with an aggregate design capacity of 18.5 million tons. The Minnesota division recalled about 200 salaried and 950 hourly employees, less than two-thirds of its 1985 staff, to meet the reduced production target. Minntac remained the largest taconite operation on the Mesabi Range, despite the cutbacks.

On September 1, Basic Manufacturing and Technologies of Utah Inc. purchased Geneva, the only integrated steel plant operation west of the Mississippi, from USX for an undisclosed sum. It was renamed Geneva Steel of Utah and initially employed 872 steelworkers and about 200 managerial and clerical people, down from a combined total of more than 2,100 in 1986. The plant's principal products were plate, hot-rolled coil, and welded pipe. Minntac was continuing to provide acid pellets for the two blast furnaces at Geneva as part of the purchase agreement.

Mining was resumed in the Iron Springs mining district of Iron County to provide feed for the sinter plant.[5] Plus 3/8-inch coarse ore and minus 3/8-inch fines averaging 56% iron (Fe) were being transported 230 miles on the Union Pacific Railroad to Geneva. The actual mining was contracted out to the Gilbert Development Corp. Run-of-mine ore was being crushed and screened at the Comstock Mine, a property leased by Geneva from CF&I Steel Corp. of Pueblo, CO. Gilbert Development was also producing its own magnetically cobbed material from stockpiled ore at the Mountain Iron Mine, 4 miles to the southwest. The Mountain Iron property was leased directly by Gilbert Development from CF&I. The district, 15 miles west of Cedar City, has provided magnetite and hematite ores for blast furnaces in the Rocky Mountain region on an intermittent basis since 1923.

Initial efforts by Armco Inc. and the State of Minnesota to reopen the bankrupt Reserve Mining Co. were unsuccessful. On January 9, the court-appointed trustee for Reserve announced that the company's Peter Mitchell Mine at Babbitt and the E. W. Davis pelletizing plant at the nearby port of Silver Bay would be permanently closed. The two operations had been on standby for more than 6 months as a result of the chapter 11 bankruptcy filing of LTV Corp. Armco, LTV's partner in the joint venture, could not carry the entire cost of operating Reserve by itself and suspended production on July 21, 1986, 4 days after LTV's filing. Armco was unable to attract a new partner and was forced to place Reserve in chapter 11 bankruptcy on August 7, 1986.

Under the closure agreement, most of Reserve's 800 laid-off employees became eligible for pension and limited health insurance benefits. A new pension fund was to be established with $650,000 from the sale of stockpiled pellets, 10% of the profits from selling part of Reserve's assets, and 15% of the $16 million owed Reserve by the State of Minnesota for an occupation tax overcharge. The Pension Benefit Guaranty Corp., an agency of the Federal Government, would guarantee the basic benefits in Reserve's existing plans if it found them underfunded. Parts of the pelletizing plant and equipment were being maintained in a standby mode in the hope of eventually finding a buyer. The USWA locals also ended their blockade of the plant entrances as part of the agreement. Union officials set up the blockade September 1, 1986, in order to prevent the trustees from selling any of Reserve's equipment or stockpiled pellets until health benefits were restored to the employees. The entire agreement was being reviewed by a Federal bankruptcy judge in New York City. On January 22, the Governor of Minnesota approved a $25,000 study to determine whether reopening Reserve under new management would be economically possible.

In a related action on January 27, the Minnesota Pollution Control Agency Board approved Reserve's request to reduce the number of its environmental monitoring sites at the Milepost 7 tailings basin northwest of Silver Bay. The concentration of airborne, asbestos-like, silicate fibers had dropped dramatically since the company shut down its pelletizing plant and halted the flow of taconite tailings into the basin. The monitoring program would be reevaluated periodically by the State to ensure that the air and water quality of the basin area did not deteriorate. If Reserve remained closed, an estimated $57 million would have to be spent to decommission the sprawling tailings basin.

In September, the trustee for Reserve decided to release all of the pellets left in the Silver Bay stockpile. A total of 164,991 tons had been sitting at the port since the 1986 shutdown. All of this material was taken by LTV Steel in early October. An additional 17,762 tons of pellets was recovered during cleanup operations and shipped out in November. Since then, the State of Minnesota established an interagency task force to explore the possibility of reopening both the mine and the pelletizing plant. Armco expressed a willingness to buy up to 900,000 tons of pellets annually from a successfully restructured operation, but many roadblocks to reopening remained. The recent sale of one-half of the flotation cells and other equipment considered excess by the trustee reduced the effective annual production capacity of the pelletizing plant from 6 million tons to 4 million tons. When Reserve went into production in August 1955, it had a design capacity of 3.75 million tons. However, improvements made between 1957 and 1966 raised the design capacity in steps to about 9.8 million tons.

Minnesota produced 72% of the national output of usable ore in 1987. Production of pellets totaled 32.15 million tons, equivalent to about 62% of installed production capacity of the State's six active taconite plants.[6] The remainder of the output consisted of hematite concentrates produced from natural ores by LTV Steel and Rhude & Fryberger Inc.

A total of seven taconite plants were operable in 1987, but one—the E. W. Davis Works at Silver Bay—was left idle throughout the year by the bankruptcy filings of LTV and Reserve. An eighth, the Butler Taconite facility near Nashwauk, was being dismantled by Investment Recovery Systems Inc. Butler's former operator, M. A. Hanna Co., shipped the last 125,000 tons of pellets left in the defunct operation's stockpiles at the port of Superior.

All of LTV's natural ore production came from its McKinley Extension Mine north of Aurora. In July, Rhude & Fryberger stopped processing ore at its Rana Mine on the outskirts of Kinney and suspended all shipments indefinitely on October 31. The company had already halted operations at its Plummer-Diamond property in 1986. The Pittsburgh Pacific Co. shipped only 90 tons of concentrates recovered from natural ores stockpiled at the Connie Mine and permanently closed the last of its eight beneficiating operations on the Mesabi Range. The two closures left LTV the only active supplier of beneficiated natural ore in the Lake Superior district.

National Steel Pellet Co. (NSPC) was operated from January 1 to June 7 and from August 2 to December 31, producing 4.31 million tons of pellets. As the result of improvements in productivity, the Keewatin Mine and pelletizing plant now has an effective annual pellet production capacity of 4.7 million tons.

On November 14, rank-and-file employees at the complex ratified a new 21-month contract, narrowly averting a strike. The new contract, which expires August 1, 1989, froze wages and reduced Sunday premium pay from time-and-one-half to time-and-one-quarter. Vacation pay was also cut. In exchange for the concessions, hourly workers became eligible for a profit-sharing plan tied to the profits of the parent company, National Steel Corp. In addition, pension benefits were improved and new limits were placed on outside contracting. The 370 employees, represented by USWA Local 2660, had been without a contract since July 31, 1986, when contracts for all six taconite operations on the Mesabi Range expired. Four of the six mines had negotiated new contracts that reduced or froze wages and benefits prior to the NSPC settlement. At yearend, LTV Steel Mining Co. was the only operation left on the Mesabi Range that was operating without a contract.

At the time of the labor settlement, both NSPC and Eveleth Mines were negotiating with the Minnesota Power and Development Co. for a reduction in long-term electric power rates. In recent years, power has accounted for about 27% of NSPC's production costs. Under its existing 10-year contract, NSPC was obligated to pay the cost of having a minimum amount of electrical capacity on hand, regardless of usage. All of the taconite companies on the Mesabi Range signed such long-term take-or-pay contracts in the 1970's to avoid building their own generating plants. However, these contracts worked against NSPC and the others when they were forced to shut down for extended periods during the recent recession.

The Erie Mining Co. was renamed LTV Steel Mining Co. in February. The name change eliminated some of the confusion generated by a complex exchange of equity interests in May 1986. At that time, LTV Steel, Bethlehem Steel Corp., Stelco, and Acme Steel Co. (then Interlake Inc.) traded holdings in Erie and two other iron mines. As part of the agreement, LTV Steel relinquished its interests in both the Hibbing Taconite Co. and the Iron Ore Co. of Canada (IOC) in exchange for full ownership of Erie.

Pickands Mather continued to manage Erie for LTV Steel. The 11-million-ton-per-year complex at Hoyt Lakes operated continuously throughout the year, except for a 5-week vacation period beginning in late June. On a normal day, at least 22 of the 27 shaft furnaces would be running in the pelletizing plant. The Hoyt Lakes plant produced 6.66 million tons of pellets and 114,000 tons of chips in 1987 and shipped 6.98 million tons of pellets and chips through the port of Taconite Harbor. The production included sizable amounts of fluxed pellets shipped to LTV Steel's Cleveland Works for blast furnace trials. The fluxstone was being shipped from Michigan to Taconite Harbor, where it was loaded into rail cars returning to Hoyt Lakes.

During the first half of 1987, low-silica taconite was mined at the Dunka Pit, 22 miles northeast of Hoyt Lakes, and blended with Hoyt Lakes ores to reduce the silica content of the pellets. In August, the company installed a flotation circuit at the concentrator to help lower the silica content of the final concentrate from 4.65% to about 3.70%.[7] The four-line flotation circuit was acquired from the closed Carr Fork copper mine in Utah and was scheduled to start up in mid-1988. Carbinder and several other organic binders were being evaluated to further lower pellet silica.

Hibbing Taconite operated from January 10 to yearend and produced a record high 7.82 million tons of acid pellets, averaging 64.66% Fe and 4.74% SiO_2 on a wet basis. In mid-April, the company began increasing pellet production from an annual rate of 5.5 million tons to full capacity—9 million tons—to meet additional orders from Bethlehem Steel. All nine lines in the concentrator and all three furnaces in the pelletizing plant were operating by yearend. The Hibtac plant had a design capacity of only 8.1 million tons and had never operated above the 6.8-million-ton level. Recent improvements in the milling part of the operation have enabled the company to exceed the design limit set in 1979 when the processing facilities were expanded by 2.7 million tons. About 40 employees were added to the existing work force of 550. The mine and pelletizing plant were managed by the Pickands Mather subsidiary of CCI, which has a 15% equity in Hibtac. The Hibtac production increase helped offset losses at mines in Labrador and Quebec that were paralyzed by labor strikes during March and April. Bethlehem, which held a 70.3% equity in Hibtac, was also the largest partner in IOC. Stelco, the third Hibtac partner holding the remaining 14.7% equity, permanently closed its wholly owned Griffith Mine near Ear Falls, Ontario, Canada, in March 1986 and began relying heavily on shipments from its Wabush Mines joint venture in Labrador and Quebec.

The Minntac facility of USX was idle for a total of 136 days, producing only 7.64 million tons of acid pellets or 41% of installed capacity. Although the pelletizing plant at Mountain Iron was designed to produce 18.5 million tons per year, its effective capacity is more like 12.5 million tons. Operations were resumed on May 17 after production had stabilized at the company's reopened steel mills. By mid-June, the mining complex had returned to its normal pellet production rate of 34,000 tons per day.

On October 9, management announced that it would spend $8 million to convert Minntac's four active grate-kiln systems to fluxed pellet production. A small percentage of nonfluxed, or acid, pellets would continue to be produced for steel customers whose blast furnaces could not use the new pellets. Minntac was also successfully using 1/16- to 1/4-inch-diameter particles of pulverized waste wood to fire two of the rotary kilns. Waste wood was supplying more than 40% of the energy used on both pelletizing lines and recently had been more cost-effective than natural gas.

Eveleth Mines halted operations in early December after meeting its production goal of 3.50 million tons of pellets. Eveleth had a design capacity of 6.1 million tons per year; however, the No. 1 grate-kiln system at the Fairlane plant had been down for some time, limiting production to 3.8 million tons.

Oglebay Norton Co., the facility manager and the only partner not making steel, was put in a difficult position in 1986 by the LTV bankruptcy filing. The bankruptcy court authorized LTV to reject Oglebay's long-term pellet sales contract and one of two vessel transportation contracts. LTV did not purchase any pellets from Oglebay in 1986 or 1987 under the existing long-term agreement and chose instead to raise the output of its wholly owned mine at Hoyt Lakes. Eveleth's other owners—Armco, the Rouge Steel Co., and Stelco—lessened Oglebay's predicament by agreeing to take the production share previously contracted to LTV. Oglebay continued to do business with LTV on either a cargo-by-cargo or seasonal basis.

For the first time, the entire run at Fairlane was dedicated to the production of partially fluxed pellets. The pellets contained a 1% limestone additive and were made using the organic binder, Peridur, in place of bentonite. The final product averaged 64.64% Fe, 5.00% SiO_2, and 0.017% P on a wet basis, with the lime (CaO) and magnesia (MgO) running 0.81% and 0.39%, respectively. The new Peridur-plus-limestone (PL) pellet was designed to improve the reducibility of the blast furnace burden and had been under full-scale development at Fairlane since 1984.

In mid-June, union workers at Eveleth ratified a new 34-month contract that cut their wages by 99 cents per hour and benefits by 63 cents per hour. The cut lowered the average union wage to about $12 per hour. At the same time, the 483 workers became eligible for incentive pay and regained some jobs lost to outside contractors. The new contract, which took effect July 1, also improved job security and streamlined grievance procedures. The workers, members of USWA Local 6860, had been negotiating with Oglebay for almost a year. The Eveleth agreement was similar to one worked out in January between the union and USX's Minntac operation. Rouge, which has a 31.7% equity in Eveleth, had threatened to cancel a 400,000-ton order for pellets unless labor costs were reduced.

Oglebay filed an environmental assessment plan with the Minnesota Department of Natural Resources in November, seeking approval to expand the north pit of the Thunderbird Mine toward the city of Virginia. Under the long-term plan, Eveleth would expand the pit by 400 acres and create three new stockpiles. One of these stockpiles would be located in the old Rouchleau Pit on the southeastern edge of the city.

On November 1, 1986, Inland Steel Mining Co. began converting its Minorca Mine near the city of Virginia to 100% fluxed pellet production. At the same time, the company's Chicago-based parent, Inland Steel Co., directed CCI to begin converting part of the Empire mining complex at Palmer, MI, to fluxed production. Inland continued to have a 40% equity in the Upper Peninsula joint venture. The blended fluxstone for both operations was being supplied by another Inland division, Inland Lime & Stone Co. A total of $17 million was budgeted to pay for the Minorca and Empire changeovers, improvements at the dolomite and limestone quarries in Michigan, and the installation of new equipment at various points to crush, transfer, and grind the fluxstone. The bulk of the fluxed pellets was to be used in the No. 7 blast furnace at Inland's Indiana Harbor Works in East Chicago, IN. (See "Consumption and Uses.")

Pelletizing operations were halted at Minorca from July 31 to August 30 so that the last phase of the conversion could be completed. A cone crusher and a flux grinding circuit were incorporated into the operation, and more burners were added to the furnace.[8] A variety of organic binders, including Alcotac and Peridur, were being evaluated. The modified facility had an annual design capacity of 2.5 million tons of fluxed pellets and had begun making a product that assayed 61.50% Fe and 3.9% SiO_2 on a wet basis. Minorca produced 1.39 million tons of acid pellets and 832,000 tons of fluxed pellets in 1987.

Michigan produced 26% of the national output of usable ore in 1987. Production consisted entirely of pellets produced from ores mined at the Empire and Tilden Mines in Marquette County. Both mining ventures were managed and partially owned by Cleveland-Cliffs Iron. The company's wholly owned Republic Mine remained idle throughout the year. Production of pellets totaled 12.29 million tons, of which 7.63 million tons was produced at the Empire plant and 4.66 million tons was produced at Tilden. The Empire facility was operated throughout the year and produced at 95% capacity. In contrast, the effective utilization of Tilden for the year was only 58%.

In the last few years, Tilden was used as a swing operation because it produced pellet feed from hematite-rich taconite instead of magnetite-rich taconite. It is technically easier and considerably cheaper to beneficiate magnetite-rich taconite. Relatively simple magnetic separators can recover the magnetite, while the hematite must be selectively flocculated and passed through a series of flotation cells to remove accompanying silicates. Until now, the operation of this flocculation-flotation circuitry and the accompanying consumption of expensive flotation reagents made Tilden a higher cost producer than the adjacent Empire Mine, which recovers only magnetite. The development of the magnetite ores under Schoolhouse Lake was expected to change the economics of the entire operation. A breakthrough was achieved in early December when hourly workers at both Upper Peninsula mines ratified a new 3-year contract that called for wage deferrals to finance the $25 million project. At yearend, CCI still needed approval of its steelmaking partners and environmental regulators to proceed with the changeover.

Empire produced a record-high number of pellets in 1987 and began limited mining of its Cliffs Drive I ore body so that the beneficiating and pelletizing facilities could operate at full capacity in 1988. Empire and Tilden had begun producing significant tonnages of fluxed pellets for their steelmaking partners. Most of Empire's fluxed pellets, about 13% of the pelletizing plant's total output, went to Inland Steel. Two grades of fluxed pellets were produced at Tilden, accounting for more than one-half of its output for the year. Empire was using a 47-53 blend of dolomite and limestone made by Inland Lime & Stone Co. at its Gulliver, MI, quarry, while Tilden opted for a 70-30 blend from the Calcite and Cedarville quarries of the Michigan Limestone Operations Limited Partnership. The two fluxstone mixes were being shipped in self-unloaders to the docks at Presque Isle, where they could be stockpiled and later hauled to the pelletizing plants by truck.

In Missouri, Pea Ridge Iron Ore Co. produced about 700,000 tons of iron ore products at its underground mine near Sullivan. The bulk of the production consisted of 633,000 tons of olivine-enriched pellets made from magnetite concentrate. The mine and plant, wholly owned by Fluor Corp., were operated throughout 1987.

The addition of 5% olivine increases the reducibility of the pellet, while improving its high-temperature properties in the blast furnace and increasing its resistance to low-temperature breakdown. The olivine was being imported from Norway and ground on-site. Only two of five shaft furnaces were operating in the 1.65-million-ton-per-year pelletizing plant because of the shutdown of Lone Star Steel Co.'s blast furnace near Daingerfield, TX, in the first quarter of 1986. Lone Star had been a major customer of Pea Ridge together with the National Steel Corp. Pea Ridge continued to ship pellets on the Union Pacific Railroad for a distance of 100 miles to National Steel's Granite City steelworks, across the Mississippi River from St. Louis.

Pea Ridge also produced heavy-medium magnetite for coal cleaning, a variety of iron oxides for pigments and use in ceramic magnets, as well as hematite for use in well-drilling fluids. The company was one of the few sources of byproduct pyrite concentrate still operating in the United States.

Fluor completed a restructuring of its natural resource investments in 1987 that resulted in the reconfiguring of its coal and lead subsidiaries and the sale of its gold and domestic zinc operations. In August, Fluor also took steps to divest itself of Pea Ridge and make the iron ore operation a quasi-independent subsidiary. The Missouri mine became part of Fluor when the California-based engineering and construction agglomerate acquired St. Joe Minerals Corp. in 1981.

CONSUMPTION AND USES

Consumption of iron ore was about 9% more than that of 1986, owing to increased demand from the iron and steel industry. Consumption for ironmaking and steelmaking totaled about 60.4 million tons, including 53.8 million tons in blast furnaces, 6.2 million tons in sintering plants, 0.3 million tons for production of direct-reduced iron (DRI), and 0.1 million tons in steelmaking furnaces. An additional 23,000 tons was used by the industry for miscellaneous and unspecified purposes. Consumption of iron ore for manufacture of cement, heavy-medium materials, pigments, ballast, and miscellaneous products was approximately 1.0 million tons.

In the iron and steel industry, monthly consumption of ore averaged 5.01 million tons, compared with 4.61 million tons in 1986. Consumption jumped 24% between February and March after USX settled with the USWA and resumed hot-metal production at its blast furnaces in Indiana, Ohio, and Pennsylvania. However, even after this jump, demand for ore was extremely weak in comparison with 1984 monthly data and still remained below the depressed levels of early 1986. Total consumption for the first 6 months was only 28.46 million tons, down 10% from the same period in 1986. On June 30, 47 blast furnaces were in operation, up from 32 at the beginning of the year.

A turnaround occurred in the second half of the year. Consumption began to pick up in August and continued rising until it peaked at 5.77 million tons in December. The increase in consumption resulted from the strengthening of overall demand for steel products, with shipments to industrial construction companies and machinery manufacturers showing the greatest growth. At yearend, 49 of the 87 blast furnaces available were on line.

Consumption of iron ore and agglomerates reported by integrated producers of iron and steel totaled 65.32 million tons, including 47.87 million tons of pellets, 16.53 million tons of sinter, and 0.92 million tons of natural coarse ore. Of the primary ore consumed, an estimated 73% was of domestic origin, 14% came from Canada, and 13% came from other countries.

Estimated consumption of other materials in sintering plants included 2.30 million tons of mill scale, 0.79 million tons of flue dust, 3.86 million tons of limestone and dolomite, 1.34 million tons of slag and slag scrap, and 0.69 million tons of coke breeze. Other iron-bearing materials charged directly to blast furnaces included about 34,000 tons of manganiferous iron ore, 1.27 million tons of steel-furnace slag, 0.17 million tons of mill scale, and 0.88 million tons of slag scrap.

The No. 7 blast furnace at Inland's Indiana Harbor Works was taken out of production for 96 days so that it could be relined with a newly developed refractory brick and modernized at a cost of $30 million. The unit, which has a working volume of 123,897 cubic feet, is Inland's most efficient ironmaking furnace and the largest in the Western Hemisphere. The furnace was being fed the new fluxed pellets produced at Minorca and Empire. The improvements were expected to increase the hot metal output of the furnace by 15% to 9,000 short tons per day.

On June 13, Wheeling-Pittsburgh halted all agglomerating operations at its Follansbee, WV, byproduct coke and sinter plant. The U.S. District Court for western Pennsylvania ordered the sintering part of the complex closed indefinitely because it failed to meet air pollution standards established under the Federal Clean Air Act. The ruling was an outgrowth of a suit brought against Wheeling-Pittsburgh by the U.S. Environmental Protection Agency. The company had been operating under the protection of Federal bankruptcy laws since April 1985 and was unable to provide the $3 million needed for additional emission control equipment. The closure forced the layoff of 100 workers and complicated pig iron production at the company's five blast furnaces across the Ohio River in Steubenville.

STOCKS

Stocks of iron ore and agglomerates reported at U.S. mines, docks, and consuming plants had been gradually dropping for more than 30 years. This trend slowed somewhat in 1987. At yearend, total industry stocks were only 20.59 million tons, down 8% from 1986. The decline was due primarily to a reduction of domestic ore stocks at furnace yards. Furnace yard stocks stood at 16.30 million tons, a 61% drop from the 42.27 million tons reported at the end of 1977. Combined stocks at furnace yards and receiving docks included 12.77 million tons of domestic ores, 2.40 million tons of Canadian ores, and 3.16 million tons of other foreign ores. Mine stocks at yearend were 12% less than those of 1986, with the exhaustion of pellets from Reserve and Butler.

End-of-month stocks reported at mines peaked at 10.49 million tons in March and declined to 2.62 million tons at yearend, while stocks of ore at consuming plants ranged from a low of 9.03 million tons in May to a high of 16.30 million tons in December. As in previous years, these variations were principally caused by the seasonal nature of ore shipping on the Great Lakes.

Stocks of unagglomerated concentrates reported at pelletizing plants totaled 523,000 tons at yearend. This material is not included in mine stocks of usable ore reported in the accompanying tables because it is considered an intermediate product. Also, mine stock data after 1983 do not include byproduct ore, owing to the change in classification reported in this publication in 1983; data for previous years remain unchanged to avoid disclosing company proprietary information.

TRANSPORTATION

Vessel shipments of iron ore from U.S. ports on the upper Great Lakes totaled 47.08 million tons, about 24% more than those of 1986. Nearly 90% was destined for U.S. consumers, with the rest going to Canada. Shipments of iron ore through the St. Lawrence Seaway to U.S. ports on the Great Lakes totaled 4.07 million tons and accounted for about 25% of U.S. imports. The balance of imports, 12.51 million tons, was shipped primarily through ports on the east and gulf coasts.

Ore shipments from five of the seven U.S. ports on the upper Great Lakes increased from the levels of 1986, with the largest increase at Marquette, MI. Tonnage shipped from each port in 1987 was as follows:

Port	Date of first shipment	Date of last shipment	Total tonnage (thousand long tons)
Duluth, MN	Mar. 28	Dec. 25	7,595
Two Harbors, MN	Apr. 2	Jan. 14	7,122
Silver Bay, MN[1]	--	--	183
Taconite Harbor, MN	Mar. 31	Jan. 6	7,899
Superior, WI	Mar. 24	Jan. 7	11,313
Marquette, MI	Mar. 26	Jan. 12	7,062
Escanaba, MI	Mar. 6	Jan. 23	5,907
Total[2]			47,081

[1]Operations ceased after LTV Steel Co., the co-owner of Reserve Mining Co., filed for bankruptcy on July 17, 1986. All of the stockpiled pellets that remained at Silver Bay were shipped out Oct.-Nov. 1987.

[2]Covers the 1987 navigation season, which extended from Mar. 6, 1987, to Jan. 23, 1988.

Source: Lake Carriers' Association, 1987 Annual Report.

The number of vessel shipments from all seven ports totaled 1,313, indicating an average cargo of 35,858 tons. Individual cargoes of 60,000 tons or more were loaded at six of the ports during the year, although the average shipment from individual ports ranged from 23,004 tons at Marquette to 45,138 tons at Taconite Harbor, MN.

Between November 1986 and June 1987, precipitation over the Great Lakes basin was 25% below normal. As a result, the abnormally high water levels of 1985-86 on the Great Lakes receded during the year, reducing iron ore loadings of the larger carriers to normal tonnages. To meet the strong demand for iron ore during the fourth quarter, the U.S. Army Corps of Engineers agreed to keep the Soo Locks open until January 15, 1988, instead of the traditional closing date of December 15. The shipping season formerly ended in mid-December because natural ores, once the predominant cargo, would freeze in the hold and could not be unloaded. However, the lower moisture content of present-day taconite pellets and the advent of vessels with hulls strengthened against ice enable the industry to operate until early January.

Lake freight rates for iron ore on January 1, 1987, were those that had been in effect since April 1984. On November 10, the published rates for self-unloaders were dramatically lowered and discounts were created to encourage the use of Class X vessels (i.e., vessels with hulls greater than 1,000 feet in length). The rates were as follows:

From	To	Dollars per long ton		
		Apr. 1984	Nov. 10, 1987[1]	
			Class X	Other
Head of the Lakes	Lower lake ports	7.41	4.50	5.25
Marquette	----do	6.11	--	4.40
Escanaba	Lake Erie ports	5.64	3.40	3.95
Do	Lower Lake Michigan ports	4.45	2.70	3.00

[1]Excludes winter surcharges for shipments after Dec. 15 and before Apr. 15.

Sources: Cliffs Mining Co., Skillings' Mining Review, and Interlake Steamship Co.

Published bulk vessel freight rates from the Gulf of St. Lawrence to Lake Erie and Lake Michigan were $5.00 and $7.00 per ton, respectively. Freight rates for self-unloading vessels were $1.50 per ton higher. These rates may include toll charges on the St. Lawrence Seaway, which amount to about $1.24 per ton.

The two principal issues concerning U.S. lake shipping in 1987 continued to be the proposed construction of a second Poe-class lock at Sault Ste. Marie and the question of sharing domestic lake and coastal trade with Canadian vessels. The latter issue was rejuvenated during the Free Trade Area Agreement negotiations with Canada, and caused the Reagan Administration to review the justifications for existing cabotage laws.

At the present time, the Poe Lock is the only one at Sault Ste. Marie that can handle vessels with a length greater than 680 feet. Of the 59 dry-bulk cargo vessels registered in the U.S. Great Lakes fleet, 29 must use the Poe Lock to transit the St. Mary's Fall Canal. These 29 vessels account for more than 72% of active carrying capacity.[9] A lengthy shutdown of the Poe Lock could seriously disrupt lake shipping and sharply increase haulage costs in the region for iron ore and at least five other bulk commodities.

On November 17, 1986, the President signed the Water Resources Development Act (Public Law 99-662). Section 1149 of this law authorized construction of a second Poe-size lock. However, funding continued to be a problem. The new law required that a local sponsor pay 35% of the estimated $240 million construction costs. The States bordering the Great Lakes argue that foreign shipping would also use the proposed lock and, therefore, the Federal Government should bear the entire cost of the project. About 30% of the cargoes currently transiting the locks go to Canada or overseas. The Great Lakes States further argue that interior States like Montana, the Dakotas, and West Virginia likewise benefit from the locks. The position taken by the Lake Carriers' Association (LCA) is that the national defense role of the Soo Locks alone justifies full Federal funding. If Congress were to appropriate all of the necessary funds in 1989, groundbreaking could not take place until 1992, and the project could not be completed before 2001.

The cabotage issue is a complex one with serious long-term implications for the U.S. Great Lakes fleet. The United States has had cabotage laws since 1789 to ensure a reliable domestic shipping service and to be able to rapidly expand the Nation's maritime capabilities in the event of a national emergency. One of the key cabotage laws is section 27 of title I of the Merchant Marine Act of 1936. This section, known as the Jones Act, mandates that all domestic waterborne commerce be conducted in vessels that are U.S.-built, -owned, and -crewed.

The Government of Canada wanted these cabotage restrictions waived as part of the Free Trade Area Agreement. In exchange, U.S. vessels would have been allowed to carry cargo between Canadian ports. If approved, Canadian ore carriers would have been able to haul pellets from Duluth to Cleveland. United States and Canadian iron ore shipments on the Great Lakes for 1983 through 1987 are compared in the following tabulation:

Loading district	United States and Canadian iron ore shipments on the Great Lakes (thousand long tons)				
	1983	1984	1985	1986	1987
Lake Superior	35,056	38,152	37,363	31,177	41,174
Lake Michigan	7,416	8,619	7,385	7,378	5,907
Lake Huron	172	217	--	--	--
Eastern Canada	9,440	10,276	7,423	6,996	7,981
Total[1]	52,085	57,265	52,171	45,551	55,063
U.S. flag fleet shipments[2]	NA	NA	43,332	38,834	48,155
Percent carried by U.S. fleet	NA	NA	83	85	87

NA Not available.
[1]Includes transshipments. Data may not add to totals shown because of independent rounding.
[2]Includes mill scale, scarfer ore, and slag, in addition to iron ore.

Source: Lake Carriers' Association Annual Reports.

The hard-pressed members of the LCA and other groups opposed the Canadian proposal because the Federal Government in Ottawa continued to contribute to the pension and health programs of the Canadian merchant marine and heavily subsidized its shipbuilding industry in the 1970's. Because of these and related arguments, the United States and Canadian negotiators decided to remove the maritime provisions from the final agreement. At yearend, the Free Trade Area Agreement was awaiting ratification by Congress and the Canadian Parliament.

The State of Wisconsin, the city of Superior, and the Burlington Northern Dock Corporation were still locked in litigation over a taconite tax passed by the State legislature in 1977. During the last 10 years, the railroad subsidiary had been required to pay a 5-cent-per-ton tax on pellets railed from the western half of the Mesabi Range to the company's Allouez terminal. Burlington Northern had protested the tax since its inception and had brought several suits against the city of Superior, which collects the dock tax and retains 70% of the monies. The remaining 30% is sent to the State treasury.

In June 1986, the Wisconsin Supreme Court ruled that the taconite tax was unconstitutional and violated the commerce clause of the U.S. Constitution by discriminating against ore mined outside of Wisconsin. The Wisconsin attorney general then appealed the ruling of the State court to the U.S. Supreme Court. On January 12, 1987, the Court upheld the State court's ruling, forcing the city of Superior and Wisconsin to refund the $5.4 million paid under protest by Burlington Northern between 1977 and 1985, plus interest.

In 1985, the State legislature changed the tax law and removed the part that the State supreme court had found objectionable. In May 1987, Burlington Northern sued the city again, claiming that the redrafted tax was also unconstitutional. At yearend 1987, negotiations were still in progress between city, State, and company officials.

Published railway freight rates for pellets from mines to upper lake shipping ports were unchanged in Minnesota in 1987. The volume rate for pellets from the western Mesabi Range to the Allouez docks at Superior remained at $5.01 per ton. For pellets from the Marquette Range of Michigan, the rate to Escanaba remained at $2.68 per ton. However, on January 18, the rate to Presque Isle was lowered from $2.40 to $2.15 per ton. Dock-handling charges at Duluth, Superior, and Escanaba ranged from 69 to 94 cents per ton.

Rail rates from lower lake ports to a number of consuming points were rolled back to 1985 levels in November 1986, but most of these rollbacks were erased at the end of 1987. Several other key rates were raised substantially at this time. Most ore transfer charges were also increased slightly at yearend. At Lake Erie ports, charges for transfering ore from rail-of-vessel or dock-receiving areas directly into railway cars ranged from $0.97 to $1.52 per ton. Key rail rates for 1986 through 1987 are compared in the following tabulation:

From	To	Type of rate[1]	Dollars per long ton		
			Jan. 1, 1986	Nov. 17, 1986	Jan. 1, 1988
Lake Erie ports	Pittsburgh and Wheeling districts.	Multiple car	10.74	10.62	11.45
Baltimore, MD	Pittsburgh district	do	11.68	11.49	NA
Do	do	Single car	15.77	15.77	16.26
Philadelphia, PA	do	do	16.48	NA	17.57
Mesabi Range	Granite City, IL	Multiple car	19.07	23.35	24.33
Pea Ridge, MO	do	do	6.41	6.41	6.41

NA Not available.
[1]As a result of the Staggers Rail Act of 1980, which partially deregulated the railroads, it has become difficult to obtain accurate freight rate data. Published tariff rates are only suggested rates and may be significantly higher than the actual contract rates.

Sources: Cliffs Mining Co., Skillings' Mining Review, and Minnesota Mining Directory.

All-rail shipments of pellets from Minnesota by the Duluth, Missabe and Iron Range Railway Co. and connecting lines amounted to only 431,000 tons, down from 1.5 million tons in 1985, because of the USX labor dispute and the subsequent idling of the Geneva Works near Provo, UT. Shipments to Geneva from the Minntac plant were resumed in the fourth quarter of 1987 after the steelworks were sold to Basic Manufacturing and Technologies of Utah. Some pellets were also hauled all-rail to National Steel's two blast furnaces at Granite City, IL. Shipments of pellets and small quantities of natural ore to the ports of Duluth and Two Harbors totaled 14.72 million tons for a total ore movement on the railway of 15.15 million tons during the 1987-88 shipping season.

Published nominal ocean freight rates for iron ore from eastern Canada to U.S. mid-Atlantic ports were $3.50 to $3.75 per ton, but spot rates quoted for cargoes of 60,000 to 95,000 tons ranged from $2.75 to $3.75 per ton. A few shipments reported from Brazil to east coast ports indicated freight rates of $4.50 to $4.95 per ton.

PRICES

In 1985, three Lake Superior producers adopted new price bases for their pellets in response to increasing competition between domestic and foreign producers in the U.S. market. Pickands Mather and Inland Steel Mining both began quoting a price of 59.4 cents per long ton unit (ltu) of iron, natural, delivered to hold-of-vessel at *upper* lake ports. For more than two decades, Lake Superior pellet prices had been quoted for delivery to rail-of-vessel at lower lake ports. USX made price comparisons even more difficult by quoting 72.5 cents per *dry* ltu of iron for Minntac pellets, delivered rail-of-vessel at lower lake ports. In 1987, domestic pricing was further complicated by the emergence of a significant spot market for pellets.[10] Spot sales of pellets first appeared in North America in 1982 when demand for steel collapsed because of the recession. Several steelmakers were starved for cash at the time, but had large, unneeded inventories of raw materials that could be resold. The subsequent bankruptcy filings of Wheeling-Pittsburgh and LTV helped the spot market to grow by nullifying a number of long-term purchase contracts.

In mid-January, Cleveland-Cliffs Iron reduced the price of its Lake Superior iron ore pellets from 86.90 cents per ltu of iron, natural, to 72.45 cents per ltu. The new price, which was retroactive to December 30, 1986, applied to pellets delivered rail-of-vessel at lower lake ports. The previous price of 86.90 cents had been in effect since February 26, 1982. In February, Oglebay announced an identical 16.5% reduction for its standard grade pellets, effective March 1. Oglebay's new Eveleth special grade was listed at 74.00 cents per ltu. Mineral Services Inc. continued to quote its August 1985 price of 58.0 cents per ltu. USX adopted a different strategy and switched its pricing, effective May 20, to an f.o.b. mine basis. The new price for Minntac acid pellets was 37.344 cents per *dry* ltu of iron, delivered into rail cars at the Minnesota mine. This price equated to about $23.87 per long ton of undried pellets containing 63.92% Fe and 2.29% moisture. Inland Steel then countered everyone by dropping the price of its Minorca pellets from 59.40 cents per ltu to 46.84 cents per ltu. The range of all of the above prices was approximately equivalent to $34.50 to $55.62 per long ton of pellets containing 64% iron, delivered rail-of-vessel at lower lake ports.

Published prices for Lake Superior ores, per ton, basis 51.5% iron, natural, delivered rail-of-vessel at lower lake ports, remained as follows: Mesabi non-Bessemer ore, $30.03 for coarse ore and $31.53 for fines; and manganiferous ore, $32.78. These prices were not very significant in 1987 because most Mesabi non-Bessemer ore was produced and consumed by LTV Steel, and none of the manganiferous ore was mined. Pellets made up more than 96% of ore shipped from the Lake Superior district.

Prices for most Canadian and other foreign ores marketed in the United States were not available. The published price of Wabush pellets, f.o.b. Pointe Noire, Quebec, remained at 63.5 cents per ltu. The average f.o.b. value of all Canadian ores imported by the United States, as determined from data compiled by the Bureau of Census, was $31.34 per long ton. Data from this source indicated average f.o.b. values of $14.01 per ton for Liberian ores and $17.81 per ton for Brazilian ores. Other sources indicate that most imported Canadian ore consisted of pellets, Liberian ores consisted of fines and washed lumpy ore, and about two-thirds of the ore imported from Brazil consisted of pellets. F.o.b. value data for Venezuelan ores were not determinable because much of the ore was apparently valued on a c.i.f. basis.

Published f.o.b. prices for DRI were also unchanged from those quoted in 1986, and were as follows, per metric ton: at Georgetown, SC, $125 to $135; at Contrecoeur, Quebec, $115; and at Point Lisas, Trinidad and Tobago, $120. The apparent f.o.b. value of some shipments of DRI imported from Venezuela since 1985 ranged from about $79 to $110 per long ton.

FOREIGN TRADE

U.S. exports of iron ore were 12% higher than those of 1986 because of increased demand from the Canadian steel industry. Virtually all exports consisted of pellets shipped via the Great Lakes to Canadian steel companies that are partners in U.S. taconite projects in Minnesota and Michigan. Consumption of iron ore at Canadian blast furnaces totaled 13.08 million tons, about 5% more than that of 1986. This improvement in Canadian blast furnace activity was largely the result of a 9% increase in downstream shipments of rolled steel products.

U.S. imports for consumption of iron ore decreased slightly to 16.58 million tons. A 57% decline of imports into the Mobile customs district offset small increases for Baltimore, Chicago, and Philadelphia. Total tonnage for 1987 was still 7% greater than the mean of the previous 5 years, 15.49 million tons. For the first time in more than a decade, Canadian ores accounted for less than one-half of the total U.S. imports. In the last few years, Canada had struggled to maintain its traditional 13% to 23% share of the increasingly competitive U.S. market, which has shrunk 48% since 1979. Brazil, the next largest supplier after Canada, gradually increased its share from a 10-year low of 1.8% in 1982 to 6.1% in 1987.

In June, shipload quantities of Australian ore began arriving at east coast ports after a hiatus of 7 years. Considerably larger tonnages were scheduled for delivery from the Pilbara region of Western Australia in 1988. The Broken Hill Pty. Co. Ltd. (BHP) announced that Bethlehem had agreed to buy 108,000 tons of pellets from BHP's Whyalla works in South Australia. This sale would be BHP's first to Bethlehem since the Australian Government's iron ore embargo of 1938.

WORLD REVIEW

At least 46 countries mined iron ore during the year, producing a total of 869 million tons. The U.S.S.R. was the largest producer, with an output of 191.4 million tons of concentrate and 65.6 million tons of pellets. Soviet production accounted for about 27% of the world's marketable output in terms of metal content. World production of pig iron, which directly reflects ore consumption, increased slightly to 504 million long tons.

The world ore trade was estimated at 365 million tons, of which about 85% was oceanborne. Brazil, the leading exporter, shipped 96 million tons to world markets in 1987, an amount 5% greater than that of 1986. Shipments from Australia, the second largest exporter, dropped from 81 to 79 million tons because of reduced imports by Japanese steelmakers, who cut back on pig iron production by 2%. The recently expanded EC received 119 million tons of ore and agglomerates, edging out Japan as the world's principal importer. Japanese imports decreased 3% from 113 million tons to 110 million tons.

World production of pellets was estimated at 203 million tons, about 81% of installed capacity. Most pelletizing plants in Brazil, Canada, Sweden, and the U.S.S.R. operated close to rated capacity, contrasting sharply with the situation in the United States. The merchant plant in Bahrain was forced to suspend operations in early 1986 and had no production in 1987. The plant, which was inaugurated in late 1984, had difficulty operating in the midst of the Iran-Iraq war.

World output of DRI was estimated by Midrex Corp. at 13.4 million tons, about 61% of installed capacity, as low prices for ferrous scrap continued to limit production.[11] Negotiations were under way to relocate the two-module plant of Norddeutsche Ferrowerke (Nord Ferro) at Emden, Federal Republic of Germany, to India. The permanent closure of the 0.87-million-ton-per-year West German plant, along with that of a plant in New Zealand, offset the startup of additional capacity at Kursk in the U.S.S.R. These changes reduced global DRI capacity from 23.2 million tons to 22.0 million tons. The improved utilization of existing gas-based facilities in Egypt, Mexico, the U.S.S.R., and Venezuela were largely responsible for the 9% increase in world DRI production between 1986 and 1987. About 47% of the total output for 1987 was produced in Mexico, Venezuela, and other countries in Latin America.

In the past, iron ore exporters normally completed their annual price negotiations in Europe before fixing prices in Japan. The tradition arose because European contracts are based on the calendar year, while Japanese contracts are on an April-to-March fiscal year. This year, in a break from tradition, BHP settled its Mount Newman contract with Japanese steelmakers on February 20, triggering a worldwide reappraisal of iron ore prices. Japanese ore buyers were able to complete most of their fiscal year 1987 price negotiations with foreign producers by September. In almost every case, irrespective of ore type, the new price was lower than that for fiscal year 1986. Price cuts for fines and lump ore ranged from 3.8% to 6.8%. European steelmakers, who were dissatisfied with their 1986 contracts, also succeeded in winning price cuts of 6% to 11% for fines, but were forced to pay 1% to 5% more for pellets.

On an f.o.b. (shipping port) basis, most 1987 prices apparently ranged from about $10.80 to $16.50 per long dry ton (ldt) for fines, $15.20 to $18.70 per ldt for lump, and $18.10 to $27.20 per ldt for pellets. Delivered prices (at receiving port) were about $2 to $10 higher, depending on ocean freight costs. The Japanese contract prices are listed in the following tabulation, f.o.b., in U.S. cents per *dry* ltu of iron unless otherwise specified:

Country and producer	Ore type	Prices (Apr. 1-Mar. 31)	
		FY 1986	FY 1987
Australia:			
Hamersley Iron Pty. Ltd. and Mount Newman Mining Co. Pty. Ltd	Lump ore	30.29	28.78
Do	Fines	25.97	24.67
Robe River Iron Associates	do	22.97	21.50
Savage River Mines Ltd	Pellets	36.02	34.72
Brazil:			
Cia. Nipo-Brasileira de Pelotização (Nibrasco)	do	35.29	35.29
Cia. Vale do Rio Doce (Carajás)	Fines	23.66	22.24
Cia. Vale do Rio Doce and Minerações Brasileiras Reunidas S.A	Lump ore	23.66	22.24
Minerações Brasileiras Reunidas S.A	Fines	24.21	22.76
Samarco Mineração S.A	Pellet feed	19.46	18.29
Canada: Iron Ore Co. of Canada (Carol Lake)	Concentrates	22.44	21.26
Chile: Cía. Minera del Pacífico S.A. (El Algarrobo)	Pellets	36.10	34.72
India:			
Minerals and Metals Trading Corp. (Bailadila)	Lump ore	29.21	27.75
Do	Fines	24.95	23.70
Liberia: LAMCO Joint Venture Operating Co	do	22.40	20.47
Peru: Empresa Minera del Hierro del Perú S.A	Pellets	27.59	27.59
South Africa, Republic of:			
South African Iron and Steel Industrial Corp. Ltd	Lump ore	[1]23.91	[1]22.34
Do	Fines	[1]20.55	[1]19.15

[1]Price per dry metric ton unit.

Source: The TEX Report (Tokyo), v. 20, No. 4664, Apr. 20, 1988, pp. 12-13.

Ocean freight rates for iron ore reversed their long-term decline in January and began rising. Published rates for spot charterings to the EC from Western Australia ranged from $5.80 to $8.30 per dwt for cargoes of 120,000 to 140,000 dwt, compared with $5.30 to $7.30 in 1986. The 1987 rate ranges for other shipments to the EC are shown in the following tabulation:

Country	Loading port	Cargo size (thousand deadweight tons)	Rate (dollars per deadweight ton)
Brazil	South Atlantic ports	100-140	3.00- 8.00
Do	do	220-250	2.80- 3.65
Canada	Sept-Iles or Port Cartier	100-140	2.95- 5.20
Liberia	Buchanan or Monrovia	60- 80	3.50- 6.85
Mauritania	Nouadhibou	80-100	2.20- 4.30
Sweden	Narvik (Norway)	80-100	2.25- 3.50
Venezuela	Puerto Ordáz	40- 60	6.80-10.15

Sources: Drewry Shipping Consultants Ltd. (London), Maritime Data Network Ltd. (London), and The TEX Report (Tokyo).

Rates for cargoes of 120,000 to 140,000 dwt to Japan from Western Australia ranged from $4.40 to $4.90. Higher rates applied to Port Latta in Tasmania because it cannot accommodate vessels greater than 95,000 dwt and is farther from Japan. Rates to Japan from the Brazilian port of Tubarão for somewhat smaller cargoes were $5.30 to $9.50.

[1]Physical scientist, Branch of Ferrous Metals.
[2]Unless otherwise specified, the unit of weight used in this chapter is the long ton of 2,240 pounds.
[3]Wall Street Journal. An Older Work Force Burdens Big Producers in the Basic Industries. Mar. 5, 1987, pp. 1, 21.
[4]Skillings, D. N., Jr. TDCI Now Operating World's Latest Iron Ore Pellet Plant at Divrigi in Anatollia Region. Skillings' Min. Rev., v. 76, No. 2, Jan. 10, 1987, pp. 14-21.
[5]Skillings, D. N., Jr. North American Iron Ore Industry in Major Recovery in 1988 To Reach Seven-Year Production Peak of 97.6 Million Gross Tons. Skillings' Min. Rev., v. 77, No. 31, Jul. 30, 1988, pp. 14-26.
[6]There was an error in the "Domestic Production" section of the 1986 chapter. Minnesota pellet production was 25.88 million tons in 1986, not 36.44 million tons as published. The 36.44-million-ton number was the 1986 production total for the Lake Superior district. As a result, the capacity utilization should have been 43%, not 61%.
[7]Skillings, D. N., Jr. U.S. Iron Ore Industry To Recover Moderately in 1987 to Level of 45 Million Gross Tons of Pellets and Ore. Skillings' Min. Rev., v. 76, No. 30, Jul. 25, 1987, pp. 14-23.
[8]Work cited in footnote 5.
[9]Lake Carriers' Association (Cleveland, OH). 1987 Annual Report. 98 pp.
[10]Kirsis, K. M., and P. J. Kakela. U.S. Spot Iron Ore Market: Prices, Buyers & Sellers. Skillings' Min. Rev., v. 76, No. 46, Nov. 14, 1987, pp. 4-9.
[11]Midrex Corp. Direct From Midrex. MIDREX Plants Produce 61% of World's DRI in 1987. V. 13, No. 3, 2d quarter, 1988, p. 10.

Table 2.—Employment at iron ore mines and beneficiating plants, quantity and tenor of ore produced, and average output per worker hour in the United States in 1987, by district and State

District and State	Average number of employees	Worker hours (thousands)	Production (thousand long tons)			Iron content (natural) (percent)	Average per worker hour (long tons)		
			Crude ore	Usable ore	Iron contained (in usable ore)		Crude ore	Usable ore	Iron contained
Lake Superior:									
Michigan	1,834	3,527	35,925	12,294	7,830	63.7	10.19	3.49	2.22
Minnesota	3,737	7,777	108,632	33,645	21,657	64.4	13.97	4.33	2.79
Total or average	5,571	11,304	[1]144,556	45,939	29,487	64.2	12.79	4.06	2.61
Other States[2]	210	363	1,209	878	557	63.4	3.33	2.42	1.53
Grand total or average	5,781	11,667	145,765	46,817	30,044	64.2	12.49	4.01	2.58

[1]Data do not add to total shown because of independent rounding.
[2]Includes California, Missouri, Montana, New Mexico, Texas, and Utah.

Table 3.—Crude iron ore[1] mined in the United States in 1987, by district, State, and mining method

(Thousand long tons, unless otherwise specified, and exclusive of ore containing 5% or more manganese)

District and State	Number of mines	Open pit	Under-ground	Total quantity[2]
Lake Superior:				
Michigan	2	35,925	--	35,925
Minnesota	9	108,632	--	108,632
Total[2]	11	144,556	--	144,556
Other States:				
Missouri	1	--	1,001	1,001
Other[3]	7	207	--	207
Total[2]	8	207	1,001	1,209
Grand total[2]	19	144,764	1,001	145,765

[1]Excludes byproduct ore.
[2]Data may not add to totals shown because of independent rounding.
[3]Includes California, Montana, New Mexico, Texas, and Utah.

Table 4.—Usable iron ore produced in the United States in 1987, 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	Concen-trates	Agglomer-ates	Total quantity
Lake Superior:				
Michigan	--	--	12,294	12,294
Minnesota	88	1,404	32,153	33,645
Total	88	1,404	44,447	45,939
Other States:				
Missouri	--	40	660	700
Other[1]	178	W	--	178
Total	178	40	660	878
Grand total	266	1,444	45,107	46,817

W Withheld to avoid disclosing company proprietary data; included with "Direct-shipping ore."
[1]Includes California, Montana, New Mexico, Texas, and Utah.

Table 5.—Shipments of usable iron ore[1] from mines in the United States in 1987

(Exclusive of ore containing 5% or more manganese)

District and State	Gross weight of ore shipped (thousand long tons)				Average iron content (natural) (percent)	Value (thousands)
	Direct-shipping ore	Concen-trates	Agglom-erates	Total[2]		
Lake Superior:						
Michigan	--	--	12,312	12,312	63.7	W
Minnesota	88	1,549	32,016	33,654	64.3	$1,012,788
Total reportable[2] or average	88	1,549	44,328	45,965	64.2	1,012,788
Other States:						
Missouri	--	40	705	744	65.9	W
Other[3]	437	([4])	--	437	59.3	8,678
Total reportable[2] or average	437	40	705	1,181	63.5	8,678
Total withheld	--	--	--	--	--	481,621
Grand total[2] or average	525	1,589	45,033	47,146	64.2	1,503,087

W Withheld to avoid disclosing company proprietary data; included in "Total withheld."
[1]Includes byproduct ore.
[2]Data may not add to totals shown because of independent rounding.
[3]Includes California, Montana, New Mexico, New York, Texas, and Utah.
[4]Included with "Direct-shipping ore" to avoid disclosing company proprietary data.

Table 6.—Usable iron ore produced in the U.S. Lake Superior district, by range

(Thousand long tons and exclusive after 1905 of ore containing 5% or more manganese)

Year	Mar-quette	Menom-inee	Gogebic	Ver-milion	Mesabi	Cuyuna	Spring Valley	Black River Falls	Total[1]
1854-1980	507,608	329,269	320,334	103,528	3,286,994	70,336	8,149	8,618	4,634,836
1981	15,508	75	--	--	51,025	--	--	854	67,462
1982	6,874	--	--	--	23,898	--	--	241	31,013
1983	9,339	--	--	--	26,255	--	--	--	35,594
1984	12,982	--	--	--	36,697	--	--	--	49,679
1985	12,479	--	--	--	34,910	--	--	--	47,388
1986	10,558	--	--	--	r27,042	--	--	--	r37,600
1987	12,294	--	--	--	33,645	--	--	--	45,939
Total[1]	587,642	329,344	320,334	103,528	3,520,466	70,336	8,149	9,713	4,949,512

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

Table 7.—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
1982	32,173	63.50	0.018	5.40	0.13	0.31	2.60
1983	42,418	63.32	.018	5.35	.12	.29	2.64
1984	48,613	63.48	.018	5.28	.14	.32	2.66
1985	46,916	63.64	.016	5.17	.11	.29	2.63
1986	40,674	63.61	.015	5.21	.11	.29	2.66
1987	46,723	63.46	.014	5.12	.10	.24	2.31

[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, 1982-86. This series is no longer published. The 1987 data are based on information reported to the Bureau of Mines.

Table 8.—U.S. consumption of iron ore and agglomerates in 1987, by region

(Thousand long tons and exclusive of ore containing 5% or more manganese)

Region	Iron ore and concentrates[1]		Agglomerates[2]		Miscella-neous[3]	Total reportable
	Blast furnaces	Steel furnaces	Blast furnaces	Steel furnaces		
Great Lakes[4]	W	W	46,101	W	W	46,101
Northeastern, Southern, Western[5]	W	W	18,245	W	W	18,245
Undistributed	836	80	--	404	1,032	2,352
Total	836	80	64,346	[6]404	1,032	66,698

W Withheld to avoid disclosing company proprietary data; included with "Undistributed."
[1]Excludes pellets or other agglomerated products.
[2]Includes approximately 39,471 units of pellets produced at U.S. mines and 8,420 units of foreign pellets and other agglomerates.
[3]Includes iron ore consumed in production of cement and iron ore shipped for use in manufacturing paint, ferrites, heavy media, cattle feed, refractory and weighting materials, and for use in lead smelting.
[4]Includes Illinois, Indiana, Michigan, and Ohio.
[5]Includes Alabama, Kentucky, Maryland, Pennsylvania, Utah, and West Virginia.
[6]Includes an estimated 320 units of ore and agglomerates used for production of direct-reduced iron for steelmaking.

Table 9.—U.S. exports of iron ore, by country

(Thousand long tons and thousand dollars)

Country	1985		1986		1987	
	Quantity	Value	Quantity	Value	Quantity	Value
Canada	5,033	240,435	4,479	204,600	5,011	198,108
India	--	--	(1)	17	--	--
Mexico	(1)	10	1	45	1	42
Netherlands	--	--	(1)	17	--	--
Venezuela	(1)	22	(1)	39	1	95
Other	(1)	87	(1)	20	(1)	9
Total[2]	5,033	240,557	4,482	204,738	5,013	198,254

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

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

(Thousand long tons and thousand dollars)

Country	1985		1986		1987	
	Quantity	Value	Quantity	Value	Quantity	Value
Australia	--	--	10	86	191	5,141
Brazil	2,540	49,322	3,693	71,045	3,640	64,820
Canada	8,557	325,248	8,696	311,757	7,854	246,181
Chile	164	2,320	93	2,126	626	12,601
Liberia	2,206	31,014	1,487	21,855	979	13,707
Mauritania	--	--	65	1,158	406	6,403
Peru	121	2,722	91	2,429	83	1,691
Philippines	--	--	56	1,504	58	1,575
Spain	--	--	--	--	1	27
Sweden	65	1,503	104	2,473	137	3,334
Venezuela	[1]2,068	[1]39,369	[2]2,309	[2]42,126	[3]2,580	[3]52,889
Other	50	769	[r]138	[r]4,083	29	413
Total[4]	15,771	452,267	16,743	460,643	16,583	408,783

[r]Revised.
[1]Excludes approximately 214,000 long tons of sponge iron valued at $15,635,828, originally reported as iron ore.
[2]Excludes approximately 83,000 long tons of sponge iron valued at $8,340,609, originally reported as iron ore.
[3]Excludes approximately 18,000 long tons of sponge iron valued at $1,849,584, originally reported as iron ore.
[4]Data may not add to totals shown because of independent rounding.

Table 11.—U.S. imports for consumption of iron ore, by customs district

(Thousand long tons and thousand dollars)

Customs district	1985		1986		1987	
	Quantity	Value	Quantity	Value	Quantity	Value
Baltimore	3,673	71,363	5,567	144,725	5,881	125,887
Buffalo	(1)	5	(1)	25	(1)	30
Chicago	2,594	58,712	1,537	37,958	1,976	40,224
Cleveland	1,646	59,853	1,707	67,123	1,466	54,551
Detroit	542	19,107	382	17,798	627	27,196
Houston	165	2,541	42	745	9	177
Mobile	2,600	111,772	2,434	64,317	1,046	22,645
New Orleans	878	16,266	1,569	31,052	1,506	27,230
Philadelphia	3,408	107,029	3,237	90,592	3,749	103,101
Other	266	5,620	268	6,308	323	7,743
Total[2]	15,771	452,267	16,743	460,643	16,583	408,783

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

Table 12.—Iron ore, iron ore concentrates, and iron ore agglomerates: World production, by country[1]

(Thousand long tons)

Country[2]	Gross weight[3]					Metal content[4]				
	1983	1984	1985	1986[p]	1987[e]	1983	1984	1985	1986[p]	1987[e]
Albania[e 5]	840	[6]1,063	1,100	[r]1,130	1,180	280	350	370	[r]375	395
Algeria	3,626	3,606	3,716	3,307	3,330	1,813	1,839	1,678	[e]1,650	1,660
Argentina	[r]581	[r]563	629	797	750	332	[r]341	383	506	470
Australia	69,916	92,900	91,392	92,648	98,400	44,583	57,400	[e]57,600	59,170	62,000
Austria	3,484	3,543	3,218	3,071	3,000	1,090	1,120	1,003	961	930
Bolivia	11	--	--	--	--	7	--	--	--	--
Brazil	87,315	[r]110,361	126,225	130,199	129,500	57,064	[r]71,739	[r e]85,830	[r e]88,540	88,100
Bulgaria	1,775	2,030	1,954	2,145	2,170	545	612	597	651	655
Canada[7]	32,699	40,416	38,878	35,596	37,000	20,964	25,664	24,733	22,639	23,500
Chile	[r]5,717	[r]6,579	6,431	6,871	6,580	[r]3,434	[r]3,928	3,904	4,131	3,940
China[e]	70,000	74,000	79,000	88,600	98,400	35,000	37,000	39,000	44,300	49,200
Colombia	449	434	440	643	[6]605	202	195	198	[r e]230	270
Czechoslovakia	1,873	1,839	[e]1,870	[e]1,870	1,570	482	473	[e]480	[e]490	390
Egypt	2,188	1,871	1,919	2,101	2,170	1,094	935	960	[e]1,048	1,080
Finland[8]	1,257	1,212	[e]1,180	[e]590	--	809	776	[e]740	[e]380	--
France	15,678	14,605	14,219	12,240	[6]10,739	4,981	4,606	4,464	3,800	[6]3,221
German Democratic Republic[9]	39	[r]35	30	([10])	--	20	20	30	([10])	--
Germany, Federal Republic of	961	962	1,018	706	[6]243	275	288	304	209	[6]67
Greece[5]	1,322	1,899	2,210	1,178	[6]1,065	563	797	928	482	436
Hungary	434	377	306	--	--	104	91	74	--	--
India	[e]38,187	40,378	41,873	47,045	[6]51,179	23,905	25,276	26,212	29,450	32,100
Indonesia	131	82	129	151	[6]191	76	47	75	88	[6]111
Iran[e 11]	[r]1,639	[r]2,668	[r]2,755	[r]2,760	2,760	[r]935	[r]1,530	[r]1,580	[r]1,580	1,580
Japan	293	319	333	286	[6]261	182	199	209	179	[6]163
Korea, North[e]	7,900	7,900	7,900	7,900	7,900	[r]3,150	[r]3,150	[r]3,150	[r]3,150	3,150
Korea, Republic of	645	615	533	573	460	[r]361	344	299	321	260
Liberia	14,701	14,862	15,076	15,053	[6]13,525	9,114	9,212	9,271	9,330	8,400
Malaysia	112	191	179	205	[6]158	69	117	109	125	[6]96
Mauritania[12]	7,268	9,377	9,186	8,788	[6]8,858	4,724	5,663	[r e]5,970	[r e]5,710	5,760
Mexico[13]	7,913	8,186	7,696	7,183	7,400	5,222	5,402	5,080	4,741	[6]4,887
Morocco	170	160	188	193	[6]207	104	99	116	121	[6]126
New Zealand[14]	2,168	2,376	2,480	[r e]2,540	[6]2,254	1,236	1,354	1,402	[e]1,400	1,280
Norway	3,489	3,776	3,413	3,601	[6]3,091	2,271	2,462	2,218	2,340	[6]2,010
Peru	[r]4,219	[r]3,916	4,815	4,956	4,770	[r]2,847	[r]2,621	3,238	3,303	3,200
Philippines	3	--	--	--	--	2	--	--	--	--

See footnotes at end of table.

Table 12.—Iron ore, iron ore concentrates, and iron ore agglomerates: World production, by country[1] —Continued

(Thousand long tons)

Country[2]	Gross weight[3]					Metal content[4]				
	1983	1984	1985	1986[p]	1987[e]	1983	1984	1985	1986[p]	1987[e]
Poland	10	11	11	9	8	3	3	3	2	2
Portugal[15]	35	35	72	50	30	12	12	11	19	15
Romania	1,956	1,886	2,251	2,393	2,360	607	512	531	561	560
Sierra Leone	413	349	[e]69	--	--	260	219	[e]39	--	--
South Africa, Republic of[16]	16,343	24,258	24,028	24,096	21,650	10,459	15,500	14,838	15,180	13,330
Spain[17]	7,331	7,146	6,361	5,993	3,740	3,457	3,502	3,139	2,734	1,870
Sweden	14,040	17,837	20,131	20,165	[6]19,317	9,124	11,003	13,287	[e]13,306	[6]12,073
Thailand	39	60	93	36	[6]95	22	32	51	21	[6]53
Tunisia	311	303	304	306	295	166	163	163	[r][e]164	160
Turkey	4,085	3,973	3,931	5,166	[6]3,313	2,213	2,157	2,129	2,798	[6]1,794
U.S.S.R	241,328	243,201	243,728	246,011	247,000	131,454	132,680	133,852	134,836	136,000
United Kingdom	378	397	270	284	295	80	84	59	[e]63	59
United States[17]	37,562	51,269	48,751	38,862	[6]46,817	24,167	33,110	31,296	24,895	[6]30,044
Venezuela	9,562	12,848	15,972	18,823	17,500	5,924	7,965	9,902	[e]11,650	10,800
Yugoslavia	4,939	5,237	5,391	6,513	5,900	1,505	1,808	[e]1,770	[e]1,970	1,770
Zambia	1	1	1	1	[6]1	([18])	([18])	1	([18])	[6]1
Zimbabwe	911	912	1,083	1,092	1,090	[r]565	[r]566	671	677	677
Total	[r]728,247	[r]822,824	844,738	854,726	869,127	[r]417,858	[r]474,966	493,947	500,276	508,645

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

[1]Table includes data available through July 22, 1988.

[2]In addition to the countries listed, Cuba and Vietnam may produce iron ore, but definitive information on output levels, if any, is not available.

[3]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.

[4]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 for which grades are Bureau of Mines estimates: Albania, China, Hungary, and North Korea.

[5]Nickeliferous iron ore.

[6]Reported figure.

[7]Series represent gross weight and metal content of usable iron ore (including byproduct ore) actually produced, natural weight.

[8]Includes magnetite concentrate, pelletized iron oxide (from roasted pyrite), and roasted pyrite (purple ore).

[9]Includes "roasted ore," presumably from pyrite, not separable from available sources.

[10]Revised to zero.

[11]Data are for year beginning Mar. 21 of that stated.

[12]Gross weight is exported iron ore (Mauritania exports all of its iron ore).

[13]Gross weight calculated from reported iron content based on grade of 66% Fe.

[14]Concentrates from titaniferous magnetite beach sands.

[15]Includes manganiferous iron ore.

[16]Includes magnetite ore as follows, in thousand long tons: 1983—3,414; 1984—3,780; 1985—3,550; 1986—3,940 (estimated); and 1987—4,900.

[17]Includes byproduct ore.

[18]Less than 1/2 unit.

Iron Oxide Pigments

By Donald P. Mickelsen[1]

U.S. mine production, shipments, and value of crude iron oxide pigments, and total domestic shipments and value of natural and synthetic finished iron oxides increased in 1987. Unit values for most categories of finished iron oxides increased. Synthetic iron oxides comprised 64% of all shipments. BASF Corp., Chemicals Div., a producer of small amounts of synthetic iron oxide pigments, ceased domestic production.

Construction materials was the largest end use for iron oxide pigments, followed, in order of rank, by paints and coatings; colorants for ceramics, glass, paper, plastics, rubber, and textiles; foundry sands; industrial chemicals; ferrites; and other.

Domestic list prices for iron oxides remained stable for the year, with list prices for natural iron oxides being unchanged from those in 1986, and synthetic iron oxides increasing only moderately. Price increases for synthetics reflected increased costs in materials and production.

The United States imported 90% more iron oxide pigments than it exported, the result of greatly increased imports and decreased exports. This was attributed to the decrease of the value of the U.S. dollar against foreign currencies and the strength of the domestic market. U.S. imports for consumption of both natural and synthetic iron oxide pigments increased significantly compared with those of 1986, with the synthetic black and red categories increasing dramatically. World mine production of natural iron oxide pigments for reporting countries increased compared with that of 1986.

Domestic Data Coverage.—Mine production and sales data for crude iron oxide pigments and sales data for finished iron oxide pigments and iron oxides from steel plant wastes were compiled from voluntary responses received from an annual survey of U.S. producers conducted by the Bureau of Mines. Responses for crude iron oxide mine production and sales data were received from five companies representing 100% of all iron oxide pigment producers known to mine or ship crude iron oxide pigments in the United States as shown in table 1. Of the 16 operations canvassed for finished iron oxide pigment sales data in 1987, all responded, representing 100% of the total production shown in table 2. Of the six companies canvassed for sales data for iron oxide recovered from steel plant wastes, including steel plant dust and regenerator oxide, 83% responded, representing 37% of the estimated production shown in the text discussion under "Domestic Production." Remaining data were estimated through analysis of industry trends and practices.

Table 1.—Salient U.S. iron oxide pigments statistics

	1983	1984	1985	1986	1987
Mine production ____ short tons__	26,499	29,307	32,234	33,889	35,071
Crude pigments sold or used ____ do____	41,875	53,017	46,585	40,987	42,773
Value ____ thousands__	$2,427	$2,819	$2,826	$2,908	$3,598
Finished pigments sold ____ short tons__	122,861	129,492	126,822	r128,357	137,010
Value ____ thousands__	$110,662	$122,620	$122,716	r$126,388	$136,427
Exports ____ short tons__	12,661	32,428	29,720	28,841	22,249
Value ____ thousands__	$20,692	$31,832	$27,574	$30,830	$31,689
Imports for consumption ____ short tons__	30,747	38,239	39,799	36,773	42,322
Value ____ thousands__	$16,684	$21,523	$22,565	$21,517	$20,680

rRevised.

DOMESTIC PRODUCTION

Mine production of crude iron oxide pigments increased slightly over 1986 levels, while shipments increased 4% in quantity and 24% in value. Four companies mined and shipped various grades of iron oxide pigments. One company in Georgia mined and shipped ocher; magnetite was mined and shipped by a company in Missouri; and of two companies in Virginia, one mined and shipped sienna and umber, and the other shipped umber. In addition, Cleveland-Cliffs Iron Co., which permanently closed its Mather Mine in northern Michigan in 1979, continued to ship hematite from stockpiles.

Total domestic shipments of finished iron oxide pigments, excluding regenerator oxide, steel plant waste, and magnetic iron oxide, increased 7% in quantity and 8% in value compared with that of 1986. Synthetic iron oxides comprised the majority of total shipments, increasing significantly in quantity and value, while natural iron oxide pigments increased overall only slightly when compared with 1986 levels. Shipments of natural iron oxides were affected mainly by an increase in the red iron oxide category, by far the largest category, accounting for almost one-half of the natural oxides shipped in 1987. Total values for natural finished iron oxides in general increased, including red iron oxide, which increased 10% in 1987, recovering somewhat from a sharp drop, which occurred in 1986.

Iron oxide for use in magnetic applications was produced domestically but is not shown in table 2. Production and shipment data are unavailable because of their proprietary nature.

An estimated 37,000 short tons[2] of steel plant byproduct iron oxides, in the form of regenerator oxide and steel plant wastes and dust, was shipped in 1987. Of the six plants canvassed, representing 45% of estimated shipments with a value of $1.5 million, one-half showed increases. Data on the remaining steel plant wastes, while unavailable, are estimated to be used in the manufacture of ferrites, according to officials in the industry.

In 1987, Hoover Color Corp. added a new line of micaceous primer pigments to its natural iron oxide production. Micaceous iron oxide is a specular hematite whose particle has an elongated flaky shape. This plate-like structure, according to the company, improves corrosion resistance. In the past, natural micaceous iron oxides were produced mainly in Europe, but the Hoover product is produced domestically, has a reddish-brown color, and an iron content of 90%.[3] Iron oxide pigment data, as shown in this publication, are becoming more generalized in various categories to protect company confidential information as fewer companies remain in the iron oxide business.

Table 2.—Finished iron oxide pigments sold by processors in the United States, by kind

Kind	1986		1987	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Natural:				
Black: Magnetite	6,401	$1,095	6,332	$1,142
Brown:				
Iron oxide	W	W	W	W
Umbers:				
Burnt	[1]3,311	[1]2,989	W	W
Raw	(2)	(2)	W	W
Red:				
Iron oxide[3]	22,878	3,294	24,259	3,612
Sienna, burnt	[4]334	[4]311	W	W
Yellow:				
Ocher	W	W	W	W
Sienna, raw	(5)	(5)	W	W
Undistributed	14,335	4,525	18,517	7,852
Total[6]	47,259	12,213	49,108	12,606

See footnotes at end of table.

Table 2.—Finished iron oxide pigments sold by processors in the United States, by kind —Continued

Kind	1986 Quantity (short tons)	1986 Value (thousands)	1987 Quantity (short tons)	1987 Value (thousands)
Synthetic:				
Brown: Iron oxide[7]	r20,213	r$28,102	24,287	$34,340
Red: Iron oxide	36,182	49,780	36,816	52,901
Yellow: Iron oxide[8]	24,703	36,293	26,799	36,579
Other: Specialty oxides	(9)	(9)	(9)	(9)
Mixtures of natural and synthetic iron oxides	(9)	(9)	(9)	(9)
Total[6]	r81,098	r114,175	87,902	123,821
Grand total[6]	r128,357	r126,388	137,010	136,427

rRevised. W Withheld to avoid disclosing company proprietary data; included with "Undistributed."
[1]Includes raw umber.
[2]Included with burnt umber to avoid disclosing company proprietary data.
[3]Includes pyrite cinder.
[4]Includes raw sienna.
[5]Included with burnt sienna to avoid disclosing company proprietary data.
[6]Data may not add to totals shown because of independent rounding.
[7]Includes synthetic black iron oxide.
[8]Includes other specialty oxides and mixtures of natural and synthetic iron oxides.
[9]Included with synthetic yellow iron oxide to avoid disclosing company proprietary data.

Table 3.—Producers of iron oxide pigments in the United States in 1987

Producer	Mailing address	Plant location
Finished pigments:		
American Minerals Inc	Box 677 Camden, NJ 08101	Camden, NJ.
Blue Ridge Talc Co. Inc	Box 39 Henry, VA 24102	Henry, VA.
Chemalloy Co. Inc	Box 350 Bryn Mawr, PA 19010	Bryn Mawr, PA.
Columbian Chemicals Co	1600 Parkwood Circle Suite 400 Atlanta, GA 30339	St. Louis, MO, and Monmouth Junction, NJ.
DCS Color & Supply Co. Inc	2011 South Allis St. Milwaukee, WI 53207	Milwaukee, WI.
Foote Mineral Co	Route 100 Exton, PA 19341	Exton, PA.
Hilton-Davis Co	2235 Langdon Farm Rd. Cincinnati, OH 45237	Cincinnati, OH.
Hoover Color Corp	Box 218 Hiwassee, VA 24347	Hiwassee, VA.
Mobay Corp., Inorganic Chemicals Div	Mobay Rd. Pittsburgh, PA 15205	New Martinsville, WV.
New Riverside Ochre Co	Box 387 Cartersville, GA 30120	Cartersville, GA.
Pea Ridge Iron Ore Co	Route 4 Sullivan, MO 63080	Sullivan, MO.
Pfizer Pigment Inc	640 North 13th St. Easton, PA 18041	Emeryville, CA; East St. Louis, IL; Easton, PA.
Prince Manufacturing Co	700 Lehigh St. Bowmanstown, PA 18030	Quincy, IL, and Bowmanstown, PA.
Pea Ridge Iron Ore Co	Route 4 Sullivan, MO 63080	Sullivan, MO.
Solomon Grind-Chem Services Inc	Box 8288 Springfield, IL 62791	Springfield, IL.
Crude pigments:		
Cleveland-Cliffs Iron Co., Mather Mine and Pioneer plant (closed July 31, 1979; shipping from stockpile).	1100 Superior Ave. Cleveland, OH 44114	Negaunee, MI.
Hoover Color Corp	Box 218 Hiwassee, VA 24347	Hiwassee, VA.
New Riverside Ochre Co	Box 387 Cartersville, GA 30120	Cartersville, GA.
Virginia Earth Pigments Co	Box 1866 Pulaski, VA 24301	Hillsville, VA.

CONSUMPTION AND USES

Iron oxide pigments were consumed mainly as an ingredient in construction materials; in coatings; and as colorants for ceramics, glass, paper, plastics, rubber, and textiles. In some cases, end-use data reported by producers may be estimated, because some producers keep less detailed end-use records than others.

Iron oxide pigment consumption in construction materials increased to become the largest end use for iron oxide pigments in 1987, surpassing use for coatings, which has been traditionally the largest consuming sector. Construction materials accounted for nearly one-third of iron oxide usage in 1987 and totaled 43,214 tons, increasing significantly over the 1986 level of 37,697 tons. According to F. W. Dodge, the Information Systems Div. of McGraw-Hill Co., newly started construction in 1987 reached a record-high value of $254.7 billion. Nonbuilding construction, including public works and utilities, represented the largest growth area, increasing 8% to a value of $45.3 billion. Nonresidential building rose 7% to a record-high $89.4 billion, which was strengthened by a 15% gain in institutional structures. Residential housing declined slightly to $119.9 billion.[4]

Coatings accounted for slightly less than one-third of the iron oxide pigment consumption, decreasing moderately in 1987 to 39,270 tons compared with 41,900 tons in 1986. Shipments of lacquer, paint, and varnish, reported by the U.S. Department of Commerce,[5] totaled about 1 billion gallons of coatings valued at $9.5 billion, up only slightly in volume but 7% in value over that of 1986. Architectural coatings comprised 51% of all shipments and totaled 510 million gallons; product coatings—original equipment manufacture was 36% of shipments, or 360 million gallons; and special-purpose coatings was 13%, or 133 million gallons.

Of all iron oxides, 12%, or 16,683 tons, was consumed as colorants for plastics, glass and ceramics, rubber, and paper and textiles, in order of rank, remaining unchanged from the levels of consumption in 1986. Iron oxides, which are the second largest type of inorganic pigments consumed, are popular because of their low cost, coloring effectiveness in thermoplastics and thermosets, and Food and Drug Administration acceptance for food contact and medical applications.

The remaining 27% of reported iron oxide pigment consumption, in order of rank, was for use in foundry sands, industrial chemicals, the manufacture of animal feed and fertilizers, ferrites, cosmetics, and other end uses.

Regenerator oxide and steel plant dust, not accounted for in table 4, were used mainly in the manufacture of ferrites, with lesser amounts used in coatings, as colorants for construction materials, and in fertilizers and foundry sands. An estimated 37,000 tons was shipped for consumption in 1987. Magnetic iron oxides, also not included in the table, were mainly used in the manufacture of magnetic media such as magnetic tapes and floppy disks, magnetic toners, and other electronic applications.

Table 4.—Estimated iron oxide pigment consumption,[1] by end use, as a percentage of reported shipments

End use	All iron oxides		Natural iron oxides		Synthetic iron oxides	
	1986	1987	1986	1987	1986	1987
Coatings (industrial finishes, trade sales: lacquers, paints, varnishes	[r]33	29	19	19	[r]41	34
Construction materials (cement, mortar, preformed concrete, roofing granules)	29	32	30	24	[r]29	36
Colorants for ceramics, glass, paper, plastics, rubber, textiles	12	12	12	13	[r]12	12
Foundry sands	[r]5	6	14	17	([2])	--
Industrial chemicals (such as catalysts)	6	5	W	W	W	W
Animal feed and fertilizers	[r]5	4	11	9	W	W
Other (including cosmetics and ferrites)	10	12	[3]14	[3]18	[r] [4]18	[4]18
Total	100	100	100	100	100	100

[r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Data do not include magnetic iron oxide usage.
[2]Revised to zero.
[3]Includes industrial chemicals iron oxide usage.
[4]Includes animal feed and fertilizers and industrial chemicals iron oxide usage.

PRICES

List prices for natural grades of iron oxide pigments and black synthetic iron oxide pigments sold in 1987 by major producers remained unchanged from those of 1986. Prices for brown, red, and yellow synthetic iron oxide pigments increased several percent, reflecting higher materials and production costs. A strong domestic market, the decline in the value of the U.S. dollar, and close competition among producers and distributors of natural and synthetic iron oxide pigments led to a stable domestic market in 1987.[6]

Table 5.—Prices quoted on finished iron oxide pigments, per pound, bulk shipments,[1] December 31, 1987

Pigment	Low	High
Black:		
Natural	--	$0.2700
Synthetic	$0.6900	.7150
Micaceous	--	.6875
Brown:		
Ground iron ore	.1300	.1450
Metallic	.1650	.2950
Pure, synthetic	--	.7350
Sienna, domestic, burnt	--	.4500
Sienna, domestic, raw	.3600	.4400
Sienna, Italian, burnt	.4500	.7300
Umber, Turkish, burnt	.4350	.5200
Vandyke brown	--	.4450
Red:		
Domestic primers, natural, micronized	--	.2375
Pure, synthetic	--	.6900
Spanish	--	.2950
Yellow:		
Synthetic	--	.7100
Ocher, domestic	--	.2200

[1]Prices shown represent the best information available but are not to be considered definite according to the source.

Source: American Paint and Coatings Journal.

FOREIGN TRADE

The United States imported 90% more iron oxide pigments than it exported in 1987 according to the U.S. Department of Commerce. This trade imbalance represented an increase of 62% over that of 1986 and was the result of increased domestic demand and the decline in the value of the U.S. dollar against foreign currencies. Total value of U.S. exports of iron oxide pigments was $31.7 million, or $11 million greater than that of U.S. imports, resulting in a trade surplus for this commodity.

U.S. exports of pigment-grade iron oxides and hydroxides decreased 23% in quantity but increased slightly in value compared with those of 1986. These exports were received by 45 countries, principally in Europe, other North American countries, and Asia. Chief destinations for pigment-grade iron oxide pigments, in order of rank, were the Federal Republic of Germany, Canada, Japan, and the United Kingdom. Exports to the Federal Republic of Germany decreased 49% in quantity and 38% in value from those of 1986. Exports of other grades of iron oxides and hydroxides increased 11% in quantity and 7% in value compared with those of 1986. Main destinations were, in order of rank, the Republic of Korea, Mexico, Belgium-Luxembourg, Australia, Brazil, and Japan.

U.S. imports for consumption of iron oxide pigments increased significantly in quantity but decreased slightly in value compared with those of 1986, and were received from 30 countries. Imports of synthetic iron oxides increased 14% in quantity but decreased 6% in value. Synthetic iron oxides comprised over three-quarters of all imports received, a slight decrease from that of 1986. Synthetic black and red grades of iron oxides increased in quantity, while synthetic yellow and other synthetic grades decreased. Synthetic iron oxides were received chiefly from Canada, the Federal Republic of Germany, Mexico, Japan, and the United Kingdom, comprising 42%, 29%, 10%, 8%, and 3%, respectively, of total imports, with 8% received from other countries.

U.S. imports of natural iron oxides increased 20% in quantity and 15% in value compared with 1986 levels. The most sizable increases, which were mainly responsible for overall increases in natural imports, occurred in crude umbers and in Vandyke brown, which rose significantly over 1986 levels. Cyprus, the Federal Republic of Germany, Canada, and Spain, in order of rank, supplied 92% of all imports of natural iron oxides. Finished umber was primarily received from Cyprus and the United Kingdom; sienna, from Austria and Italy; and Vandyke brown, from the Federal Republic of Germany. Minor amounts of natural crude and synthetic iron oxides were received and stored in bonded warehouses for future consumption.

Periodically, iron oxide pigments also enter the United States under the combined classification "Iron compounds, other." In 1987, iron oxides, including regenerator oxides, were received from Canada and several Western European countries.

Table 6.—U.S. exports of iron oxides and hydroxides, by country

Country	1986				1987			
	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)
Algeria	--	--	58	$50	--	--	169	$156
Argentina	2	$31	10	34	8	$28	20	71
Australia	168	250	263	630	173	468	393	783
Belgium-Luxembourg	35	71	630	945	9	12	403	647
Brazil	83	178	188	736	28	81	384	1,177
Bulgaria	14	43	6	19	--	--	24	81
Canada	2,868	3,748	322	817	3,920	6,186	304	493
China	39	75	52	230	82	291	15	60
Colombia	59	51	20	24	42	38	146	156
Costa Rica	--	--	--	--	--	--	12	18
Denmark	38	153	--	--	24	277	135	473
Dominican Republic	32	43	3	6	135	147	--	--
Ecuador	23	58	5	9	17	35	1	2
Egypt	--	--	53	35	--	--	2	19
El Salvador	3	4	(1)	1	(1)	4	40	59
Finland	--	--	20	43	--	--	10	15
France	415	1,447	161	289	386	1,415	126	274
Germany, Federal Republic of	19,875	10,799	180	353	10,205	6,705	90	184
Honduras	--	--	--	--	19	36	--	--
Hong Kong	767	2,151	463	2,023	1,032	2,972	153	623
India	2	9	10	29	1	9	133	662
Indonesia	31	95	223	79	12	20	40	50
Ireland	40	87	3	4	90	211	5	12
Israel	3	8	3	31	--	--	--	--
Italy	355	1,749	12	19	508	2,173	1	2
Jamaica	7	9	--	--	--	--	1	2
Japan	1,795	2,565	756	1,883	2,697	2,721	369	757
Korea, Republic of	74	107	2,584	9,318	379	560	3,407	12,105
Malaysia	23	23	--	--	2	3	57	103
Mexico	376	426	1,073	1,811	456	531	1,594	2,433
Netherlands	46	172	88	211	121	260	118	188
Netherlands Antilles	--	--	--	--	--	--	11	49
New Zealand	7	16	21	47	2	3	4	9
Panama	(1)	1	2	4	3	6	--	--
Peru	8	123	--	--	5	7	--	--
Philippines	117	139	3	10	107	146	22	21
Singapore	61	86	181	625	10	20	91	225
South Africa, Republic of	5	11	6	13	39	120	--	--
Spain	5	22	19	12	40	106	72	246
Sweden	--	--	11	16	16	236	4	9
Switzerland	22	66	(1)	1	1	3	--	--
Taiwan	286	625	95	224	244	590	51	83
Thailand	52	48	--	--	236	194	26	27
Trinidad	--	--	--	--	13	3	14	28
Turkey	5	34	--	--	7	13	--	--
United Kingdom	1,049	5,188	237	532	1,059	4,799	219	340
Uruguay	5	8	--	--	1	3	1	2
Venezuela	38	87	45	39	114	227	20	86
Other	8	23	1	2	7	30	3	10
Total[2]	28,841	30,830	7,807	21,154	22,249	31,689	8,691	22,737

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

Source: Bureau of the Census.

Table 7.—U.S. imports for consumption of selected iron oxide pigments, by type

Type	1986 Quantity (short tons)	1986 Value (thousands)	1987 Quantity (short tons)	1987 Value (thousands)	Major sources, 1987[1] (short tons)
Natural:					
Crude:					
Ocher	603	$72	53	$91	France 45; West Germany 5; Japan 3.
Sienna	46	13	19	4	Cyprus 19.
Umber	5,119	838	5,667	915	Cyprus 5,640; West Germany 26; United Kingdom 1.
Other	207	377	753	557	Canada 686; Japan 62; Peru 4; West Germany 1.
Total[1]	5,974	1,301	6,491	1,566	
Finished:					
Ocher	1	6	6	8	Canada 6.
Sienna	98	60	270	173	Italy 146; Austria 79; Cyprus 35; West Germany 6; Canada 3; United Kingdom 1.
Umber	736	233	456	143	Cyprus 352; United Kingdom 84; Spain 20.
Vandyke brown	572	293	1,576	342	West Germany 1,463; Belgium 113.
Other	638	242	845	212	Spain 602; Mexico 220; Canada 19; West Germany 3; Japan 1.
Total[1]	2,045	834	3,152	878	
Synthetic:					
Black	1,041	605	4,726	718	Canada 4,502; West Germany 143; Netherlands 40; Japan 24; Mexico 15; China 2; Hong Kong 1.
Red	6,987	2,960	10,916	3,575	Canada 6,273; West Germany 2,055; Japan 1,094; Mexico 992; Spain 168; United Kingdom 97; Brazil 76; Belgium 69; China 60; Republic of Korea 22; Netherlands 11.
Yellow	13,102	5,524	11,225	6,843	West Germany 6,201; Mexico 2,194; United Kingdom 976; Canada 969; Brazil 600; Japan 91; Netherlands 60; China 59; Belgium 40; Spain 20; Portugal 9; Denmark 4.
Other[2]	7,624	10,293	5,811	7,100	Canada 2,026; Japan 1,515; West Germany 1,151; Netherlands 851; Belgium 88; United Kingdom 69; Austria 40; Mexico 28; Norway 20; Portugal 20; Sweden 4.
Total[1]	28,754	19,382	32,679	18,235	
Grand total[1]	36,773	21,517	42,322	20,680	

[1]Data may not add to totals shown because of independent rounding.
[2]Includes synthetic brown oxides, transparent oxides, and magnetic and precursor oxides.

Source: Bureau of the Census.

Table 8.—U.S. imports for consumption of iron oxide and iron hydroxide pigments, by country

Country	Natural				Synthetic			
	1986		1987		1986		1987	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Austria	--	--	79	$66	79	$54	40	$35
Belgium-Luxembourg	20	$6	113	14	145	142	196	98
Brazil	--	--	--	--	545	363	676	411
Canada	22	31	713	135	6,807	1,612	13,770	2,559
China	--	--	--	--	14	7	121	64
Cyprus	5,379	947	6,045	1,027	--	--	--	--
Denmark	--	--	--	--	1	4	4	7
France	639	104	45	21	18	52	--	--
Germany, Federal Republic of	613	340	1,504	460	14,017	7,806	9,549	6,934
Ireland	--	--	--	--	22	14	--	--
Italy	86	48	146	78	--	--	--	--
Japan	110	320	66	335	2,175	6,229	2,724	4,505
Korea, Republic of	--	--	--	--	--	--	22	16
Mexico	--	--	220	12	2,604	1,613	3,230	1,938
Netherlands	21	10	--	--	146	79	961	439
Norway	--	--	--	--	--	--	20	52
Peru	--	--	4	112	20	6	--	--
Portugal	--	--	--	--	--	--	29	233
Spain	926	225	622	136	213	40	188	80
Sweden	--	--	--	--	7	165	4	26
Switzerland	1	9	(1)	2	(1)	2	(1)	9
United Kingdom	184	83	87	47	1,922	1,126	1,142	825
Other	18	12	(1)	(1)	r20	r67	1	4
Total[2]	8,019	2,135	9,643	2,445	28,754	19,382	32,679	18,235

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

Source: Bureau of the Census.

WORLD REVIEW

World mine production of natural iron oxide pigments for reporting countries increased 6% compared with that of 1986, totaling 253,000 tons. In addition to the countries listed in table 9, other countries, including the centrally planned economy countries, produced natural iron oxide pigments in 1987. Production data, however, are not available.

Synthetic iron oxides comprise the largest percentage of colored inorganic pigment production in the world. Their popularity is attributed to a performance-price relationship. Iron oxides exhibit high tinctorial strength and hiding power, chemical resistance, lightfastness, and weatherfastness at low pigmentation costs. Synthetic iron oxides have made continuous gains in total market share over natural iron oxides because of product consistency, higher tinting strengths, and more saturated color shades compared to natural grades. Principal world producers of synthetic iron oxides include, in decreasing order, the Federal Republic of Germany, the United States, Japan, Mexico, and Brazil. One published article has placed worldwide demand for both natural and synthetic iron oxide pigments at 570,000 tons.[7]

In 1987, sales of iron oxides in Japan were expected to decrease slightly to 168,200 tons. This follows a surprising 13% jump in sales from 1985 to 1986. Magnetic material end uses were expected to continue to dominate iron oxide sales, comprising over 70% of the total, or 120,000 tons. Other major end uses for Japanese-produced iron oxides were, in order of rank, paints, roads, printing inks, building materials, synthetic resins, ceramics, paper, and other.[8]

In the United Kingdom, Deanshanger Oxides Ltd. announced plans to expand its synthetic iron oxides plant at Deanshanger, Milton Keynes, England. The company plans to invest $15 million to increase production capacity and improve technology, and to make major environmental improvements over the next 2 years. Deanshanger Oxides, the only manufacturer of synthetic iron oxide pigments in the United Kingdom, produces a product labeled "Deanox." Deanox is used domestically in concrete, paint, paper, plastics, roof tiles, and rubber. It is also exported to a range of overseas markets.[9]

[1]Mineral industry specialist, Branch of Ferrous Metals.
[2]Unless otherwise specified, the unit of weight in this chapter is the short ton.
[3]American Paint and Coatings Journal. New Products: PT Micaceous Primer Pigment. V. 71, No. 47, May 4, 1987, p. 67.
[4]———. December Contracts Gain—Dodge Construction up Percent for Month, 2 Percent for Year. V. 72, No. 34, Feb. 1, 1988, p. 15.
[5]Bureau of the Census (Dep. Commerce). Paint, Varnish, and Lacquer. Rep. M28F(87)-12, 1987.
[6]American Paint and Coatings Journal. The Markets: 1987—The Year Raw Material Prices Turned Around. V. 72, No. 29, Dec. 28, 1987, p. 22.
[7]Seymour, R. B. Coatings Progress in the Mid 1980's. J. Coatings Technol., v. 59, No. 745, Feb. 1987, pp. 49-55.
[8]Roskill Information Services Ltd. (London). Roskill's Letter From Japan. Ferric Oxide: 1987 Demand Expected To Fall 2% as Domestic Market Weakens. RLJ No. 138, Oct. 1987, pp. 11-12.
[9]Polymers Paint Colour Journal (London). Deanshanger Oxides To Invest 10M. V. 177, No. 4185, Feb. 18, 1987, p. 82.

Table 9.—Natural iron oxide pigments: World mine production, by country[1]

(Short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Argentina	940	[r]834	3,307	2,205	2,800
Austria	12,935	[e]12,700	12,768	12,930	12,800
Brazil	4,211	4,689	[e]5,000	[e]5,200	5,500
Canada[e]	3,100	3,100	2,200	2,200	2,200
Chile	7,442	17,762	9,065	4,854	5,500
Cyprus	17,637	14,440	13,448	11,023	11,000
France[e]	17,600	16,500	16,000	16,500	17,100
Germany, Federal Republic of[3]	21,921	17,833	17,377	12,528	12,600
India	97,701	118,886	119,655	94,040	104,700
Iran[4]	3,858	10,031	4,740	[r e]4,700	4,700
Italy[e]	1,000	900	950	960	950
Pakistan (ocher)	[r]1,187	[r]1,153	610	670	2,100
Paraguay[e]	200	275	[r]290	[r]275	275
South Africa, Republic of	1,861	1,092	829	1,655	1,640
Spain:					
Ocher	10,890	11,371	11,346	[e]11,600	11,600
Red iron oxide[e]	22,000	22,000	23,000	22,000	22,000
United States	26,499	29,307	32,234	33,889	[5]35,071
Zimbabwe[e]	1,100	1,100	1,100	[5]228	220

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through Apr. 15, 1988.
[2]In addition to the countries listed, a considerable number of others undoubtedly produce iron oxide pigments, but output is not reported, and no basis is available for formulating estimates of output levels. Such countries include (but are not limited to) China and the U.S.S.R. Because unreported output is probably substantial, this table is not added to provide a world total.
[3]Includes Vandyke brown.
[4]Iranian calendar year (Mar. 21 to Mar. 20), beginning in the year stated.
[5]Reported figure.

Iron and Steel

By Frederick J. Schottman[1]

Production and shipments of domestic steel increased because of stronger demand. Imports of steel from most major steel-producing countries remained restricted by trade agreements, and the lower value of the U.S. dollar made the United States a less attractive market for foreign producers. On the other hand, the lower dollar value helped domestic producers to increase exports.

The domestic industry continued restructuring. Several companies were in bankruptcy and numerous companies changed ownership. The minimill sector was consolidated as leading companies bought independent mills. The financial performance of most companies improved as higher prices and shipments led to improved profitability.

Total world production increased, and the balance between supply and demand improved after a long period of excess capacity. The steel industries in most industrialized countries continued to close older capacity while new capacity was being installed or planned in less developed countries.

Table 1.—Salient iron and steel statistics

(Thousand short tons unless otherwise specified)

	1983	1984	1985	1986	1987
United States:					
Pig iron:					
Production	48,770	51,961	49,963	44,287	48,308
Shipments	49,081	52,164	50,010	44,372	48,370
Average value, per ton	$205.19	$195.43	$202.46	$187.52	$189.75
Exports[1]	6	57	32	47	50
Imports for consumption[1]	242	702	338	295	355
Steel:[2]					
Production of raw steel:					
Carbon	73,783	79,918	76,699	71,413	77,976
Stainless	1,750	1,772	1,683	1,689	2,028
All other alloy	9,082	10,838	9,877	8,505	9,147
Total	84,615	92,528	88,259	[3]81,606	89,151
Capability utilization[4] percent	56.2	68.4	66.1	63.8	79.5
Net shipments of steel mill products	67,584	73,740	73,043	70,263	76,654
Producer price index for steel mill products[5]	100.9	104.7	104.7	99.8	102.3
Exports of major iron and steel products[1]	1,589	1,413	1,266	r1,201	1,419
Imports for consumption of major iron and steel products[1]	17,964	27,488	25,707	r22,145	21,534
World: Production:					
Pig iron	r509,706	r546,234	556,301	p553,369	e564,918
Raw steel (ingots and castings)	r730,750	r782,918	789,980	p783,347	e804,843

eEstimated. pPreliminary. rRevised.
[1]Bureau of the Census.
[2]American Iron and Steel Institute (AISI).
[3]Data do not add to total shown because of independent rounding.
[4]Raw steel production capability is defined by AISI as the tonnage capability to produce raw steel for a sustained full order book.
[5]Bureau of Labor Statistics.

Domestic Data Coverage.—Domestic data for the iron and steel industry are developed by the Bureau of Mines from the annual "Blast Furnace and Steel Furnace Report." Of the 28 iron and steel operations to which a survey request was sent, 73% responded, representing 77% of the total pig iron production shown in table 1. Production for nonrespondents was estimated using data from prior year reports and from published and privately communicated information.

DOMESTIC PRODUCTION

Production of raw steel and shipments of finished steel products recovered from the low levels in 1986, which had been depressed by major strikes. Shipments were the highest since 1981. Capability utilization was low early in the year because of a continuing strike, but rose to more than 80% during most of the last 9 months of the year. The American Iron and Steel Institute (AISI) estimated that the raw steel production capability of the industry declined to 112.2 million short tons in 1987, down from 127.9 in 1986 and 160.0 million in 1977. The industry continued to shift to more modern processes for production and casting of raw steel. The fraction of steel produced in electric furnaces again increased while that produced in open-hearth furnaces decreased. Basic oxygen furnaces (BOF), electric furnaces, and open-hearth furnaces produced 58.9%, 38.1%, and 3.0%, respectively, of raw steel. New continuous casters helped boost the portion of steel that was continuously cast to 59.8%, up from 55.2% in 1986.

Shipments for almost all steel products increased, with particularly large increases for products used by the construction and machinery industries. Shipments of structural shapes, plates, and reinforcing bar were each up 14% compared with those in 1986. Shipments of products used in the automotive industry and in consumer goods such as appliances increased by smaller amounts. Shipments of most types of sheet increased 5% to 7%. Shipments of electrolytic galvanized sheet increased 59% as new galvanizing lines came up to normal operations. Shipments to the oil and gas industry recovered from low levels in 1986 but remained below the levels of earlier years. Shipments to the can industry rose about 7%, reversing a long-term downtrend.

Total shipments of iron and steel castings, as reported by the Bureau of the Census, were little changed. Shipments of gray iron, ductile iron, and malleable iron castings in 1987 were 5.687, 2.919, and 0.318 million tons, respectively, compared with 5.829, 0.975, and 0.320 million tons, respectively, in 1986. Shipments of steel castings were 0.830 million tons in 1987 compared with 0.826 in 1986.

Employment in the iron and steel industry, as reported by AISI, was again lower. Average employment for the year was down to 163,000 from 175,000 in 1986. The industry employed 121,000 workers on wages and 42,000 on salary. Employment rose during the year as production increased, and reported employment in December was 172,000. Unions representing workers in the steel industry continued to make concessions in new labor contracts. New contracts at Rouge Steel Co. and Allegheny Ludlum Corp. essentially froze base wages and provided for a reduction of 300 jobs through attrition at Rouge. A contract at Latrobe Steel Co. included wage reductions. The contract, settling a 6-month strike at USX Corp., reduced labor costs about 10% by reducing hourly costs by about $2 per hour and approved changes designed to improve productivity. In return, the union won concessions for profit sharing and a company commitment to modernization projects.

Despite new concessionary contracts, average employment costs for hourly employees, as reported by AISI, increased slightly to $23.707, up from $23.242 in 1986.

For the first time since 1981, the companies reporting financial data to AISI had positive total net income. These companies had a total net income of $1.017 billion, equal to 3.8% of sales.

Following the settlement of its strike, USX announced cutbacks that would reduce its raw steel capacity from 26.2 to 19 million tons per year. During the year, USX permanently closed its Baytown, TX, plate mill and Saxonburg, PA, sinter plant. After USX announced that there were no plans to reopen the Geneva integrated steel mill at Provo, UT, the plant was bought by a newly formed company, Basic Manufacturing & Technologies of Utah Inc., and reopened as Geneva Steel Co. To make the investment attractive, workers at the plant agreed to a contract cutting labor costs by about 30% in return for profit sharing.

Employees at McLouth Steel Products Corp. bought majority ownership in the company through an Employee Stock Ownership Plan (ESOP). McLouth had been sold while in bankruptcy in 1982 but had not been able to recover financially. ESOP's provide companies with certain tax benefits. Weirton Steel Co., with the Nation's largest ESOP-assisted financial plan, has operated profitably since it was sold to its workers in 1983.

Sharon Steel Corp. filed for bankruptcy under chapter 11 of the Federal Bankruptcy Code. Two other integrated steel companies, Wheeling-Pittsburgh Steel Co. and LTV Steel Co., had filed for bankruptcy in earlier years. The three companies continued to operate while trying to restructure financially.

Several other facilities were closed during the year. Phoenix Steel Corp. closed its Claymont, DE, plate plant and its Phoenixville, PA, pipe mill. The company had emerged from bankruptcy in 1985 under a new owner and was again seeking to sell the plants. Armco Inc. shut down a meltshop and bar mill at its Kansas City, MO, plant, but more modern parts of the plant continued to operate. In specialty steel, Braeburn Alloy Steel Div. of CCX Inc. stopped melting operations for tool steel at Lower Burrell, PA, and Carpenter Technology Corp. began to phase out production of stainless steel at Bridgeport, CT. The minimill industry was consolidated by the purchase of independent mills by multiplant companies. Florida Steel Corp. bought Knoxville Iron Co., a minimill in Knoxville, TN, and North Star Steel Co. agreed to buy Milton Manufacturing Co., a relatively small and old minimill in Milton, PA.

Kentucky Electric Steel Corp. reopened its steel mill in Ashland, KY, which had been closed in 1985. The steelmaking division of Copperweld Corp. was spunoff as CSC Industries Inc.

Inland Steel Industries Inc. and Nippon Steel Corp. formed a joint venture to build a $400 million, 2.5-million-ton-per-year cold-rolling mill to process steel from Inland's Indiana Harbor, IN, integrated steel mill. When completed in 1990, the mill was to replace older mills at Indiana Harbor and to improve quality while reducing production costs through improved productivity.

Nucor Corp. was building two new major electric-furnace steel mills. The Nucor-Yamato Steel Co., a joint venture with Yamato Kogyo of Japan, planned to produce 650,000 tons per year of large structural shapes at Blytheville, AR. The $175 million mill was to use new rolling technology developed by Yamato and was to employ 600 workers.

Nucor was also building an 800,000-ton-per-year minimill in Crawfordsville, IN, to produce hot- and cold-rolled sheet. The plant was designed with new thin-slab continuous casting technology that was to produce a 2-inch-thick slab compared with a 6-inch slab in conventional casting. The thinner slab was expected to significantly reduce rolling costs.

Materials Used in Ironmaking.—Domestic pellets charged to blast furnaces totaled 44.18 million tons, and sinter charged amounted to 18.45 million tons. Pellets and other agglomerates from foreign sources amounted to 9.44 million tons. A total of 11.21 million tons of iron ore was consumed by agglomerating plants at or near blast furnaces, producing 18.48 million tons of agglomerates. Other materials consumed by agglomerating plants were 2.57 million tons of mill scale, 0.88 million tons of flue dust, 0.69 million tons of coke breeze, and 4.32 million tons of fluxes.

According to AISI, blast furnaces consumed 32.0 billion cubic feet of oxygen. AISI also reported that blast furnaces consumed, in addition to coke, 37.6 billion cubic feet of natural gas; 16.8 billion cubic feet of coke oven gas; 142.6 million gallons of oil; and 4.4 million gallons of tar and pitch.

Materials Used in Steelmaking.—According to AISI, steelmaking furnaces consumed 4.40 million tons of lime, 0.88 million tons of limestone, 0.13 million tons of fluorspar, 0.82 million tons of other fluxes, and 135.3 billion cubic feet of oxygen. Metalliferous materials consumed in domestic steel furnaces, per ton of raw steel produced, averaged 1,085 pounds of pig iron, 1,096 pounds of scrap, 25 pounds of ferroalloys, and 4 pounds of ore and agglomerates. The comparable figures for 1986 were 1,076 pounds of pig iron, 1,164 pounds of scrap, 24 pounds of ferroalloys, and 5 pounds of ore and agglomerates.

PRICES

The producer price index for steel mill products, as reported by the Bureau of Labor Statistics, was relatively stable during most of 1987 but began to rise late in the year. The index was within the range of 100.7 to 102.3 during the first three quarters, but rose steadily from 102.2 in September to 106.3 at yearend. Prices strengthened late in the year because of relatively tight supplies for some products and because of rising raw material costs.

Products produced primarily by minimills had relatively steep price increases because of higher scrap prices in the second half of 1987. Between December 1986 and December 1987, the price indexes for merchant quality bars and light structurals both increased 13%. The index for wire rod increased 7%.

Although prices for flat-rolled products had been expected to weaken when USX restarted production after its strike settlement, these prices generally held steady through the summer and then began to rise as demand picked up. The price index for carbon steel plate rose 18% from December 1986 to December 1987. A rebound in capital equipment demand combined with the shutdown of plate capacity had tightened the supply situation. However, the price recovery was from low levels, and at yearend, prices were still below those in 1982. Other flat-rolled products were increased by smaller amounts.

FOREIGN TRADE

Exports of iron and steel products increased significantly for the second year because of the lower value of the U.S. dollar in international trade.

Imports for consumption of iron and steel products declined for the second year. Imports of most steel products from most major exporting countries remained controlled by export restraint agreements. Stronger international markets and the lower value of the dollar made the U.S. market less attractive to exporters. The same factors also helped boost the average value of imported steel mill products 9% from $388 per ton in 1986 to $421 per ton in 1987.

The European Economic Community (EEC) remained the largest supplier of imported steel with 28% of the total, while Japan supplied 21%, and Canada, 18%. Canada remained the most important exporting country without an export-restraint agreement.

In July, a program of special tariffs and quotas on specialty steel, which was set to expire, was extended to September 1989. The new expiration date coincided with the expiration date of export restraint agreements covering most other steel products.

WORLD REVIEW

World production of pig iron and steel increased. With declining capacity in the industrialized countries, the supply and demand of steel was moving into better balance. However, there remained significant local imbalances because of currency fluctuations and long-term trends in the world economy.

Europe and Japan faced problems of excess capacity. The steel industries in Europe continued to shrink as obsolete capacity was closed. The EEC had made significant progress in restructuring its steel industry. The EEC ended production quotas on some products and indicated its intention to end all quotas. The Japanese steel industry had suffered a loss in international competitiveness when the yen appreciated in value, and almost all major steel companies announced plans for cuts in capacity and major reductions in employment.

On the other hand, developing countries with low labor costs, and in some cases with low raw materials costs, planned capacity increases. Pohang Iron & Steel Co. Ltd. in the Republic of Korea started production at its second plant and announced further expansion plans. Brazil, although limited by foreign debt problems, planned further expansions. China continued a steady growth in capacity. Vigorous expansion of electric-furnace steel mills in Turkey was making it a major steel exporter.

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[1]Physical scientist, Branch of Ferrous Metals.

Table 2.—Pig iron produced and shipped in the United States in 1987, by State

State	Production (thousand short tons)	Shipped from furnaces		Average value per ton at furnace
		Quantity (thousand short tons)	Value (thousands)	
Alabama, Kentucky, Maryland, Utah, West Virginia	8,965	8,912	$1,630,957	$183.01
Illinois, Indiana, Michigan	23,975	24,108	4,328,844	179.56
Ohio	10,299	10,297	2,155,359	209.32
Pennsylvania	5,070	5,053	1,063,041	210.38
Total or average	[1]48,308	48,370	9,178,201	189.75

[1]Data do not add to total shown because of independent rounding.

Table 3.—Foreign iron ore and manganiferous iron ore (excluding agglomerates) consumed in manufacturing pig iron in the United States, by source

(Thousand short tons)

Source	1986[1]	1987[2]
Brazil	62	33
Canada	111	112
Venezuela	690	W
Other	27	809
Total	[3]889	954

W Withheld to avoid diclosing proprietary data; included with "Other."
[1]Excludes 8,392,815 tons used in making agglomerates.
[2]Excludes 10,064,740 tons used in making agglomerates.
[3]Data do not add to total shown because of independent rounding.

Table 4.—Iron ore and other metalliferous materials, coke, and fluxes consumed in blast furnaces, and pig iron produced in the United States, by State

(Thousand short tons unless otherwise specified)

State	Metalliferous materials consumed in blast furnaces: Iron and manganiferous ores: Domestic	Iron and manganiferous ores: Foreign	Agglomerates	Net ores and agglomerates[1]	Net scrap[2]	Miscellaneous[3]	Net total[4]	Net coke	Fluxes	Pig iron produced	Metalliferous materials consumed per ton of pig iron made (short tons): Net ores and agglomerates[1]	Net scrap[2]	Miscellaneous[3]	Net total[4]	Coke and fluxes consumed per ton of pig iron (short tons): Net coke	Fluxes
1986:																
Illinois	--	--	3,337	3,332	383	61	3,776	1,233	203	2,382	1.399	0.161	0.026	1.585	0.518	0.085
Indiana and Michigan	1	9	28,421	28,211	951	439	29,601	9,167	504	18,656	1.512	.051	.024	1.587	.491	.027
Ohio	8	32	13,989	13,946	428	552	14,927	5,123	743	9,457	1.475	.045	.058	1.578	.542	.079
Pennsylvania	59	591	6,071	6,648	71	150	6,868	2,440	397	4,423	1.503	.061	.034	1.553	.552	.090
Alabama, Kentucky, Maryland	--	247	9,258	9,439	39	238	9,717	2,985	280	6,230	1.515	.006	.038	1.560	.479	.045
Texas, Utah, West Virginia	36	11	4,830	4,847	207	62	5,116	1,625	120	3,141	1.543	.066	.020	1.629	.517	.038
Total[4] or average	104	889	65,906	66,422	2,079	1,502	70,004	22,573	[5]2,247	44,287	1.500	.047	.034	1.581	.510	.051
1987:																
Illinois, Indiana, Michigan	1	11	36,221	36,000	2,060	509	38,569	11,430	533	23,975	1.502	.086	.021	1.069	.477	.022
Ohio	W	W	15,462	15,456	787	784	17,027	5,556	984	10,299	1.501	.076	.076	1.653	.539	.096
Pennsylvania	W	W	7,697	7,600	262	159	8,020	2,751	413	5,070	1.499	.052	.031	1.582	.543	.081
Alabama, Kentucky, Maryland, Utah, West Virginia	5	109	13,536	13,581	280	251	14,112	4,294	202	8,965	1.515	.031	.028	1.574	.479	.023
Total[4] or average	6	954	72,917	72,637	3,389	1,703	77,728	24,031	[6]2,131	48,308	1.504	.070	.035	1.609	.497	.044

W Withheld to avoid disclosing company proprietary data; included with "Agglomerates."

[1]Net ores and agglomerates equal ore plus flue dust used minus flue dust recovered.

[2]Excludes home scrap produced at blast furnaces.

[3]Does not include recycled material.

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

[5]Fluxes consisted of the following: 1,320,000 tons of limestone, 1,000 tons of burnt lime, 757,000 tons of dolomite, and 170,000 tons of other fluxes, excluding 2,385,000 tons of limestone, 20,000 tons of burnt lime, 1,200,000 tons of dolomite, and 16,000 tons of other fluxes used in agglomerating production at ore near steel plants and an unknown quantity used in making agglomerates at mines.

[6]Fluxes consisted of the following: 1,388,000 tons of limestone, 500 tons of burnt lime, 644,000 tons of dolomite, and 99,000 tons of other fluxes, excluding 3,125,000 tons of limestone, 1,363,000 tons of dolomite, and 25,000 tons of other fluxes used in agglomerating production at or near steel plants and an unknown quantity used in making agglomerates at mines.

Table 5.—Pig iron shipped from blast furnaces in the United States, by grade[1]

Grade	1986			1987		
	Quantity (thousand short tons)	Value		Quantity (thousand short tons)	Value	
		Total (thousands)	Average per ton		Total (thousands)	Average per ton
Basic	43,223	$8,135,905	$188.23	46,853	$8,951,667	$191.06
Foundry	W	W	W	W	W	W
All other (not ferroalloys)	1,149	184,780	160.86	1,517	226,534	149.33
Total or average	44,372	[2]8,320,686	187.52	48,370	9,178,201	189.75

W Withheld to avoid disclosing company proprietary data; included with "All other."
[1]Includes molten iron transferred directly to steel furnaces.
[2]Data do not add to total shown because of independent rounding.

Table 6.—Number of blast furnaces in the United States, by State

State	1986			1987		
	In blast[1]	Out of blast	Total	In blast[1]	Out of blast	Total
Alabama	3	1	4	1	3	4
Illinois	3	2	5	3	2	5
Indiana	11	7	18	11	6	17
Kentucky	2	--	2	2	--	2
Maryland	1	3	4	1	3	4
Michigan	6	3	9	5	3	8
Ohio	10	8	18	10	7	17
Pennsylvania	5	10	15	7	7	14
Texas	--	1	1	--	--	--
Utah	2	1	3	--	3	3
West Virginia	2	2	4	3	1	4
Total	45	38	83	43	35	78

[1]In blast for 180 days or more during the year.

Table 7.—U.S. steel production, by type of furnace

(Thousand short tons)

Year	Open-hearth	Basic oxygen converter	Electric	Total[1]
1983	5,951	52,050	26,615	84,615
1984	8,336	52,822	31,370	92,528
1985	6,428	51,885	29,946	88,259
1986	3,330	47,885	30,390	81,606
1987	2,666	52,496	33,989	89,151

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

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			
1983	9	96	75	33	48,300	1,063	45,280
1984	43	98	78	43	51,291	1,166	48,415
1985	54	91	79	29	49,257	1,088	50,002
1986	24	70	87	3	43,910	979	47,475
1987	89	W	98	W	48,347	1,122	[4]48,873

W Withheld to avoid disclosing company proprietary data; included with "Domestic."
[1]Basic oxygen converter, open-hearth, and electric.
[2]Consumed in integrated steel plants only.
[3]Includes manganese metal, ferrochromium, ferromanganese, ferromolybdenum, ferrosilicon, silicomanganese, and spiegeleisen. Includes ferroalloys added to steel outside the furnace.
[4]Internal evaluation indicates that scrap consumption is understated by approximately 4.0 million short tons.

Table 9.—U.S. consumption of pig iron, by type of furnace or other use

Type of furnace or other use	1985		1986		1987	
	Thousand short tons	Percent of total	Thousand short tons	Percent of total	Thousand short tons	Percent of total
Basic oxygen converter	44,515	86.6	41,582	91.2	46,741	93.4
Open-hearth	4,737	9.2	2,325	5.1	W	W
Electric	503	1.0	313	.7	1,880	3.8
Cupola	501	1.0	428	.9	370	.7
Air and other furnaces[1]	56	.1	58	.1	56	.1
Direct castings[2]	1,100	2.1	899	2.0	982	2.0
Total[3]	51,411	100.0	45,604	100.0	50,030	100.0

W Withheld to avoid disclosing company proprietary data; included with "Electric."
[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 may not add to totals shown because of independent rounding.

Table 10.—U.S. consumption of pig iron,[1] by State

(Thousand short tons)

State	1986	1987
Alabama	W	931
Connecticut	W	3
Illinois	2,372	2,577
Indiana	14,044	16,708
Iowa	43	38
Kansas	6	8
Massachusetts	16	10
Michigan	4,929	4,934
Minnesota	13	15
New York	12	11
Ohio	9,973	11,658
Pennsylvania	4,702	5,195
Tennessee	W	8
Texas	62	12
Virginia	W	18
West Virginia	W	2,584
Wisconsin	45	42
Undistributed[2]	9,385	5,277
Total[3]	45,604	50,030

W Withheld to avoid disclosing company proprietary data; included with "Undistributed."
[1]Includes molten pig iron used for ingot molds and direct castings.
[2]Includes California, Florida, Kentucky, Louisiana (1987), Maine, Maryland, Missouri, New Hampshire, New Jersey, North Carolina, Oklahoma (1987), Oregon, South Carolina, Utah, Washington, and data indicated by symbol W.
[3]Data may not add to totals shown because of independent rounding.

Table 11.—U.S. exports of major iron and steel products

Product	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)	1987 Quantity (short tons)	1987 Value (thousands)
Steel mill products:						
Ingots, blooms, billets, slabs, sheet bars	89,708	$28,000	58,885	$18,812	73,543	$34,285
Wire rods	4,922	8,047	6,206	9,195	8,850	15,200
Structural shapes, 3 inches and over	41,633	40,461	31,698	21,275	63,159	28,283
Structural shapes, under 3 inches	7,139	7,897	6,995	7,463	11,563	10,196
Sheet piling	628	466	5,729	6,136	2,552	1,637
Plates	82,988	57,784	69,565	55,709	96,538	67,655
Rails and track accessories	10,937	10,844	9,447	11,057	11,988	13,228
Wheels and axles	2,493	14,875	3,685	18,796	3,766	17,767
Concrete reinforcing bars	7,409	3,553	14,197	4,907	20,550	8,213
Bars, carbon, hot-rolled	27,577	11,842	19,561	9,572	40,675	18,272
Bars, alloy, hot-rolled	34,871	37,298	25,862	33,900	24,845	41,408
Bars, cold-finished	20,854	28,182	13,491	22,291	21,925	29,831
Hollow drill steel	1,062	1,891	790	1,730	1,677	2,850
Pipe and tubing	199,258	285,182	121,050	188,212	149,941	220,513
Wire	18,758	31,215	26,081	37,574	26,146	44,178
Nails, brads, spikes, staples	5,445	21,670	5,862	31,659	7,905	34,285
Blackplate	32,754	7,704	70,488	22,178	73,967	27,731
Tinplate and terneplate	141,729	64,463	214,122	71,312	172,842	71,794
Sheets, hot-rolled	56,696	35,429	75,906	46,204	80,001	67,933
Sheets, cold-rolled	46,465	47,968	37,672	130,547	46,685	45,866
Strip, hot-rolled	12,482	13,742	13,683	17,386	28,321	21,448
Strip, cold-rolled	23,827	41,073	20,863	32,574	15,838	45,802
Plates, sheets, strip, galvanized, coated or clad	60,319	55,493	r74,685	r59,896	110,705	81,222
Total[1]	929,954	855,078	r926,521	r858,386	1,093,982	949,597
Other steel products:						
Plates and sheets, fabricated	13,677	27,214	11,133	18,023	10,708	20,806
Structural shapes, fabricated	46,770	93,396	34,098	67,121	35,662	70,791
Architectural and ornamental work	1,765	8,174	2,552	7,171	1,472	5,532
Sashes and frames	6,815	20,339	4,242	16,765	5,462	20,639
Pipe and tube fittings	16,362	126,336	18,645	155,183	25,189	182,307
Conduit	5,472	8,010	r2,883	r4,930	5,631	6,376
Bolts and nuts	58,944	106,094	44,186	100,502	55,608	88,229
Forgings	46,269	68,444	46,649	67,505	78,202	83,824
Cast-steel rolls	1,471	2,389	1,243	2,582	1,880	2,700
Railway track material	2,843	5,276	2,812	4,272	5,774	1,259
Total[1]	200,387	465,672	r168,444	r444,053	225,587	482,464
Iron products:						
Cast-iron pipes, tubes, fittings	41,523	64,236	65,307	69,253	31,898	52,586
Iron castings	94,419	90,994	40,473	34,909	67,197	55,134
Total[1]	135,942	155,230	105,780	104,161	99,095	107,719
Grand total[1]	1,266,283	1,475,980	r1,200,744	r1,406,601	1,418,665	1,539,781

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

Source: Bureau of the Census.

Table 12.—U.S. imports for consumption of pig iron, by country

Country	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)	1987 Quantity (short tons)	1987 Value (thousands)
Australia	17	$15	--	--	21,158	$1,577
Brazil	130,762	13,772	143,154	$15,472	118,736	12,235
Canada	166,291	29,920	112,607	20,324	209,898	37,985
China	1,968	330	6,041	1,129	--	--
France	7,241	1,219	--	--	--	--
Norway	--	--	--	--	4,561	543
South Africa, Republic of	30,504	4,936	32,944	5,434	--	--
Other	r1,475	r427	221	124	359	160
Total	338,258	50,619	294,967	[1]42,482	354,712	52,500

rRevised.
[1]Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

Table 13.—U.S. imports for consumption of major iron and steel products

Product	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)	1987 Quantity (short tons)	1987 Value (thousands)
Steel mill products:						
Ingots, blooms, billets, slabs, sheet bars	1,878,953	$385,462	1,907,274	$391,269	2,101,145	$468,889
Wire rods	1,479,749	501,994	1,367,221	472,387	1,471,949	501,989
Structural shapes, 3 inches and over	2,019,245	580,305	1,748,604	515,737	1,778,314	537,598
Structural shapes, under 3 inches	140,317	53,507	166,369	61,515	140,469	56,708
Sheet piling	102,790	37,837	107,013	40,047	109,705	42,712
Plates	2,303,682	628,335	r1,593,056	r457,362	1,676,588	857,523
Rails and track accessories	358,442	127,906	266,084	79,999	227,869	66,454
Wheels and axles	23,604	19,638	9,626	9,614	18,120	13,433
Concrete reinforcing bars	409,612	88,353	454,735	102,718	351,632	87,143
Bars, carbon, hot-rolled	445,001	152,544	419,699	135,123	441,858	148,977
Bars, alloy, hot-rolled	207,427	112,279	r171,546	r96,615	176,968	100,350
Bars, cold-finished	326,395	213,153	r236,149	r169,188	222,639	182,735
Hollow drill steel	1,260	1,383	1,378	1,530	2,050	2,383
Welded pipe and tubing	2,529,895	1,028,470	1,939,948	786,443	1,758,349	729,688
Other pipe and tubing	1,942,051	1,173,810	r996,864	592,187	969,191	559,035
Wire	629,086	428,856	583,072	396,936	607,185	393,244
Wire nails	403,522	199,126	393,673	219,223	440,746	257,209
Wire fencing, galvanized	25,311	16,915	24,475	18,038	21,358	17,688
Blackplate	241,375	99,928	205,937	r84,835	159,779	72,050
Tinplate and terneplate	419,242	222,114	380,268	199,484	363,524	193,110
Sheets, hot-rolled	2,433,705	708,727	2,101,876	594,816	2,134,221	666,220
Sheets, cold-rolled	2,803,532	1,208,379	r2,764,195	r1,175,118	2,329,020	1,102,208
Sheets, coated (including galvanized)	2,621,340	1,226,192	2,489,419	1,158,634	2,577,799	1,297,140
Strip, carbon, hot-rolled	62,154	19,353	43,557	15,486	18,130	9,341
Strip, carbon, cold-rolled	216,458	127,200	123,380	94,380	102,028	82,980
Strip, alloy, hot- or cold-rolled (including stainless)	67,849	105,585	49,846	81,192	28,083	50,821
Plates, sheets, strip, electrolytically coated (other than with tin, lead, or zinc)	186,485	98,291	131,379	69,596	122,097	69,538
Total[1]	24,278,482	9,565,642	r20,676,642	r8,019,473	20,350,816	8,567,164
Other steel products:						
Plates, sheets, strip, fabricated	36,157	16,578	47,822	22,459	84,076	40,705
Structural shapes, fabricated	285,169	271,542	r352,500	r278,020	214,208	162,846
Pipe fittings	118,328	176,135	r92,218	r142,322	67,948	133,544
Rigid conduit	17,650	11,955	r19,491	r11,376	4,910	3,399
Bale ties made from strip	812	634	752	616	437	384
Nails, brads, spikes, staples, tacks, not of wire	45,801	60,298	50,823	70,083	53,861	95,393
Bolts, nuts, rivets, washers, etc.	638,314	724,509	647,002	748,820	565,651	682,007
Forgings	68,915	47,270	46,864	34,395	28,983	25,720
Total[1]	1,211,146	1,308,921	r1,257,473	r1,308,091	1,020,073	1,143,999
Iron products:						
Cast-iron pipes, tubes, fittings	78,395	59,455	57,799	59,808	60,220	59,606
Iron castings	139,313	85,088	152,632	92,222	103,173	102,062
Total[1]	217,708	144,543	210,432	152,030	163,393	161,668
Grand total[1]	25,707,336	11,019,106	r22,144,546	r9,479,595	21,534,282	9,872,830

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

Source: Bureau of the Census.

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

(Thousand short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Algeria[e]	[3]1,213	1,210	1,210	1,210	1,210
Argentina[4]	2,052	1,983	3,306	2,866	[3]3,070
Australia	5,561	5,874	6,181	6,492	[3]6,151
Austria	3,660	4,128	4,083	3,692	3,580
Belgium	8,849	9,886	9,611	8,863	8,800
Brazil[4]	14,269	18,960	20,911	22,432	22,390
Bulgaria	1,789	1,739	1,876	1,760	1,760
Burma	17	9	--	--	--
Canada	9,443	10,629	10,654	10,195	10,500
Chile	595	655	639	651	680
China	41,204	44,070	[e]48,100	[e]55,300	59,400
Colombia	266	278	258	352	353
Czechoslovakia	10,434	10,539	[e]10,500	[e]10,500	11,000
Egypt	216	248	175	[e]220	220
Finland	2,092	2,242	[e]2,000	[e]2,100	2,100
France	15,274	16,578	17,004	[e]15,500	14,700
German Democratic Republic[5]	2,433	2,598	2,842	3,018	2,870
Germany, Federal Republic of	29,319	33,293	34,757	31,987	[3]31,435
Greece[e]	152	152	[r]154	[r]180	180
Hungary	2,256	[r]2,312	2,309	2,264	[3]2,325
India	10,016	10,342	10,841	11,584	12,100
Iran	265	276	276	276	276
Italy	11,399	12,818	12,851	13,122	11,500
Japan	80,398	88,629	88,812	82,289	[3]80,875
Korea, North[e]	6,100	6,300	6,400	6,400	6,400
Korea, Republic of	8,845	9,660	9,737	9,940	[3]12,188
Luxembourg[5]	2,553	3,051	3,037	2,923	[3]2,541
Mexico[4]	5,549	5,924	5,616	5,566	5,720
Morocco[e]	17	17	17	17	17
Netherlands	4,130	5,430	5,312	5,101	[3]6,035
New Zealand[e] [4]	170	190	190	220	220
Norway	623	602	670	[e]690	660
Pakistan	520	624	885	983	1,000
Paraguay	--	--	--	--	35
Peru[4]	154	[r]73	228	300	[3]278
Poland	10,710	11,002	10,810	11,626	11,600
Portugal	391	411	457	463	[3]480
Romania	9,028	10,535	10,154	10,283	10,250
South Africa, Republic of	5,746	6,013	7,247	[e]7,500	7,400
Spain	5,950	5,884	6,037	5,291	5,300
Sweden[4]	2,328	2,561	2,811	[e]2,900	2,800
Switzerland	11	60	73	87	88
Taiwan	3,764	3,704	3,780	[e]4,100	4,190
Thailand	(6)	--	--	--	--
Trinidad and Tobago (sponge iron)	313	263	226	371	570
Tunisia	162	165	[e]165	[e]165	165
Turkey	2,997	3,199	3,520	4,041	[3]4,892
U.S.S.R[e]	121,000	121,600	120,600	[r]124,800	125,000
United Kingdom	10,447	10,458	11,443	10,676	[3]13,246
United States	48,770	51,961	49,963	44,287	[3]48,308
Venezuela[4]	2,476	3,511	3,391	[e]3,700	4,050
Yugoslavia	3,136	3,147	3,439	3,376	3,300
Zimbabwe	644	441	743	[e]710	710
Total	[r]509,706	[r]546,234	556,301	553,369	564,918

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

[1]Table excludes ferroalloy production except where otherwise noted. Table includes data available through July 1, 1988.

[2]In addition to the countries listed, Vietnam and Zaire have facilities to produce pig iron and may have produced limited quantities during 1983-87; however, output is not reported, and available information is inadequate to make reliable estimates of output levels.

[3]Reported figure.

[4]Includes sponge iron output.

[5]Includes blast furnace ferralloys.

[6]Less than 1/2 unit.

Table 15.—Raw steel:[1] World production, by country[2]

(Thousand short tons)

Country[3]	1983	1984	1985	1986[p]	1987[e]
Algeria[e]	660	770	830	830	830
Angola[e]	11	11	11	11	11
Argentina	3,244	2,918	3,243	3,566	[4]4,005
Australia	6,236	6,948	7,251	7,389	6,660
Austria	4,862	5,368	5,137	4,731	4,750
Bangladesh[5]	52	80	111	106	[4]90
Belgium	11,196	12,459	11,776	10,741	10,600
Brazil	16,160	20,267	22,549	23,406	[4]24,505
Bulgaria	3,121	3,172	3,245	3,268	3,200
Canada	14,140	16,220	15,983	15,543	[4]16,204
Chile	681	763	759	778	800
China	44,040	47,800	[e]51,500	[e]57,400	61,700
Colombia	531	550	584	[e]669	[4]356
Cuba	388	358	442	459	[4]419
Czechoslovakia	16,561	16,348	16,574	[r]16,500	17,100
Denmark	543	604	582	697	610
Ecuador	25	20	20	19	28
Egypt	216	638	588	[e]610	610
El Salvador	17	12	13	[e]12	13
Finland	2,663	2,901	2,776	[e]3,150	2,870
France	19,426	20,944	20,759	[e]19,800	[4]19,540
German Democratic Republic	7,958	8,348	8,656	8,782	9,040
Germany, Federal Republic of	39,384	43,419	44,640	40,933	[4]39,957
Greece	946	987	1,086	[e]1,050	1,050
Hong Kong[e]	130	130	130	130	130
Hungary	3,986	4,134	4,019	4,095	4,080
India[6]	11,359	11,402	12,185	12,596	13,343
Indonesia	882	1,100	1,323	[e]1,650	1,760
Iran[e]	1,300	1,300	[r]990	[r]990	990
Ireland	155	183	224	229	220
Israel[e]	[4]165	220	170	170	170
Italy	23,891	26,484	26,173	25,212	25,200
Japan	107,121	116,389	116,050	108,330	[4]108,592
Jordan[e]	150	150	150	150	150
Kenya[e]	11	11	11	11	11
Korea, North[e]	6,700	7,200	7,200	7,200	7,200
Korea, Republic of	13,134	14,366	14,924	16,043	[4]18,499
Luxembourg	3,631	4,395	4,349	4,084	[4]3,639
Malaysia[e]	390	390	[r]610	830	880
Mexico	7,692	8,333	8,121	7,904	8,280
Morocco[e]	7	7	7	7	7
Netherlands	4,935	6,326	6,081	5,824	[4]5,602
New Zealand	257	302	250	[e]316	330
Nigeria	201	206	280	220	220
Norway	987	1,014	[e]1,000	922	940
Pakistan[e]	600	670	770	880	910
Paraguay	--	--	--	--	[4]4
Peru	330	[r]371	438	536	550
Philippines	220	[r]288	276	[e]276	280
Poland	17,897	18,224	17,776	18,898	19,000
Portugal	743	761	733	780	580
Qatar	526	527	588	559	550
Romania	13,881	15,914	15,206	[e]15,400	15,400
Saudi Arabia	441	928	1,219	[e]1,200	1,200
Singapore[e]	386	390	390	390	390
South Africa, Republic of	7,926	8,628	9,460	[e]9,700	9,590
Spain	14,034	14,864	15,691	13,201	13,100
Sweden	4,537	5,186	5,305	5,192	5,070
Switzerland	920	1,078	1,088	1,185	1,210
Syria	90	76	[e]76	[e]76	76
Taiwan	5,530	5,758	5,871	[e]6,300	6,390
Thailand	[r]375	420	493	510	530
Trinidad and Tobago	231	219	192	360	410
Tunisia	180	186	187	200	200
Turkey	4,226	4,773	5,456	5,926	[4]7,765
U.S.S.R	168,118	170,018	170,492	176,976	178,600
United Kingdom	16,519	16,668	17,331	16,326	[4]19,208
United States	84,615	92,528	88,259	81,606	[4]89,151
Uruguay	51	45	43	44	34

See footnotes at end of table.

Table 15.—Raw steel:[1] World production, by country[2] —Continued

(Thousand short tons)

Country[3]	1983	1984	1985	1986[p]	1987[e]
Venezuela[6]	2,820	3,241	3,710	3,822	4,080
Vietnam[e]	110	110	120	120	120
Yugoslavia	4,558	4,669	4,938	4,981	[4]4,814
Zimbabwe	741	431	[e]510	[e]540	440
Total	[r]730,750	[r]782,918	789,980	783,347	804,843

[e]Estimated. [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]Table includes data available through July 1, 1988.

[3]In addition to the countries listed, Ghana, Libya, and Mozambique are known to have steelmaking plants; however, available information is inadequate to make reliable estimates of output levels. Burma reportedly has a remelt capacity of 40,000 tons; however, plant output, if any, is not known.

[4]Reported figure.

[5]Data are for year ending June 30 of that stated.

[6]Includes steel castings.

Iron and Steel Scrap

By Raymond E. Brown[1]

Brokers, dealers, and other outside sources supplied domestic consumers in 1987 with 42.1 million short tons[2] of all types of ferrous scrap at a delivered value of approximately $3.55 billion, while exporting 10.4 million tons (excluding rerolling material and ships, boats, and other vessels for scrapping) valued at $967 million. In 1986, domestic consumers received 37.1 million tons at a delivered value of approximately $2.69 billion; exports totaled 11.7 million tons valued at $1.05 billion.

Domestic Data Coverage.—Domestic production data for ferrous scrap are developed by the Bureau of Mines from voluntary monthly or annual surveys of U.S. operations. Of the operations to which a survey request was sent, 66% responded, representing an estimated 72% of the total consumption shown in table 2 for three types of scrap consumers. Consumption for the nonrespondents was estimated using prior reports adjusted by industry trends. An estimation error is also contained in the difference between the reported total consumption of purchased and home scrap and the sum of scrap receipts plus home scrap production, less scrap shipments, and adjustments for stock changes. For scrap consumption data shown in table 2, this difference amounted to 2% for manufacturers of pig iron and raw steel and castings, 0.1% for manufacturers of steel castings, 0.5% for iron foundries and miscellaneous users, and 1% average for all types of manufacturers combined.

Table 1.—Salient U.S. iron and steel scrap and pig iron statistics

(Thousand short tons and thousand dollars)

	1983	1984	1985	1986	1987
Stocks, Dec. 31:					
Scrap at consumer plants	5,807	5,261	5,104	4,344	4,844
Pig iron at consumer and supplier plants	345	304	266	188	281
Total	6,152	5,565	5,370	4,532	5,125
Consumption:					
Scrap	61,782	65,702	70,493	65,856	68,303
Pig iron	50,070	53,202	51,411	45,604	50,030
Exports:					
Scrap (excludes rerolling material and ships, boats, and other vessels for scrapping)	7,520	9,498	9,950	11,704	10,367
Value	$636,723	$917,981	$918,186	$1,053,849	$967,018
Imports for consumption:					
Scrap (includes tinplate and terneplate)	641	577	611	724	843
Value	$48,219	$47,427	$46,480	$49,073	$82,016

Legislation and Government Programs.—Attorneys for the Ferrous Scrap Consumers Coalition asked the Office of the U.S. Trade Representative for information under section 305 of the Trade Act of 1974, as amended, about various countries' restrictions on exports of ferrous scrap. The U.S. Department of Commerce released a report in June that analyzed trends in the U.S. ferrous scrap industry. The study noted that decreased recycling and increased disposal have come about as a result of enactment and stronger enforcement of environmental statutes and regulations.[3]

The Environmental Protection Agency (EPA) published revised particulate emission controls on July 1. Under the new regulations, smaller particles would have to be captured by emission control equipment.[4] Subsequently, the American Iron and Steel Institute filed a petition in the U.S. Court of Appeals seeking a review of those revised controls. In October, the U.S. Court of Appeals upheld a challenge to EPA's authority to regulate certain materials as "solid waste" under the Federal hazardous waste regulations.

The U.S. Department of Transportation proposed tightening regulations governing hazardous materials on November 6. The proposed regulations would apply to shipments of spontaneously combustible materials such as ferrous metal borings, shavings, and turnings or cuttings in a form subject to self-heating.[5]

AVAILABLE SUPPLY, CONSUMPTION, AND STOCKS

Overall domestic demand for ferrous scrap by the iron and steel and the ferrous castings industries, the major consumers of this raw material, increased by about 10% in 1987 compared with that of 1986. Domestic demand for ferrous scrap by producers of pig iron and raw steel was up by a larger quantity than that for the ferrous castings industry. Since spring, prices for most premium grades of ferrous scrap rose significantly because of higher steel and ferrous castings production, a larger share of steel production in electric furnaces, lower generation of home scrap because of increased continuous casting, and a weakening dollar, which helped to fend off both ferrous scrap and steel imports. In October, certain steel mills began adding scrap surcharges to the base price of some of their steel products. Also, some minimills, which are scrap-based electric arc furnace (EAF) operations, stopped accepting orders from new customers and placed old customers on allocation.

USX Corp., a major scrap consumer, and the United Steelworkers of America reached a labor agreement in January that ended an unprecedented 6-month-long strike. In February, USX announced that it would close four steelmaking facilities indefinitely. The plants to be closed were in Provo, UT; Baytown, TX; and McKeesport and Saxonburg, PA. Subsequently, on August 31, USX sold its Geneva works near Provo, UT, to Basic Manufacturing & Technologies of Utah Inc., a group of private investors. The operation would be renamed Geneva Steel of Utah. The Geneva plant has coke ovens, blast furnaces, and an openhearth shop with about 2 million tons per year of raw steelmaking capacity. USX also agreed to pay a $375,000 fine as a result of emissions generated at its Clairton, PA, cokemaking facility.

Sharon Steel Corp., Sharon, PA, filed for protection under chapter 11 of the Federal Bankruptcy Act on April 17. This was the third major U.S. steel producer attempting to reorganize under chapter 11 in recent years.

Weirton Steel Corp., Weirton, WV, after more than a year of negotiations with Korf Engineering GmbH, Federal Republic of Germany, canceled the joint construction of a new ironmaking demonstration plant utilizing Korf's Corex (previously known as KR for Kohle Reduktion) process. The Corex technology involves direct use of coal instead of coke to produce hot metal.

On November 19, the National Steel Producers Association and the American Metal Market, a Fairchild publication, cosponsored a 1-day conference in Washington, DC, on the problem of disposal of electric-furnace dust. Unless EPA grants an extension, the landfilling of hazardous EAF dust would be banned on August 8, 1988.

The domestic steel industry continued its efforts to make changes to improve competitiveness and increase earnings. Several scrap-based minimill producers have used or plan to use state-of-the-art technologies to sharply reduce overall operating costs and improve mill efficiency to provide higher quality steels and to expand product lines. For example, Nucor Corp. is testing a direct-current arc furnace and a CONSTEEL continuous steelmaking system at its Darlington, SC, plant. The CONSTEEL process was developed by J. A. Vallomy, Intersteel Technology Inc., Matthews, NC. Nucor is also installing a thin slab caster at its facility in Crawfordsville, IN, which would produce material with thicknesses as low as 2 inches and widths as great as 53 inches at a speed of up to 20 feet per minute. This system is being supplied by SMS Schloemann-Siemag AG, Dusseldorf, Federal Republic of Germany, and two of its affiliates, SMS Engineering Inc., Pittsburgh, PA, and SMS Concast Inc., Montvale, NJ. Additionally, Nucor is installing a 650,000-ton-per-year structural mill at its Blytheville, AR, plant that would make wide-flange (10 to 25 inches) beams. Nucor and Yamato Kogyo Co. Ltd. of Japan signed a contract to construct and operate the system, which is patterned after a Yamato facility in Japan.

The Institute of Scrap Iron and Steel Inc., Washington, DC, and the National Association of Recycling Industries Inc., New York, NY, voted to merge their organizations into a single scrap industry trade association. The new association would be known as the Institute of Scrap Recycling Industries (ISRI), with its headquarters in Washington, DC. ISRI also submitted a written request to the Occupational Safety and Health Administration (OSHA) seeking limited relief for scrap processors, especially to keep scrap processors classified as distributors but not as suppliers. According to ISRI, suppliers of scrap, but not distributors, should be responsible for preparing material safety data sheets. Additionally, ISRI contended that certain OSHA workplace requirements hindered effective recycling. ISRI disagreed with the OSHA regulation that considers chromium and nickel contained in stainless steel tableware potentially hazardous in a scrap plant but not in a restaurant or home.

There was a number of books and papers published in 1987 that would be of interest to collectors, dealers, brokers, exporters, processors, and consumers of ferrous scrap. A report by the Center for Metals Production assessed existing and potential EAF capacity including research and development recommendations for minimizing energy consumption and optimizing output.[6] A book by William T. Hogan, director of the Industrial Economics Research Institute of Fordham University, entitled "Minimills and Integrated Mills," subtitled "A Comparison of Steelmaking in the United States," chronicled the massive changes in the U.S. steel industry since annual production capacity reached a peak in the mid-1970's.[7] A publication of the International Iron and Steel Institute entitled "Scrap and the Steel Industry" presented information on recent developments in the field of solid metallics for ironmaking and steelmaking. Ferrous scrap topics included classification systems, sources, impact of technology changes on supply and demand, among others.[8]

Raw steel production was 88.5 million tons in 1987 compared with 81.6 million tons in 1986. The EAF share of raw steel production was 38% in 1987 and 37% in 1986. Continuous cast steel production represented 59% of total raw steel production in 1987 compared with 55% in 1986. Raw steel capacity utilization was 79% in 1987 and 64% in 1986. Net shipments of all grades of steel mill products were 76.5 million tons in 1987 and 70.3 million tons in 1986. Imports of steel mill products decreased from 20.7 million tons in 1986 to 20.4 million tons in 1987. Exports of steel mill products increased from 929,000 tons in 1986 to 1.13 million tons in 1987.

Iron castings shipments totaled 10.0 million tons in 1987 compared with 8.65 million tons (revised) in 1986. Steel castings shipments totaled 874,000 tons in 1987 compared with 829,000 tons (revised) in 1986.

Steel mills accounted for 74.8% of all scrap received from brokers, dealers, and other outside sources; steel foundries received 3.3%; and iron castings producers and miscellaneous users received 21.9%. The apparent total domestic consumption of ferrous scrap in 1987, in million tons, was composed of 44.8 net receipts (total receipts minus shipments), 24.7 home scrap, and a buildup of 0.5 stocks. The 1987 total was 69.0 million tons. This figure compared with an apparent total domestic consumption of 65.2 in 1986. The total market for U.S. scrap (net receipts plus exports minus imports) was 54.6 million tons in 1987 compared with 49.3 million tons in 1986. Stocks of ferrous scrap held by each of the three major consumers increased in 1987. Stocks held by steel mills increased by the largest quantity and by the largest percentage.

Since 1970, the ratio of total home scrap production, expressed as a percentage of total domestic apparent consumption of ferrous scrap declined significantly owing to changes in steelmaking technology. For example, the ratio declined steadily from about 60% in 1970 to about 40% in 1986. Adoption of steelmaking technology that resulted in this decline and a corresponding increase in the ratio of purchased scrap to raw steel production included conversion to electric arc furnace production, adoption of continuous casting which produced higher yields, and a number of other technical advances that increased scrap consumption in the basic oxygen furnace.

Public awareness of the solid waste problem has been driving mandatory recycling legislation by States, counties, and municipalities, which has the potential to reduce the solid waste stream. Mandatory recycling involves source separation, which means that materials are separated by home owners instead of municipal or private employees. Source separation would increase the availability of municipal ferrous scrap, a material that is currently not being recycled effectively. However, the total supply of ferrous scrap has never been a major problem in this country. In fact, ISRI has recorded a surplus of ferrous scrap for each of the last 31 years since 1956. ISRI estimated that more than 800 million tons of ferrous scrap has been placed in involuntary inventory for lack of markets. A city or county organizing a recycling program must establish markets for materials removed from the solid waste stream. To be marketable, material recovered from municipal solid waste, such as steel cans, must meet certain specifications. However, the quality of municipal ferrous scrap limits its use as a raw material for new products. This type of purchased scrap would be a major source of residual and unspecified elements if used to produce steel and ferrous castings. For a successful recycling program, municipalities would have to develop strong working relationships with brokers, processors, or manufacturers that use secondary materials. Scrap processors have developed expertise over the years in upgrading secondary materials into marketable products.

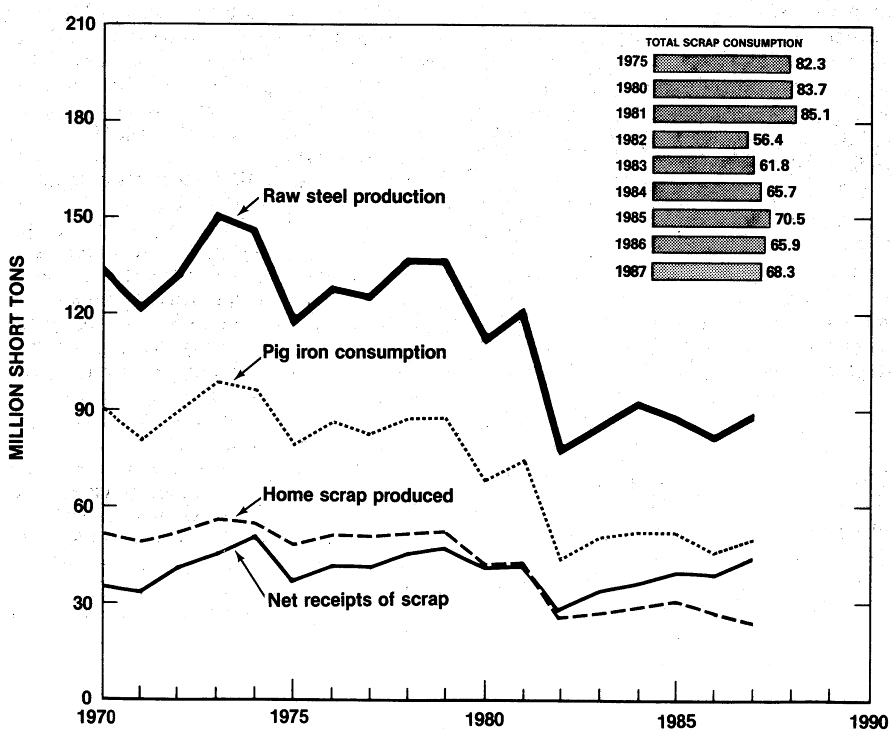

Figure 1.—Raw steel production (AISI), total iron and steel scrap consumption, pig iron consumption, home scrap production, and net scrap receipts.

PRICES

Based on average composite delivered prices per long ton quoted weekly and monthly by the American Metal Market (AMM), No. 1 heavy melting steel scrap cost $85.76 in 1987, ranging from a low of $73.72 in April to a high of $109.90 in October. Based on Iron Age data, No. 1 heavy melting steel scrap cost $85.64 in 1987, ranging from $73.17 in April to $108.92 in October. The average composite price for No. 1 heavy melting steel scrap in 1987 was higher compared with that of 1986, by 16% based on AMM data and by 17% based on Iron Age data.

In 1987, the average price for total ferrous scrap exports increased by 4% compared with that of 1986 to $93.36 per ton, while that of total imports increased by 43% to $97.29 per ton.

FOREIGN TRADE

The trade surplus in 1987 for all classes of ferrous scrap (including rerolling material and ships, boats, and other vessels for scrapping) was $914 million in value and 9.83 million tons in quantity. This is a decrease of 11% and 13% in value and quantity, respectively, compared with the 1986 record-high surplus of $1.03 billion and 11.3 million tons, respectively. The balance of trade for all U.S. merchandise consisted of a record deficit of $171 billion in 1987, up from a previous record deficit of $156 billion in 1986.

Total U.S. exports of ferrous scrap (excluding rerolling material; ships, boats, and other vessels for scrapping; stainless steel; and alloy steel) in 1987 went to 43 countries and totaled 9,945,420 tons valued at $844,445,417, which averaged $84.91 per ton. Six countries received 75.8% of the total quantity. The largest tonnages went to the Republic of Korea, 2,622,738 tons; Turkey, 2,252,637 tons; Japan, 902,462 tons; India, 874,362 tons; Mexico, 487,778 tons; and Taiwan, 400,207 tons. The value of scrap exports to these six countries was $653,296,661; 77.4% of the total.

Total U.S. exports of stainless steel scrap in 1987 went to 27 countries and consisted of 172,273 tons valued at $94,024,655 that averaged $545.79 per ton. Six countries received 85.0% of the total quantity, of which the largest tonnages went to Japan, 57,776 tons; Spain, 39,840 tons; Netherlands, 17,843 tons; Canada, 12,853 tons; Belgium, 11,850 tons; and Brazil, 6,233 tons. The value of stainless steel scrap exports to these six countries was $79,107,893; 84.1% of the total.

U.S. exports of alloy steel scrap (excluding stainless steel) in 1987 were shipped to 45 countries. The total comprised 248,974 tons valued at $28,548,281 which averaged $114.66 per ton. Six countries received 78.5% of the total quantity, of which the largest tonnages went to Singapore, 99,249 tons; Japan, 25,451 tons; Taiwan, 22,018 tons; Sweden, 21,657 tons; Canada, 14,103 tons; and Mexico, 13,013 tons. The value of alloy steel scrap to these six countries was $18,122,213; 63.5% of the total.

Total imports for consumption of iron and steel scrap in 1987 contained 2,803 tons of tinplate waste or scrap valued at $380,478. The balance of imports consisted of 826,762 tons of iron and steel scrap without dutiable alloys valued at $76,563,597 and 13,412 tons of iron or steel waste and scrap valued at $5,071,597.

WORLD REVIEW

Total world demand for iron and steel scrap in 1987 increased over that of 1986. Overall demand for ferrous scrap was higher in market economy countries than in countries with centrally planned economies. Most of the increase in demand, on a quantity basis, came from the United States. Countries with the sharpest increases in demand, on a percentage basis, were Argentina, China, the Republic of Korea, Turkey, the United Kingdom, the United States, and Venezuela.

The United States continued to be the leading exporting country of iron and steel scrap. The U.S.S.R. and the United Kingdom were also major exporters of ferrous scrap.

Work has begun on the infrastructure for a new Navipe maritime recycling center at Astakos on the west coast of Greece. Activities planned at Navipe would include the startup of a shipbreaking operation at yearend 1988 with an anticipated total annual scrap capacity of about 340,000 tons.

TECHNOLOGY

Results from testing of the CONSTEEL continuous steelmaking process at Nucor's minimill facility in Darlington, SC, established the feasibility of the system. One benefit of the continuous process was that it was more effective than a batch process and was controllable at any point in time. Also, in melting scrap, preheating up to about 800° C with primary fuel was more economical than introducing the same heat with electric energy in the furnace.[9]

There have been several reported incidents at U.S. mills in the last few years where radioactive materials have been accidently processed with metal scrap. The cleanup cost after such an incident can range into the millions of dollars. Workers, and ultimately the public, could be exposed to radioactive material. Incidents typifying the potential impact that a melted radioactive material could have can be documented by accidents that occurred at a California steel plant, a New York steel mill, and a rebar mill in Juarez, Mexico. State-of-the-art radiation-monitoring devices have been purchased and installed at strategic locations at some U.S. minimills to detect radioactive contaminated scrap so that it can be removed from incoming material.[10]

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[1]Physical scientist, Branch of Ferrous Metals.

[2]All quantities are in short tons unless otherwise specified.

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[9]Spivey, P. B., and J. A. Vallomy. Operation and Experience of the CONSTEEL Continuous Steelmaking Process at Nucor Steel. Proc. 45th Electric Furnace Conf., ISS-AIME, Chicago, IL, Dec. 8-11, 1987. AIME, Warrendale, PA, 1987, pp. 75-80.

[10]Rostik, L. F., and C. W. Avent. Environmental Controls at Work—Chaparral Experience. Proc. 45th Electric Furnace Conf., ISS-AIME, Chicago, IL, Dec. 8-11, 1987. AIME, Warrendale, PA, 1987, p. 159.

Table 2.—U.S. consumer receipts, production, consumption, shipments, and stocks of iron and steel scrap and pig iron in 1987, by grade

(Thousand short tons)

Grade	Receipts of scrap: From brokers, dealers, 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, scrap from old equipment, 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							
Carbon steel:							
Low-phosphorus plate and punchings	332	([1])	2	([1])	326	([1])	25
Cut structural and plate	1,083	109	284	--	1,329	11	146
No. 1 heavy melting steel	9,496	464	5,494	417	14,751	399	1,063
No. 2 heavy melting steel	2,909	167	844	2	3,839	16	363
No. 1 and electric-furnace bundles	6,099	192	1,111	2	6,589	607	465
No. 2 and all other bundles	808	54	74	--	902	45	64
Electric furnace, 1 foot and under (not bundles)	97	97	19	([1])	208	2	22
Railroad rails	353	11	24	--	414	--	15
Turnings and borings	700	56	213	--	984	12	75
Slag scrap (Fe content 70%)	679	189	1,961	1	2,430	207	179
Shredded or fragmentized	3,135	1,602	121	--	4,842	--	341
No. 1 busheling	1,834	220	115	([1])	2,031	77	147
All other carbon steel scrap	2,043	1,129	5,989	35	8,517	606	331
Stainless steel scrap	617	23	460	([1])	1,098	18	48
Alloy steel (except stainless)	101	137	745	([1])	965	45	152
Ingot mold and stool scrap	376	153	400	353	1,026	275	219
Machinery and cupola cast iron	7	13	3	--	19	9	2
Cast-iron borings	141	1	1	([1])	129	10	6
Motor blocks	--	--	--	--	--	--	--
Other iron scrap	408	147	338	1	806	147	146
Other mixed scrap	272	126	78	1	459	12	25
Total[2]	31,490	4,889	18,276	813	[3]51,665	2,496	3,835
MANUFACTURERS OF STEEL CASTINGS							
Carbon steel:							
Low-phosphorus plate and punchings	374	19	98	([1])	509	21	18
Cut structural and plate	149	24	16	--	179	--	19
No. 1 heavy melting steel	92	2	81	([1])	175	--	9
No. 2 heavy melting steel	169	--	1	--	164	--	12
No. 1 and electric-furnace bundles	5	--	--	--	6	--	--
No. 2 and all other bundles	--	--	--	--	--	--	--
Electric furnace, 1 foot and under (not bundles)	35	--	10	--	46	1	2
Railroad rails	4	--	([1])	--	3	--	1
Turnings and borings	20	--	9	--	27	2	1
Slag scrap (Fe content 70%)	--	--	--	--	--	--	--
Shredded or fragmentized	43	--	--	--	36	--	8
No. 1 busheling	48	5	--	--	49	([1])	1
All other carbon steel scrap	268	8	98	--	292	82	8
Stainless steel scrap	12	2	31	([1])	43	1	5
Alloy steel (except stainless)	61	--	131	--	190	3	46
Ingot mold and stool scrap	--	--	--	--	--	--	--
Machinery and cupola cast iron	37	--	3	--	39	--	3
Cast-iron borings	52	--	12	--	50	--	2
Motor blocks	([1])	--	--	--	([1])	--	--
Other iron scrap	20	--	67	--	86	4	14
Other mixed scrap	--	--	6	--	6	--	([1])
Total[2]	1,390	58	564	([1])	1,899	114	150

See footnotes at end of table.

Table 2.—U.S. consumer receipts, production, consumption, shipments, and stocks of iron and steel scrap and pig iron in 1987, by grade —Continued

(Thousand short tons)

Grade	Receipts of scrap: From brokers, dealers, 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, scrap from old equipment, buildings, etc.)	Consumption of both purchased and home scrap (includes recirculating scrap)	Shipments of scrap	Ending stocks, Dec. 31
IRON FOUNDRIES AND MISCELLANEOUS USERS							
Carbon steel:							
Low-phosphorus plate and punchings	1,019	92	236	1	1,357	(1)	43
Cut structural and plate	1,089	60	164	(1)	1,321	1	94
No. 1 heavy melting steel	131	29	351	--	217	288	19
No. 2 heavy melting steel	330	--	52	--	380	10	12
No. 1 and electric-furnace bundles	186	167	51	--	400	--	16
No. 2 and all other bundles	177	--	--	--	179	--	20
Electric furnace, 1 foot and under (not bundles)	34	3	1	--	35	--	5
Railroad rails	191	(1)	3	--	166	3	32
Turnings and borings	282	2	5	--	290	3	27
Slag scrap (Fe content 70%)	21	--	(1)	--	18	(1)	2
Shredded or fragmentized	1,350	89	(1)	--	1,487	2	86
No. 1 busheling	492	34	35	--	558	(1)	19
All other carbon steel scrap	543	7	16	(1)	549	4	46
Stainless steel scrap	13	--	6	--	14	3	3
Alloy steel (except stainless)	32	--	7	1	44	1	12
Ingot mold and stool scrap	152	(1)	183	--	352	3	29
Machinery and cupola cast iron	992	6	241	30	1,229	7	78
Cast-iron borings	610	195	75	5	867	28	60
Motor blocks	463	46	922	--	1,413	17	55
Other iron scrap	544	46	2,237	(1)	2,854	27	117
Other mixed scrap	568	13	464	(1)	1,008	23	84
Total[2]	9,221	789	5,050	38	14,739	420	859
TOTAL—ALL TYPES OF MANUFACTURERS[2]							
Carbon steel:							
Low-phosphorus plate and punchings	1,726	112	336	1	2,192	22	87
Cut structural and plate	2,321	192	465	(1)	2,830	11	259
No. 1 heavy melting steel	9,718	494	5,926	417	15,143	687	1,091
No. 2 heavy melting steel	3,409	167	897	2	4,383	25	388
No. 1 and electric-furnace bundles	6,290	359	1,162	2	6,994	607	481
No. 2 and all other bundles	985	54	74	--	1,081	45	84
Electric furnace, 1 foot and under (not bundles)	166	100	30	(1)	289	2	28
Railroad rails	548	11	27	--	583	3	48
Turnings and borings	1,002	58	227	--	1,301	17	103
Slag scrap (Fe content 70%)	700	189	1,961	1	2,448	208	181
Shredded or fragmentized	4,528	1,691	121	--	6,365	2	435
No. 1 busheling	2,375	259	150	(1)	2,639	77	166
All other carbon steel scrap	2,854	1,144	6,103	35	9,358	691	386
Stainless steel scrap	642	24	497	(1)	1,155	22	55
Alloy steel (except stainless)	195	137	884	1	1,199	49	210
Ingot mold and stool scrap	528	153	582	353	1,378	278	248
Machinery and cupola cast iron	1,036	19	248	30	1,287	16	82
Cast-iron borings	802	196	88	5	1,046	38	68
Motor blocks	463	46	922	--	1,413	17	55
Other iron scrap	972	193	2,642	2	3,746	178	277
Other mixed scrap	840	139	548	1	1,472	35	110
Grand total[2]	42,101	5,736	23,890	850	[3]68,303	3,029	4,844

[1]Less than 1/2 unit.
[2]Data may not add to totals shown because of independent rounding.
[3]Internal evaluation indicates that scrap consumption in electric furnaces operated by manufacturers of pig iron and raw steel and castings is understated by approximately 4.0 million short tons.

Table 3.—U.S. consumer receipts, production, consumption, shipments, and stocks of pig iron and direct-reduced iron in 1987

(Thousand short tons)

	Receipts	Production	Consumption	Shipments	Stocks, Dec. 31
MANUFACTURERS OF PIG IRON AND RAW STEEL AND CASTINGS					
Pig iron	2,304	48,308	48,965	1,542	223
MANUFACTURERS OF STEEL CASTINGS					
Pig iron	13	--	12	(1)	2
IRON FOUNDRIES AND MISCELLANEOUS USERS					
Pig iron	1,072	--	1,053	29	56
TOTAL—ALL TYPES OF MANUFACTURERS					
Pig iron	3,390	48,308	50,030	1,572	281
Direct-reduced or prereduced iron	449	--	280	W	107

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

Table 4.—Consumption of iron and steel scrap and pig iron in the United States in 1987, by 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]	2,345	--	--	--	--	--	2,345	--
Basic oxygen process[3]	15,692	46,741	--	--	--	--	15,692	46,741
Open-hearth furnace	1,137	W	W	W	--	--	1,137	W
Electric furnace	[4]32,044	1,606	1,782	12	4,752	262	38,578	1,880
Cupola furnace	16	118	115	--	9,764	252	9,894	370
Other (including air furnace)[5]	432	40	3	--	223	16	658	56
Direct castings[6]	--	460	--	--	--	522	--	982
Total[1]	51,665	48,965	1,899	12	14,739	1,053	68,303	50,030

W Withheld to avoid disclosing company proprietary data; included with "Electric furnace."
[1]Data may not add to totals shown because of independent rounding.
[2]Includes consumption in blast furnaces producing pig iron.
[3]Includes scrap and pig iron processed in metallurgical blast cupolas and used in oxygen converters.
[4]Internal evaluation indicates that scrap consumption in electric furnaces operated by manufacturers of pig iron and raw steel and castings is understated by approximately 4.0 million short tons.
[5]Includes vacuum melting furnaces and miscellaneous uses.
[6]Includes ingot molds and stools.

Table 5.—Proportion of iron and steel scrap and pig iron used in furnaces in the United States in 1987

(Percent)

Type of furnace	Scrap	Pig iron
Basic oxygen process	25.1	74.9
Open-hearth furnace	41.8	58.2
Electric furnace	99.2	.8
Cupola furnace	96.4	3.6
Other (including air furnace)	92.2	7.8

Table 6.—Iron and steel scrap supply[1] available for consumption in 1987, by region and State

(Thousand short tons)

Region and State	Receipts of scrap: From brokers, dealers, 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, scrap from old equipment, buildings, etc.)	Total new supply[2]	Shipments of scrap[3]	New supply available for consumption[2]
New England and Middle Atlantic:							
Connecticut, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island	1,193	79	312	6	1,590	31	1,559
Pennsylvania	5,665	511	3,761	97	10,033	666	9,367
Total[2]	6,858	590	4,073	102	11,623	697	10,926
North Central:							
Illinois	3,999	818	2,013	25	6,855	56	6,799
Indiana	4,364	907	4,648	6	9,925	823	9,102
Iowa, Kansas, Minnesota, Missouri, Nebraska, Wisconsin	3,830	236	1,384	(4)	5,450	81	5,369
Michigan	4,121	525	2,188	39	6,873	200	6,674
Ohio	6,239	934	4,304	559	12,036	766	11,270
Total[2]	22,553	3,420	14,537	629	41,139	1,926	39,214
South Atlantic:							
Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia	4,607	712	2,471	61	7,850	163	7,687
South Central:							
Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas	5,506	973	2,290	56	8,824	230	8,593
Mountain and Pacific:							
Arizona, California, Colorado, Hawaii, Oregon, Utah, Washington	2,581	41	520	3	3,143	15	3,127
Grand total[2]	42,101	5,736	23,890	850	72,577	3,029	69,548

[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 the 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.—U.S. consumption of iron and steel scrap and pig iron[1] in 1987, by region and State

(Thousand short tons)

Region and State	Pig iron and steel ingots 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	1,007	2	27	2	542	21	1,576	25
Pennsylvania	8,248	4,913	101	2	995	281	9,345	5,195
Total[2]	9,255	4,915	128	3	1,537	302	10,921	5,220
North Central:								
Illinois	5,513	2,520	148	--	1,088	57	6,749	2,577
Indiana	7,332	16,659	159	2	805	47	8,295	16,708
Iowa, Kansas, Minnesota, Missouri, Nebraska, Wisconsin	2,388	--	396	2	2,571	105	5,357	107

See footnotes at end of table.

Table 7.—U.S. consumption of iron and steel scrap and pig iron[1] in 1987, by region and State —Continued

(Thousand short tons)

Region and State	Pig iron and steel ingots and castings		Steel castings		Iron foundries and miscellaneous users		Total[2]	
	Scrap	Pig iron	Scrap	Pig iron	Scrap	Pig iron	Scrap	Pig iron
North Central —Continued								
Michigan	4,066	4,568	3	(3)	2,571	365	6,640	4,934
Ohio	8,266	11,551	298	5	2,600	103	11,163	11,658
Total[2]	27,565	35,298	1,004	9	9,635	677	38,204	35,984
South Atlantic: Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia	5,944	5,703	12	--	1,398	35	7,354	5,738
South Central: Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas	6,733	2,929	275	1	1,820	25	8,830	2,954
Mountain and Pacific: Arizona, California, Colorado, Hawaii, Oregon, Utah, Washington	2,169	120	480	(3)	347	13	2,994	134
Grand total[2]	51,665	48,965	1,899	12	14,739	1,053	68,303	50,030

[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]Less than 1/2 unit.

Table 8.—U.S. consumer stocks of iron and steel scrap and pig iron, December 31, 1987, by region and State

(Thousand short tons)

Region and State	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, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island	117	6	28	25	3	179	3
Pennsylvania	420	33	79	124	27	682	69
Total[1]	537	38	107	149	30	861	71
North Central:							
Illinois	438	(2)	11	37	1	487	10
Indiana	411	W	10	144	6	571	54
Iowa, Kansas, Minnesota, Missouri, Nebraska	313	2	5	11	14	345	13
Michigan	246	1	5	37	5	294	10
Ohio	432	7	41	97	7	584	26
Wisconsin	11	2	--	11	--	24	3
Total[1]	1,852	11	71	338	32	2,306	115
South Atlantic: Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia	429	4	2	71	9	515	40
South Central: Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas	708	2	15	108	37	873	53
Mountain and Pacific: Arizona, California, Colorado, Hawaii, Oregon, Utah, Washington	212	(2)	15	61	1	290	3
Grand total[1]	3,740	55	210	727	110	4,844	281

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 9.—U.S. average monthly price and composite price for No. 1 heavy melting steel scrap in 1987

(Per long ton)

Month	Chicago	Pittsburgh	Philadelphia	Composite price[1]
January	$78.00	$80.63	$74.85	$77.83
February	78.00	82.84	72.00	77.62
March	73.00	79.91	72.00	74.97
April	72.08	77.50	71.64	73.72
May	74.15	80.30	70.38	74.94
June	77.00	83.00	70.00	76.67
July	78.73	83.27	72.86	78.29
August	84.00	89.48	74.71	82.73
September	96.52	94.95	82.57	91.35
October	116.00	115.64	98.05	109.90
November	115.47	113.61	100.00	109.69
December	103.73	105.82	94.55	101.37
Average 1987	87.22	90.58	79.47	85.76
Average 1986	73.49	74.87	74.17	74.17

[1]American Metal Market, composite price, Chicago, Pittsburgh, and Philadelphia.

Table 10.—U.S. exports[1] of iron and steel scrap, by country

(Thousand short tons and thousand dollars)

Country	1983		1984		1985		1986		1987	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Canada	539	39,717	779	59,521	446	38,445	365	31,436	331	30,516
China	1	177	227	21,190	387	32,793	340	28,506	249	23,423
Italy	65	4,395	306	27,038	307	30,250	286	26,177	175	15,675
Japan	2,600	218,337	2,680	264,857	2,110	199,135	1,725	170,015	986	123,051
Korea, Republic of	1,476	111,051	1,833	160,892	1,978	160,674	2,989	247,055	2,630	213,550
Mexico	419	36,017	484	47,663	597	57,535	318	29,981	501	48,278
Spain	356	22,734	608	55,228	910	72,312	673	51,771	417	42,503
Taiwan	499	75,638	405	54,515	414	45,163	667	74,387	426	46,629
Turkey	700	50,851	807	69,579	955	80,133	1,417	115,334	2,254	195,971
Venezuela	20	1,197	392	33,346	471	36,384	483	36,673	150	10,273
Other	845	76,608	977	124,151	1,373	165,360	2,441	242,514	2,247	217,149
Total[2]	7,520	636,723	9,498	917,981	9,950	918,186	11,704	1,053,849	10,367	967,018

[1]Excludes rerolling material and ships, boats, and other vessels for scrapping.
[2]Data may not add to totals shown because of independent rounding.

Table 11.—U.S. exports and imports for consumption of iron and steel scrap, by class

(Thousand short tons and thousand dollars)

Class	1983		1984		1985		1986		1987	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Exports:										
No. 1 heavy melting scrap	1,895	139,935	2,512	215,482	2,766	218,593	2,922	230,519	2,446	200,980
No. 2 heavy melting scrap	720	50,081	879	70,906	767	58,537	797	58,879	579	45,994
No. 1 bundles	206	16,486	77	8,258	185	17,172	155	13,876	167	14,890
No. 2 bundles	220	13,727	286	18,836	306	21,160	301	21,095	366	23,623
Stainless steel scrap	80	44,671	164	96,426	180	104,898	165	90,066	172	94,025
Shredded steel scrap	2,029	154,753	2,775	251,976	2,559	220,320	3,495	293,040	3,314	298,259
Borings, shovelings, turnings	532	28,277	800	49,664	875	56,314	731	43,955	528	28,835
Other steel scrap[1]	1,532	164,101	1,416	155,685	1,646	162,484	2,048	209,094	2,033	195,197
Iron scrap	306	24,692	590	50,748	666	58,707	1,091	93,325	762	65,217
Total[2]	7,520	636,723	9,498	917,981	9,950	918,186	11,704	1,053,849	10,367	967,018
Ships, boats, other vessels (for scrapping)	198	9,623	283	9,503	131	6,627	212	16,475	246	20,264
Rerolling material	34	4,194	58	10,918	110	15,604	78	11,302	57	8,863
Total exports[2]	7,752	650,540	9,840	938,402	10,191	940,416	11,994	1,081,626	10,670	996,145
Imports for consumption:										
Iron and steel scrap	641	48,219	577	47,427	611	46,480	724	49,073	843	82,016

[1]Includes terneplate and tinplate.
[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	1983		1984		1985		1986		1987	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Canada	(1)	101	(1)	2,550	(1)	41	(1)	44	1	170
China	--	--	--	--	19	2,497	--	--	--	--
Korea, Republic of	5	462	--	--	--	--	--	--	(1)	8
Mexico	28	3,579	57	8,248	90	12,511	77	11,186	45	7,346
Turkey	--	--	--	--	--	--	--	--	10	1,111
Other	r(1)	r53	r(1)	r120	1	596	(1)	r72	1	228
Total[2]	34	4,194	58	10,918	110	15,604	78	11,302	57	8,863

rRevised.
[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 iron and steel scrap,[1] by country

Country	1986		1987	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Austria	58	$125	169	$350
Belgium-Luxembourg	128	236	2	5
Canada	562,603	38,151	725,622	68,558
Germany, Federal Republic of	2,365	850	863	205
Japan	12,984	1,059	16,754	1,227
Mexico	69,929	6,158	18,757	3,783
Netherlands	816	247	10,997	964
Sweden	12	35	624	153
United Kingdom	22,462	311	50,157	5,961
Other	52,201	1,899	19,032	810
Total[2]	723,558	49,073	842,971	82,016

[1]Includes tinplate and terneplate.
[2]Data may not add to totals shown because of independent rounding.

Table 14.—Iron and steel scrap consumption in selected countries[1]

(Thousand short tons)

Continent, country group, and country	1982	1983	1984	1985	1986
North America:					
Canada[2 3 4 5]	6,261	6,965	e7,000	7,905	7,804
United States[2 5 6]	56,386	61,782	65,702	70,493	65,856
Latin America:[7]					
Argentina	1,569	1,570	1,281	1,264	1,253
Brazil	5,625	6,137	6,971	7,714	7,934
Chile	146	209	237	241	152
Colombia	324	369	378	433	491
Ecuador	33	26	21	21	20
Mexico	3,332	2,383	3,181	3,413	3,253
Peru	120	186	343	r257	292
Uruguay	34	56	53	51	41
Venezuela	1,027	457	1,292	1,195	996
Central America, not further detailed	82	74	126	192	456
Europe:					
European Economic Community:[8]					
Belgium[2]	4,566	3,563	3,880	3,430	e2,900
Denmark[9]	690	644	718	656	776
France[3 4 5]	7,076	7,197	7,135	7,109	7,128
Germany, Federal Republic of[5]	19,339	19,692	20,510	20,517	18,795
Greece[e]	300	275	300	300	400
Ireland[10]	76	174	208	254	256
Italy	16,944	15,861	17,380	17,133	16,144
Luxembourg	1,450	1,508	1,857	1,761	1,644
Netherlands	1,594	1,607	1,797	1,658	[3]1,436
Portugal	522	617	e600	e600	e600
Spain	10,042	10,795	10,911	11,152	[10]9,641
United Kingdom	11,535	10,569	10,578	7,712	e7,300
European Free Trade Association:					
Austria	1,807	[3]1,797	[3]1,851	[3]1,681	[3]1,615
Finland[3]	758	786	831	838	837

See footnotes at end of table.

Table 14.—Iron and steel scrap consumption in selected countries[1] —Continued

(Thousand short tons)

Continent, country group, and country	1982	1983	1984	1985	1986
Europe —Continued					
European Free Trade Association —Continued					
Norway[3 4]	537	577	638	597	[e]600
Sweden[2 3 5]	3,145	[e]3,395	[e]3,500	[e]3,500	[e]3,500
Switzerland	[10]915	[e]915	[e]915	[e]915	[e]1,100
Council for Mutual Economic Assistance:					
Bulgaria[e]	830	820	850	850	850
Czechoslovakia[2 4 5]	8,186	8,665	8,354	8,471	8,422
German Democratic Republic[2 3 4 5]	5,649	5,682	5,779	5,593	5,516
Hungary	2,446	2,445	2,705	2,754	2,912
Poland[3]	8,983	9,796	9,630	9,490	10,070
Romania[e]	4,260	4,270	4,300	4,280	4,300
U.S.S.R.[e]	60,300	63,400	64,500	64,500	65,000
Other:					
Yugoslavia[3 4 5]	2,245	2,434	[e]2,500	[e]2,500	2,730
Africa: South Africa, Republic of[e 2]	3,060	2,600	3,000	3,300	3,500
Asia:					
China[e]	9,400	10,100	10,900	11,700	12,500
India[e]	4,200	4,050	4,060	4,300	4,400
Japan[5]	42,832	44,269	47,934	48,685	44,378
Korea, Republic of[e]	3,300	3,350	3,600	3,700	3,800
Taiwan[e 11]	1,400	1,700	1,700	1,700	1,800
Turkey[10]	[e]1,900	1,736	1,863	2,127	[e]2,200
Oceania:					
Australia[e]	2,070	1,820	2,050	2,100	2,000
New Zealand[e]	160	150	180	150	150
Total	317,456	327,473	344,099	[r]349,192	337,748

[e]Estimated. [r]Revised.

[1]Unless otherwise specified, figures represent actual reported consumption of iron and steel scrap utilized in the production of pig iron, ferroalloys, crude steel, foundry products, and rerolled steel, as well as other unspecified uses in the steel industry and by other unspecified industries as reported by the United Nations Economic Commission for Europe in its Annual Bulletin of Steel Statistics for Europe 1986, v. 14, New York, 1987, 28 pp., which is the source of all reported data unless otherwise specified. All estimates are by the Bureau of Mines.

[2]Excludes scrap consumed by steel rerollers.

[3]Excludes scrap consumed in iron foundries.

[4]Excludes scrap consumed within the steel industry for purposes other than the manufacture of pig iron, ferroalloys, crude steel, foundry products, and rerolled steel (details on use not available).

[5]Excludes scrap consumed outside the steel industry.

[6]Bureau of Mines.

[7]Data are from Instituto Latino Americano del Fierro y el Acero. Statistical Yearbook of Steel Making and Iron Ore Mining in Latin America, 1987. Santiago, 1988, 220 pp. Source does not provide details on what is included; presumably figures include total steel industry ferrous scrap consumption but exclude scrap used outside the steel industry.

[8]Portugal and Spain became members of the European Economic Community on Jan. 1, 1986.

[9]Includes scrap used in production of steel casting in shipyards, but excludes scrap, if any, used in production of pig iron and that used in iron foundries.

[10]Organization for Economic Cooperation and Development. The Iron and Steel Industry in 1982, Paris, 1984, 40 pp.; The Iron and Steel Industry in 1983, Paris, 1985, 52 pp.; The Iron and Steel Industry in 1984, Paris, 1986, 52 pp.; The Iron and Steel Industry in 1985, Paris, 1986, 52 pp.; and The Iron and Steel Industry in 1986, Paris, 1987, 52 pp.

[11]Excludes a substantial tonnage derived from shipbreaking (possibly of the order of several million tons annually) for electric-furnace-equipped steel mills.

Table 15.—Iron and steel scrap exports, by selected countries[1]

(Thousand short tons)

Continent, country group, and country	1982	1983	1984	1985	1986
North America:					
Canada	627	965	876	968	[2]990
United States[2] [3]	6,857	7,554	9,556	10,060	11,782
Latin America:					
Cuba[4]	[e]45	50	159	129	122
Mexico[2]	22	4	17	18	[e]20
Europe:					
European Economic Community:[5]					
Belgium-Luxembourg	549	752	853	811	725
Denmark	130	193	258	298	202
France	3,397	3,557	4,525	4,366	3,484
Germany, Federal Republic of	3,160	3,282	3,602	3,756	3,768
Greece	1	1	1	1	1
Ireland	65	23	47	55	45
Italy	19	20	21	11	8
Netherlands	1,300	1,678	1,851	2,023	2,192
Portugal	10	11	10	18	12
Spain	1	1	4	1	--
United Kingdom	3,387	4,182	4,758	4,982	4,230
European Free Trade Association:					
Austria	10	14	23	35	24
Finland	([6])	([6])	11	11	--
Iceland	4	7	12	7	3
Norway	35	40	23	10	9
Sweden	20	23	24	24	32
Switzerland	116	164	118	110	[2]100
Council for Mutual Economic Assistance:					
Bulgaria	63	42	53	42	4
Czechoslovakia[4]	107	137	205	155	112
German Democratic Republic[4]	22	23	40	29	8
Hungary	58	55	87	[r]44	18
Poland[2]	284	161	194	88	81
U.S.S.R.[2]	2,859	3,715	3,756	3,655	4,506
Other: Yugoslavia	70	78	157	191	174
Africa:					
Algeria[2]	62	61	91	93	[e]100
Morocco[2]	57	75	101	89	57
South Africa, Republic of[4]	4	51	51	57	112
Asia:					
Bahrain[2]	3	7	[e]10	[e]10	[e]10
Brunei	5	10	12	9	[e]10
China[4]	108	40	15	[e]25	[e]50
Cyprus	8	9	15	16	15
Hong Kong[2]	327	363	331	332	278
India[e]	20	20	20	20	20
Indonesia[2]	([6])	1	1	1	1
Japan	193	128	161	183	508
Korea, North[4]	15	7	[e]10	[e]10	28
Korea, Republic of[2]	155	314	149	82	79
Kuwait	20	77	136	[e]100	[e]100
Malaysia[2]	7	14	22	24	[e]25
Mongolia[4]	26	24	[e]25	[e]25	[e]25
Philippines[2]	2	1	2	1	1
Saudi Arabia	33	[e]35	[e]35	[e]35	[e]35
Singapore[2]	9	132	120	184	100
Taiwan[2]	443	308	223	428	310
Thailand[2]	9	2	4	4	6
Turkey	([6])	([6])	3	[2]4	[2]6
United Arab Emirates	7	[e]10	[e]10	[e]10	[e]10
Vietnam[4]	[e]10	13	2	61	101
Oceania:					
Australia[2]	1,249	574	409	555	623
New Zealand[2]	3	3	4	[r] [e]2	3
Total	[r]25,993	[r]29,011	[r]33,203	[r]34,258	37,265

[e]Estimated. [r]Revised.
[1]Unless otherwise specified, source is United Nations Economic Commission for Europe. Annual Bulletin of Steel Statistics for Europe 1986, v. 14, New York, 1987, 38 pp.
[2]Official trade returns of subject country.
[3]Includes rerolling material.
[4]Partial figure; compiled from import statistics of trading partner countries.
[5]Portugal and Spain became members of the European Economic Community on Jan. 1, 1986.
[6]Less than 1/2 unit.

Table 16.—Iron and steel scrap imports, by selected countries[1]

(Thousand short tons)

Continent, country group, and country	1982	1983	1984	1985	1986
North America:					
Canada	505	737	1,253	974	[2]827
United States[2]	468	641	577	611	724
Latin America:					
Argentina[2]	2	8	2	1	1
Brazil[2]	8	([3])	34	35	541
Chile	[e]10	[2]6	[e]10	[e]10	[2]19
Colombia[2]	30	51	48	[e]50	[e]50
Cuba[4]	[e]100	107	106	109	98
Mexico[2]	464	390	696	[r]1,016	[e]1,000
Peru[e]	[2]18	20	20	20	20
Venezuela[2]	23	20	400	547	[e]550
Europe:					
European Economic Community:[5]					
Belgium-Luxembourg	978	1,152	1,843	1,642	1,347
Denmark	97	74	146	53	133
France	304	338	449	508	389
Germany, Federal Republic of	1,421	1,424	1,935	1,776	1,517
Greece	478	573	362	345	502
Ireland	3	77	97	150	134
Italy	6,141	4,901	6,047	6,368	5,232
Netherlands	244	401	527	646	936
Portugal	138	119	132	116	114
Spain	5,249	5,227	5,531	6,776	[2]7,292
United Kingdom	41	12	37	55	52
European Free Trade Association:					
Austria	420	241	400	263	127
Finland	56	41	36	125	71
Norway	4	17	14	12	7
Sweden	583	496	925	976	769
Switzerland	118	162	301	265	[2]356
Council for Mutual Economic Assistance:					
Czechoslovakia[4]	81	173	172	48	48
German Democratic Republic	502	741	1,141	977	1,087
Hungary	15	31	22	15	9
Poland	6	6	8	6	6
U.S.S.R.[6]	27	24	49	28	49
Other: Yugoslavia	560	812	861	804	718
Africa:					
Egypt[2]	14	2	1	2	2
Morocco[2]	3	3	1	2	[e]2
South Africa, Republic of[2]	31	8	61	8	[e]50
Asia:					
Bahrain[2]	5	3	[e]3	[e]3	[e]3
China[4]	3	2	74	547	376
Hong Kong[2]	71	30	31	22	37
India[e]	500	500	500	800	800
Indonesia[2]	250	284	268	210	[e]200
Japan	2,232	4,306	4,429	3,587	3,554
Korea, Republic of[2]	1,994	2,090	2,294	2,640	3,434
Malaysia[2]	28	55	53	[e]55	[e]50
Pakistan[2]	173	132	134	169	162
Philippines[2]	28	([3])	1	1	94
Singapore[2]	103	104	87	72	230
Syria[2]	27	7	2	[e]15	[e]15
Taiwan[2]	718	811	637	766	1,351
Thailand[2]	430	707	545	725	612
Turkey	825	1,184	1,144	[2]1,323	[2]1,988
Oceania:					
Australia	[e]1	--	13	1	1
New Zealand[2]	6	3	3	3	6
Total	26,536	[r]29,253	[r]34,462	[r]36,278	37,692

[e]Estimated. [r]Revised.

[1]Unless otherwise specified, source is United Nations Economic Commission for Europe. Annual Bulletin of Steel Statistics for Europe 1986, v. 14, New York, 1987, 38 pp.

[2]Official trade returns of subject country.

[3]Less than 1/2 unit.

[4]Partial figures; compiled from export statistics of trading partner countries.

[5]Portugal and Spain became members of the European Economic Community on Jan. 1, 1986.

[6]Partial figure; compiled from incomplete returns of subject country and export statistics of trading partner countries.

Kyanite and Related Materials

By Michael J. Potter[1]

Kyanite, andalusite, and sillimanite are anhydrous aluminum silicate minerals that 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 high-performance, high-alumina refractories.

Published statistics were incomplete; however, France, India, the Republic of South Africa, and the United States appeared to be the leading world producers of kyanite-group minerals. The U.S.S.R. and perhaps a few other industrialized nations also were presumed to produce significant quantities of these materials.

U.S. kyanite output in 1987 was estimated to have decreased compared with that of 1986. Reasons for the decrease include competition from a new kyanite producer in Sweden and closing of the only other U.S. kyanite producer, Pasco Mining Inc., in Washington, GA, in late 1986.

Domestic Data Coverage.—Domestic production data for kyanite and synthetic mullite are developed by the Bureau of Mines by means of two separate, voluntary, domestic surveys. In the kyanite survey, there is one producer with two active mines who did not respond. An estimate of total production was made by the Bureau of Mines using the last reported production levels adjusted by the trend of the minerals economy.

In the synthetic mullite survey, all three of the canvassed operations responded and accounted for 100% of the total production tonnage data represented in table 1.

Legislation and Government Programs.—The allowable depletion rates for kyanite, established by the Tax Reform Act of 1969 and unchanged through 1987, were 22% for domestic production and 14% for foreign operations.

DOMESTIC PRODUCTION

Kyanite was produced at two open pit mines by Kyanite Mining Corp., which operated the Willis Mountain and East Ridge Mines in Buckingham County, VA.

There are three types of synthetic mullite. Fused synthetic mullite is made by melting Bayer process alumina and silica, or bauxite and kaolin in an electric furnace at about 3,450° F. High-temperature sintered synthetic mullite is prepared by sintering mixtures of alumina and kaolin, bauxite and kaolin, or alumina, kaolin, and kyanite above 3,180° F. Low-temperature sintered synthetic mullite is made by sintering siliceous bauxite or mixtures of bauxite and kaolin above 2,820° F.

Output of synthetic mullite in 1987 was largely of the high-temperature sintered variety, and the two producers of this material were C-E Minerals Inc. at Americus, GA, and Didier Taylor Refractories Corp. at Greenup, KY. Electric-furnace-fused mullite was produced by Electro Minerals U.S. Inc. at Niagara Falls, NY.

Table 1.—U.S. production of synthetic mullite

Year[e]	Quantity (short tons)	Value (thousands)
1983	23,000	$4,700
1984	27,000	5,300
1985	27,000	5,450
1986	W	W
1987	W	W

[e]Estimated. W Withheld to avoid disclosing company proprietary data.

CONSUMPTION AND USES

Kyanite and related materials were consumed mostly in the manufacture of high-alumina or mullite-class refractories and in lesser quantities as ingredients in ceramic compositions. U.S. kyanite, already ground to minus 35 mesh as required by the flotation process used in its separation and recovery, was marketed either in this raw form, or after heat treatment, as mullite, which was sometimes further reduced in particle size before use. In the 35- to 48-mesh range, kyanite was used mostly in monolithic refractory applications such as 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, was used in body mixes for sanitary porcelains, wall tile, investment-casting molds, and miscellaneous special-purpose ceramics.

PRICES

Prices in 1987, in British pounds, from Industrial Minerals (London) were the same as those of 1986. The 20% price increases in U.S. dollars in table 2 reflect a corresponding increase in the value of the British pound against the U.S. dollar.[2]

Table 2.—Prices of kyanite and related materials

(Dollars per short ton)

	1986	1987
Andalusite, Transvaal, 52% to 54% Al_2O_3, bulk, c.i.f. main European port	95	114
Andalusite, Transvaal, 60% Al_2O_3, c.i.f. main European port	122	147
Sillimanite, South African, 70% Al_2O_3, bags, c.i.f. main European port	259	310
U.S. kyanite, 59% to 62% Al_2O_3, 35-325 Tyler mesh, raw and/or calcined, 18-ton lots, c.i.f. main European port	122-211	147-253
U.S. kyanite, f.o.b. plant, carlots:		
Calcined	123-172	123-172
Raw	70-137	70-137

Source: Industrial Minerals (London). No. 243, Dec. 1987, p. 103.

FOREIGN TRADE

Shipments of U.S. kyanite- and mullite-containing materials were believed to have been made to destinations in Asia and Europe. Based on data from non-Government sources, imports of andalusite in 1987 were estimated to be 14,000 short tons.

WORLD REVIEW

Brazil.—Kyanite deposits occur in Goias and Minas Gerais States, with established reserves of 4 million tons. The only producer, Cianita Serra das Araras Ltda., was mining a deposit near Brasilia containing often-pure boulders of kyanite. Export markets had not yet reached earlier expectations.[3]

India.—Bharat Refractories Ltd. mined a large, high-grade deposit in the Khasi Hills in the State of Assam. The ore occurs as boulders consisting mainly of massive sillimanite. Some boulders were being sawn into bricks for direct application as refractories. Others were processed into lump material of 0.5 to 4 inches. Annual sillimanite output from the deposit was estimated to be approximately 6,000 tons.

In the Bhandara District in the State of Maharashtra, boulders of massive sillimanite-quartz-muscovite schist were mined by the Maharashtra State Mining Corp. This has become the country's largest sillimanite mining operation in recent years. Estimated annual production was approximately 8,000 tons.

In Kerala State, approximately 2,000 tons per year of sillimanite is extracted from beach sands. In the State of Orissa, a project known as the Orissa Sands Complex was being brought on-stream at one of the world's largest identified deposits of beach sands. Sillimanite content of the sands was 3%; initial production rate of sillimanite was to be approximately 30,000 tons per year.[4]

Japan.—Although there has been no mining of kyanite-group minerals, the country consumed an estimated 50,000 to 60,000 tons per year of mullite. Part of this demand was met by domestic production of synthetic mullite. The two producers were Toshiba Refractories Co. Ltd. and Asahi Glass Co. Ltd. Japan produced approximately 40,000 tons per year of synthetic mullite.[5]

Spain.—The sole producer of kyanite-group minerals has been reporting its production as kyanite, although official statistics refer to it as andalusite. Alluvium containing approximately 20% kyanite was mined by mechanical dredging, with production of kyanite being 3,000 to 4,000 tons per year. The operation was being upgraded to produce a higher alumina content product with reduced impurities for export markets.[6]

United Kingdom.—Sintered and electrofused synthetic mullite were produced by Cawoods Refractories Ltd. at several locations. The sintered mullite contained 86% mullite, with approximately 73% alumina and 0.7% iron oxide. The electrofused mullite consisted of 95% mullite, with 76.4% alumina and very little iron. The company reported its total mullite capacity as approximately 11,000 tons per year.[7]

Imports of kyanite-group minerals totaled 49,171 tons in 1986; principal countries of origin and percentages supplied were the Republic of South Africa, 50%; France, 22%; and the United States, 20%.[8]

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[1]Physical scientist, Branch of Industrial Minerals.
[2]Where necessary, values have been converted from pounds sterling (£) per metric ton to U.S. dollars per short ton at the rate of £1.00=U.S. $1.80 for 1987.
[3]Roskill Information Services Ltd. The Economics of Kyanite Group Minerals 1987. London, 5th ed., pp. 14-15.
[4]Pages 21-23 of work cited in footnote 3.
[5]Page 24 of work cited in footnote 3.
[6]Page 33 of work cited in footnote 3.
[7]Page 36 of work cited in footnote 3.
[8]Industrial Minerals (London). United Kingdom Industrial Mineral Statistics 1986. No. 236, May 1987, p. 67.

Table 3.—Kyanite: World production, by country[1]

(Short tons)

Country[2] and commodity	1983	1984	1985	1986[p]	1987[e]
Australia:					
Kyanite[3]	491	1,383	[e]1,650	[e]1,650	1,650
Sillimanite[4]	133	559	717	147	550
Brazil: Kyanite	473	1,422	[e]1,540	[e]1,650	1,650
China: Unspecified[e]	2,800	2,800	2,800	2,800	2,800
France: Andalusite	46,187	57,300	62,391	56,108	56,200
India:					
Andalusite	2,836	[e]3,000	556	[e]550	550
Kyanite	42,226	40,812	33,590	30,278	33,100
Sillimanite	8,739	14,746	18,844	16,430	16,500
Kenya: Kyanite	6	1	1	[e]1	1
Korea, Republic of: Andalusite	319	230	46	([5])	--
South Africa, Republic of:					
Andalusite	128,503	157,967	214,612	203,339	198,400
Sillimanite	898	1,445	1,474	1,466	1,430
Spain: Andalusite	4,945	3,307	3,087	2,696	2,760
Sweden: Kyanite	--	--	2,425	[e]5,500	11,000
United States:					
Kyanite	W	W	W	W	W
Mullite, synthetic[e]	23,000	27,000	27,000	W	W
Zimbabwe: Kyanite	--	--	--	2,040	2,040

[e]Estimated. [p]Preliminary. W Withheld to avoid disclosing company proprietary data.
[1]Owing to incomplete reporting, this table has not been totaled. Table includes data available through Apr. 8, 1988.
[2]In addition to the countries listed, a number of other nations produce kyanite and related materials, but output is not reported quantitatively, and no reliable basis is available for estimation of output levels.
[3]Production of kyanite began in 1982 (88 short tons) as a byproduct of mineral sands mining at Eneabba, Western Australia.
[4]In addition, about 8,000 short tons of sillimanite clay (also called kaolinized sillimanite) is produced annually containing 40% to 48% Al_2O_3.
[5]Revised to zero.

Lead

By William D. Woodbury[1]

Despite the highest domestic average annual lead price in 6 years, mine production of recoverable lead declined to the lowest level since 1967 owing to technical problems. Domestic recovery of lead from recycled scrap was more than 700,000 metric tons for the first time in 8 years, as U.S. secondary plants produced at a record capacity utilization rate. Only in the years 1977-79 had that level of secondary production been exceeded. Significant restructuring and capacity increases also occurred in the secondary sector, but one of the Nation's four remaining primary lead smelters did not operate at all during the year owing to the low domestic mine production. The Occupational Safety and Health Administration (OSHA) did not renew any expired temporary variances to its 1983 medical removal protection standard for secondary plants. OSHA estimated that 15% of the secondary industry was not in compliance at yearend.

Table 1.—Salient lead statistics

(Metric tons unless otherwise specified)

	1983	1984	1985	1986	1987
United States:					
Production:					
Domestic ores, recoverable lead content	449,295	322,677	413,955	339,793	311,298
Value thousands	$214,745	$181,745	$174,008	$165,150	$246,654
Primary lead (refined):					
From domestic ores and base bullion	r463,940	r323,989	r422,650	r348,217	336,471
From foreign ores and base bullion	55,227	65,409	71,353	22,071	37,139
Secondary lead (lead content)	503,501	633,374	615,695	r624,769	710,217
Exports (lead content):					
Lead ore and concentrates	20,119	11,858	9,987	4,380	8,764
Lead materials excluding scrap	24,351	16,563	37,322	19,778	13,586
Imports for consumption:					
Lead in ore and concentrates	19,753	29,888	2,649	4,604	873
Lead in base bullion	53	43	760	142	10,827
Lead in pigs, bars, reclaimed scrap	[1]180,569	166,515	134,521	143,511	192,260
Stocks, Dec. 31:					
Primary lead[2]	r53,405	r45,126	r84,502	r20,400	21,608
At consumers and secondary smelters	100,771	97,077	93,130	83,824	88,586
Consumption of metal, primary and secondary	1,148,487	1,207,033	1,148,298	r1,125,521	1,230,387
Price: Common lead, average, cents per pound[3]	21.68	25.55	19.07	22.05	35.94
World:					
Production:					
Mine thousand metric tons	r3,357.0	r3,261.9	3,427.9	p3,375.7	e3,453.8
Refinery[4] do	r3,264.6	r3,161.1	3,369.6	p3,229.0	e3,176.6
Secondary refinery do	r2,024.0	r2,295.1	2,291.8	p2,354.2	e2,453.2
Price: London Metal Exchange, pure lead, cash average, cents per pound	19.27	20.12	17.84	18.43	26.99

eEstimated. pPreliminary. rRevised.

[1]Includes Bureau of Mines estimate of 42,000 metric tons of pigs and bars (lead content) of U.S. brands returned from the London Metal Exchange.

[2]American Bureau of Metal Statistics Inc. (ABMS).

[3]Metals Week. Transactions on a delivered basis.

[4]Primary metal production only. Includes secondary metal production where inseparably included in country total.

Domestic consumption of lead increased to the highest level in 8 years owing to the record-high level reported by all lead-acid storage battery manufacturers. That sector exceeded 900,000 tons for the first time, which represented a record-high share of total consumption. However, demand by industrial and traction battery manufacturers decreased slightly after 4 consecutive years of significant growth. Total automotive battery shipments, including exports, were about the same as those of 1986, resulting in a large inventory buildup of starting-lighting-ignition (SLI) batteries at yearend. All other specific uses fluctuated only slightly compared with those of 1986.

After declining slightly in the first quarter of 1987, the North American producers' mean U.S. price rose steadily, reaching 42.0 cents per pound on July 7, 1987, which held through the remainder of the year. The monthly average spread against the London Metal Exchange (LME) price declined for the first 4 months, but increased spectacularly through October, reaching a record-high 14.8 cents per pound for that month. The result for the year was a significant increase in net imports of refined metal and total net imports of contained lead in all forms, including scrap, compared with 1986 imports. The U.S. average price of 42 cents per pound for the second half of 1987 was the highest sustained level since 1980. The LME average cash price for 1987 of 27 cents per pound was the highest since 1981.

Recoverable world mine production was estimated to have increased considerably, but secondary sources provided more than 40% of the estimated demand for the fourth consecutive year. World refinery production, including secondary lead, was estimated to have increased slightly from that of 1986 but was still less than world demand. World demand increased for the 5th consecutive year and equaled the record set in 1979.

Domestic Data Coverage.—Domestic data for lead are developed by the Bureau of Mines from five voluntary surveys of U.S. operations. Typical of these are the combined secondary producer and consumer monthly and annual surveys. Of the 274 consuming plants to which a survey request was sent, 256 responded, representing 97% of the total U.S. lead consumption shown in tables 1, 11, 12, 13, and 14. Of the 58 smelter-refineries to which a survey request was sent, 53 responded, representing 95% of the total refinery production of secondary lead recovered from scrap shown in tables 1, 8, 9, and 10. Production and consumption for the nonrespondents were estimated using reported prior year levels adjusted for general industry trends.

Legislation and Government Programs.—The Environmental Protection Agency (EPA) prohibited landfill or surface impoundments for any free liquid, solid, or sludge of any lead waste or its compounds containing 500 milligrams per liter or more of lead and required special hazardous waste disposal under the Resources Conservation and Recovery Act (RCRA). The requirement was taken directly from California State regulations, and EPA reserved the right to establish more stringent requirements. Many secondary smelters were already in compliance to avoid future liability. At yearend, the EPA was in the final process of determining the regulatory framework and standards for primary lead smelting and refining wastes under RCRA and was also considering modifying its leaching test for slag materials. The EPA was also considering a lowering of the drinking water standard for lead by up to 90%. The process effluent standards are also tied to this standard under the Clean Water Act. The U.S. Department of Transportation proposed a comprehensive overhaul of the regulations governing the transport of hazardous materials that reportedly would require shippers of lead concentrates to utilize leak-proof, sift-proof containment.

DOMESTIC PRODUCTION

MINE PRODUCTION

Domestic mine production of recoverable lead declined from that of 1986, and was the lowest since 1967, 2 years before the Viburnum Trend operations in Missouri fully came on-stream. The low output was attributed to technical problems, including lower average grades at some Missouri mines, and only a partial year's production from some lead-producing silver mines that had shut down in 1986 and did not come back on-stream until midyear in 1987. Eight Missouri mines, of which only seven were in operation all year, together with nine lead-producing precious metals and/or zinc and copper mines in Colorado, Idaho, and Montana, accounted for nearly all of the U.S.

mined lead output in 1987. Byproduct lead was recovered from mining in four other States during the year, accounting for less than 1,000 tons of recoverable metal. Domestic lead-producing mines operated at only 47% of capacity during the year, and the top 11 mines shown in table 6 produced more than 99% of the total.

The Doe Run Co. of St. Louis, MO, operated two mine and mill complexes involving five mines in southeastern Missouri on the Viburnum Trend. The Buick Mine, the Nation's largest producer, which had been closed since May 1986, was opened early in the year. The Brushy Creek unit did not operate in 1987. According to Homestake Mining Co.'s annual report, Doe Run milled 3.68 million tons of ore averaging 5.8% lead, which resulted in 256,000 tons of lead concentrates for Doe Run's integrated Herculaneum, MO, smelter-refinery. Homestake's share of Doe Run production was 42.5% with the balance accruing to Fluor Corp., whose St. Joe Minerals Div. was the operator. At yearend, Doe Run had 68.1 million tons of ore reserves grading 5.1% lead, according to Homestake. Approximately 65% of Doe Run's holdings are under Federal lease for which the Bureau of Land Management is paid a minimum royalty of 5% of the gross value of concentrates produced.

The Magmont Mine, equally owned by Cominco American Incorporated as operator and Dresser Industries Inc., was the second largest lead-producing mine in 1987, and its output also represented the second largest company output of mined lead. Cominco's share of Magmont's concentrates was sold to ASARCO Incorporated, and Dresser's share was tolled by Asarco at Glover, MO. According to Cominco Ltd. of Canada's annual report, Magmont milled slightly more than 1 million tons of ore averaging 7.1% lead, which produced 89,000 tons of lead concentrate grading 77.0% lead contained. This was a significant decline from 1986 owing to a 1.5% decrease in the average ore grade hoisted. At yearend, Magmont had 4.26 million tons of ore reserves grading 6.4% lead, according to Cominco. Cominco announced that shipments from its Red Dog Mine in Alaska would commence in 1990. The 54-mile road from the mine to the port on the Chukchi Sea was scheduled for completion in February 1988. At full production, the zinc-lead-silver open pit mine would be the world's largest base metal operation, producing 64,000 tons of lead and 314,000 tons of zinc per year. Red Dog's published ore reserves, including inferred, were 85 million tons grading 5.0% lead and 17.1% zinc.

Asarco operated two mine and mill complexes in the Viburnum Trend, but the refurbished Sweetwater Mine did not come on-stream until late in December. The Sweetwater Mine was the Nation's highest rated capacity lead mine at 91,000 tons per year. According to Asarco's annual report, the West Fork Mine produced at only 55% of its 50,000 tons per year of lead in concentrates capacity in 1987 owing to technical problems. As the Sweetwater and West Fork Mines work up to planned capacities, Asarco's Glover, MO, smelter-refinery will be able to operate solely with integrated, high-grade clean concentrates. Any excess resulting from Glover's supply contract with Cominco and Dresser will fulfill some of the needs of Asarco's East Helena, MT, plant. Therefore, Asarco reduced its interest in MIM Holdings Ltd. of Australia, a major lead and zinc producer, from 34.9% to 19% in the third quarter of 1987. At yearend, Asarco had lead ore reserves in Missouri of 23.1 million tons grading 4.84% at Sweetwater and 9.8 million tons grading 7.07% at West Fork.

Hecla Mining Co. reopened the Lucky Friday Mine in Idaho, normally a large lead producer, in midyear after being shut down for over a year owing to unfavorable silver prices. Production of lead was curtailed owing to startup of a new mining system in a recently developed area with reportedly lower average in situ lead grades. Pegasus Gold Inc. opened a new open pit gold-silver-zinc-lead mine in June. Known as Montana Tunnels, its anticipated capacity for lead is 5,000 tons per year.

SMELTER AND REFINERY PRODUCTION

Primary.—According to Homestake's annual report, the Doe Run smelter-refinery at Herculaneum, MO, the Nation's largest, produced just under one-half of the total domestic reported primary metal output in 1987. The plant produced about 18,000 tons more than in 1986, and operated at about 88% of its rated capacity. The Doe Run smelter-refinery at Boss, MO, did not operate during 1987, but was kept on care and maintenance. The sinter machine, however, was used while the one at the Herculaneum smelter was being rebuilt.

Asarco operated a smelter-refinery at Glover, MO, a smelter at East Helena, MT, and a refinery at Omaha, NE, that also processed secondary materials as well as the bullion from East Helena. The Glover facility contributed 33% of the Nation's 1987 primary lead production, according to Asarco's annual report, and operated well above its rated capacity for the third consecutive year owing to higher grades of raw materials feed and minimal downtime. The three U.S. primary refineries operated at only 63% of capacity in 1987, the same as in 1986, whereas the smelters were at 73% of capacity.

Secondary.—The U.S. secondary industry at yearend consisted of 20 companies, which operated 27 plants with refined metal capacities ranging from 5,000 to 80,000 tons per year and were responsible for 95% of the reported secondary production. There were also 28 small producers who operated 29 plants with annual capacities averaging 1,200 tons, which produced mainly specialty alloys for such uses as solders, brass or bronze ingots, and bearing metals. Early in the year, two plants in California and Florida with a combined annual capacity of 16,000 tons were closed. At yearend, industry installed capacity was 855,000 tons, a 55,000-ton increase from yearend 1986. Secondary capacity utilization for 1987 was a record high 83%.

Two significant mergers occurred during the year, which represented a major restructuring of integrated battery manufacturers and lead producers. Pacific Dunlop of Australia, owner of Pacific Chloride Inc., a U.S. integrated producer-manufacturer, acquired ownership of GNB Inc., also integrated, to further enhance GNB's position as the No. 2 U.S. secondary lead producer. Exide Corp., a large battery manufacturer, acquired General Battery Corp., a large integrated producer-manufacturer, thereby becoming the Nation's largest integrated battery manufacturer. Pacific Dunlop-GNB Inc. and RSR Corp., the Nation's largest secondary lead producer, each operated three smelter-refineries at yearend. Exide-General Corp., Refined Metals Corp., and Schuylkill Metals Corp. each operated two plants. These 12 plants, together with the Sanders Lead Co. smelter-refinery at Troy, AL, the world's largest secondary lead plant, accounted for nearly three-quarters of U.S. secondary lead production in 1987.

CONSUMPTION AND USES

Total domestic consumption of lead increased by 105,000 tons in 1987 compared with that of 1986, of which 100,000 tons was in the lead-acid storage battery sector, exceeding the previous record by 74,300 tons in 1978 for battery manufacturers. The battery share of total consumption also achieved a record high 78%. Most other uses increased or decreased only slightly compared with 1986 uses. Lead in all casting metals exhibited a strong comeback owing to a generally strong economy in 1987 reflected by the transportation industry, which included trucks, buses, and automobiles, as well as heavy equipment and lighter in-plant equipment. Lead for type metal, cans, tubes, and other shipping containers continued a 10-year decline as did leaded gasoline additives. Lead in power and communication cables increased for the fourth consecutive year, doubling its use in 1983 owing to the recently developed lead foil-plastic laminates supplanting other plastics.

According to statistics from the Battery Council International and Bureau of the Census, total 1987 shipments of replacement and original equipment automotive batteries, including exports, were 50,000 units greater than those shipped in 1986, less than a 0.1% increase. Export shipments increased by 667,800 units to 2,747,300 units, but domestic shipments decreased by 618,300 units, just under 1%. Total shipments of automotive batteries were 75.71 million units in 1987 compared with 75.66 million units in 1986, representing less than 500 tons of increased lead usage. There was a slight decline in lead use for industrial and traction batteries in 1987, and therefore a huge surplus of lead in the form of SLI battery inventories and materials in process (battery grids and oxides) was on hand at yearend from the excessive metal consumed. Lead demand by the industrial and traction battery sector in 1987 was estimated to be 158,700 tons.

STOCKS

Metal stocks at domestic primary refineries increased marginally, but raw material feedstocks decreased significantly, which reflected the low U.S. mine output and negligible imports for consumption of lead concentrates during 1987. Refined pig lead stocks held by secondary producers and consumers at yearend increased nominally after 3 consecutive years of decreasing owing to the high level of imports. Total yearend stocks of contained lead in all forms, excluding scrap, held by all domestic producers and consumers, was about the same as those at yearend 1986.

Stocks of lead and antimonial lead metal in the market economy countries reporting to the International Lead and Zinc Study Group (ILZSG) were approximately 412,000 tons at yearend, slightly more than 7% of 1987 total world demand, and 12,000 tons higher than stocks at yearend 1986.[2] Stocks in LME warehouses were only 16,000 tons at yearend, a decrease of 22,000 tons from those at yearend 1986, and the lowest level since 1978, when they were also at 16,000 tons.

PRICES

According to Metals Week, the North American producers U.S. price range, which had been listed at 28 to 29 cents per pound in mid-December 1986, was lowered uniformly to 27 cents in mid-January 1987 and then to 26 cents on February 3, the low level of the year. The price rose gradually from early April to 42 cents per pound on July 7, which was sustained for the remainder of the year. The spread against the LME, which was 6.9 cents per pound in January, declined during February, March, and April to a low of 2.7 cents per pound for that month. The spread then rose in each month through October, reaching a record-high 15.1 cents for the last week of that month. This resulted in almost 40% of the pig lead imports for the whole year entering in September through November. The sustained mean and quoted price of 42 cents per pound was the highest level in the U.S. since 1980 except for August of 1981 (43.9 cents). The year average for 1980 was 42.5 cents per pound on a reported transactions value-weighted basis, which is no longer available.

On the LME, the monthly average cash price fluctuated about 1 cent per pound during the first quarter of the year after dropping 2.5 cents per pound in January compared with December 1986. It rose gradually from mid-April through the third week of May, achieving the highest monthly average of the year at 31.4 cents per pound. May's average price was the highest since October 1981 (32.5 cents). This resulted in the LME physical stock level's dropping to its lowest level (10,300 tons on May 8) since February 1980, when it was 8,900 tons at monthend. Weekly average prices fluctuated between 31.4 cents per pound for the week ending July 10 and 26.8 cents per pound for the week ending October 2, 1987. The monthly average prices for the 7-month period ranged from 27.3 cents for October to 30.1 cents for July. The yearend price on December 25 was 30.3 cents per pound compared with the average of June through December of about 29 cents. The average price for the year was 27 cents per pound.

The domestic prices for lead oxides were based on the selling price plus conversion charges for pig lead in a given period. Premium adjustments were also made by individual producers to reflect differences in manufacturing techniques, freight considerations, quality and packaging requirements, or other factors. According to American Metal Market, the quoted premiums for litharge ranged from about 4.25 to 6.5 cents per pound for bags or drums in truckload lots and 10.5 to 11 cents per pound for 97% red lead. The premium for Bulk Battery (leady litharge) was about 2 cents per pound.

FOREIGN TRADE

Owing to the low domestic mine and primary metal production in the face of healthy domestic demand and prices, exports of contained lead in all forms were down from 1986 and represented the second lowest total since 1976. Raw material and metal exports were negligible, and scrap exports were down slightly. Canada, Brazil, and Taiwan received about one-half of the scrap exported, almost all of which was thought to be spent lead-acid batteries. The lead content of exported scrap was estimated to be 60%. The United States had 159,000 tons of net imports for consumption of lead in all forms, excluding chemicals, pigments, and oxides, a 69,000-ton net increase from 1986. Almost 90% of the contained lead imported was refined pig lead, three-quarters of which came from Canada and Mexico, the traditional suppliers.

Imports of chrome yellow used for highway markings and litharge, which together represented more than 80% of the lead chemicals and compounds imported for consumption, increased significantly in 1987. Total imports of all these categories remained about the same as those in 1986. Mexico accounted for almost all of the U.S. imports of litharge and red lead, and Canada supplied more than one-half of the remaining total of chemicals and compounds, including three-quarters of the chrome yellow. The Federal Republic of Germany, Hungary, and the Netherlands accounted for most of the balance of chrome yellow. The Federal Republic of Germany, Japan, and Mexico supplied virtually all of the lead acetate; the United Kingdom supplied all of the lead arsenate; China, Hong Kong and Belgium supplied 90% of the lead nitrate; and the Federal Republic of Germany and the Netherlands supplied almost 80% of the basic white lead carbonate imports. Canada, the Federal Republic of Germany, the Netherlands, and the United Kingdom accounted for 90% of the imports of all other salts, pigments, and compounds. Canada and Mexico accounted for 86% of the total U.S. imports of all lead chemicals and compounds, including oxides on a tonnage basis.

Table 2.—U.S. import duties for lead materials, January 1, 1987

(Lead content)

Item	TSUS No.	Most favored nation (MFN)	Least developed developing countries	Non-MFN
Ore	602.10	0.75 cent per pound	Free[1] or current MFN rate.	1.5 cents per pound.
Lead bullion	624.02	3.5% ad valorem	do	10.5% ad valorem.
Other unwrought	624.03	3.5% ad valorem[2]	Current MFN rate only	10.0% ad valorem.
Waste and scrap	624.04	2.3% ad valorem	Free[1] or current MFN rate.	11.5% ad valorem.

[1]Free if eligible under General System of Preferences.
[2]Established at 3.0% ad valorem (retroactive to July 1, 1983) but not to be less than 1.0625 cents per pound, on Oct. 30, 1984, by the Omnibus Trade Act.

WORLD REVIEW

According to the ILZSG statistics, consumption of soft lead and antimonial lead in the market economy countries was 4.24 million tons, compared with 4.11 million tons in 1986, 4.03 million tons in 1985, and 3.97 million tons in 1984.[3] Estimated world consumption of lead in all forms during 1987 was 5.73 million tons, compared with 5.65 million tons in 1986 (revised) and equaling the previous alltime high established in 1979. The comparable figures for 1985 and 1984 were 5.56 and 5.45 million tons, respectively (revised). Estimated world total refinery production, including that from recycled scrap, increased by nearly 50,000 tons compared with that of 1986, reflecting the increased performance of the U.S. secondary industry during 1987. The significant decrease in primary metal production in Canada because of labor-management difficulties was more than offset by the return of primary metal output in Australia to 1984 and 1985 levels. The result was the nominal increase in the total reported ILZSG metal stocks level.

Seven new lead-producing mines came onstream in 1987, which together with a major reopening in the United States and several expansions elsewhere in capacities, including China, resulted in a net capacity increase of 45,000 tons after accounting for closures and permanent reductions in output at some mines owing to declining grades or other technical reasons. The estimated yearend world capacity of 4.24 million tons per year represented a gain of 200,000 tons since 1984, the low point in world mine capacity of the decade. With the addition of a major new lead smelter in Italy and the closure of Tunisia's only smelter-refinery, estimated world lead-smelting capacity rose by 60,000 tons to 4.40 million tons per year, compared with 4.55 million tons of refinery capacity at yearend.

Australia.—The significant increase in 1987 lead mine production was primarily attributed to the return to a full year's production at Broken Hill, New South Wales, of Australia Mining & Smelting Ltd. (AM&S), and North Broken Hill Holdings Ltd. (NBHH). These mines had work stoppages due to lengthy midyear management-labor difficulties in 1986. The new Hellyer Mine in Tasmania of Aberfoyle Ltd., 46% owned by Cominco Ltd. of Canada, came onstream in midyear, treating its ore at a converted tin mill about 40 kilometers from the site. BHP Minerals Ltd. (58%)-Billiton Australia's (42%) new joint-venture mine at West Kimberly, Western Australia, began operations, and ore was stockpiled for the commissioning of the new mill scheduled for 1988. The new ore body is the first "Mississippi Valley Type" deposit to be developed in Australia, and the planned ore throughput was 320,000 tons per year. The combined capacities estimated for the two new mines was 19,500 tons per year of lead in concentrates and 68,700 tons of zinc.

Production increased slightly at Nicron Resources Ltd.'s open pit mine near Darwin in the Northern Territory, which had opened in late 1985. Accelerated underground development begun late in 1986 continued through the first half of 1987. Reserves were estimated at about 1 million tons, averaging 7.5% lead and 12.9% zinc. Production at Mount Isa Mines, Queensland, and the NBHH mines on the west coast of Tasmania and at Elura, New South Wales, remained level with those of 1986. Production declined slightly at the Woodlawn and CSA (AM&S) Mines in New South Wales. The open pit portion of the Woodlawn Mine, which was completed in May, was purchased by Denehurst Ltd. from AM&S in July. Mining continued toward an eventual target of 500,000 tons per year of ore from reserves of 2.5 million tons grading 4.8% lead and 11.8% zinc. Production at Broken Hill Associated Smelters Pty. Ltd. plant at Port Pirie, South Australia, the country's only producer of primary refined lead, increased significantly with return to normal operation following the midyear 1986 labor-management disputes. Australian lead mining capacity at yearend was estimated to be 556,000 tons per year, about 20,000 tons greater than for all of Asia, including China, but about 100,000 tons less than for the United States. Australia produced more than 150,000 tons more than the United States in 1987.

Underground development continued at Mount Isa Mines Ltd.'s Hilton silver-lead-zinc deposit 20 kilometers north of Mount Isa, Queensland. Trial stoping began in June at the rate of 2,000 tons per week. It was anticipated that a commercial mining operation based on the integration of Hilton ore into the Mount Isa Mine's declining output will start in the late 1980's, keeping MIM's output level. Proven reserves at Hilton were 11 million tons of ore grading 6.7% lead and 9.1% zinc. Probable reserves were estimated to be an additional 38 million tons of 6.4% lead and 9.3% zinc with considerable further potential in the immediate area. The Pancontinental Mining Ltd. (51%)-Outokumpu Oy of Finland (49%) joint venture completed exploratory shaft sinking at their Lady Loretta, Queensland, project begun in 1986 and continued with exploratory development, test mining, drilling, and bulk sampling. The Pancontinental-Outokumpu joint venture agreed to purchase BHP Minerals Ltd.'s interest in the Thalanga base-and-precious-metals deposit near Charters Towers in northern Queensland. It also obtained an option to buy the remaining 11% interest held by Electrolytic Zinc Co. of Australia, which would give it full ownership. The joint venture had acquired its initial 50% interest in June from Peñarroya (Australia) Pty. Ltd. The prospect has ore reserves of 7.8 million tons grading 2.7% lead, 8.7% zinc, 2.2% copper, 71 grams of silver, and 0.47 gram of gold per ton. Mining leases have been secured, and an operating pilot plant is on-site. A feasibility study was to extend through 1988 for consideration of a possible open pit and underground operation.

Austria.—The nation's only primary smelter-refinery at Gailitz, owned by Bleiberger Bergwerks-Union AG, expanded capacity by 7,000 tons per year to 24,000 tons and replaced the conventional refinery with a matching 24,000-ton-per-year electrolytic plant.

Brazil.—Cia. Paulista de Metais acquired the lead-producing Boquira Mine and Plumbum Mine in Bahia and Paraná, respectively, from Peñarroya at a cost of $18 million and was expected to raise its total lead production by 8,000 tons in 1988 to 40,000 tons per year. The new group will be called Sociedad Paulisto de Metais. The Morro Agudo Mine owned by Mineração Morro Agudo S.A., a joint venture of Cia. Mineira Metais and Paraibuna de Metais of Paracatu, Minas Gerais, opened in December with a capacity of 6,500 tons per year of lead. Cia. Paulista de Metais was expanding its primary smelter in Panelas to match the capacity of the mines acquired from Peñarroya.

Canada.—Mine production of lead increased significantly in 1987 owing to accelerated ore production at Pine Point Mines Ltd.'s (50% owned by Cominco Ltd.) mine in the Northwest Territories prior to its midyear closing. Milling was to continue through mid-1988 from the stockpiled ore with concentrate shipments to continue through 1990 to Cominco's smelter at Trail, British Columbia. Construction of the modern QSL bath-type autogeneous replacement plant continued on schedule during the year at Trail, and production was expected to start in mid-1989. The metallurgical complex at Trail was shut down for 17 weeks because of a strike. Cominco's Sullivan Mine at Kimberly, British Columbia, the other feeder for Trail, was also shut down. As a result, Canadian production of refined metal declined by more than 30,000 tons compared with 1986 production.

Curragh Resources Corp.'s large open pit Faro Mine in the Yukon Territory reached planned capacity in 1987, and development work was started at the nearby Grum and Vangorda deposits, which were planned to be gradually phased in as production from Faro declines. Giant Resources Ltd., the natural resource subsidiary of Ariadne Australia Ltd., purchased a 46% interest in the Faro Mine, equal to Curragh's share. Boliden AB of Sweden owns the remaining 8% share. East-West Minerals NL of Australia acquired the Caribou property of Anaconda Minerals Co. in New Brunswick and continued development work toward a summer 1988 startup. The open pit mine will reportedly produce about 120,000 tons per year of a bulk lead-zinc concentrate containing 15,000 tons of lead in 1989. Metallgesellschaft AG of the Federal Republic of Germany incorporated its foreign mining interests in Canada during the year as Metall Mining Corp. Ltd. Some of its assets included interests in Cominco, MIM, and Teck Corp., which are major lead and zinc producers. Canadian lead mining capacity at yearend was estimated to be about 360,000 tons per year.

Honduras.—American Pacific Holdings purchased the El Mochito Mine from AMAX Inc. in October and resumed production in November after being shut down since the end of April.

Italy.—Nuova Samim (SAMIM) brought its new primary bath smelter, a Soviet technology Kivcet design, on-stream at Porto Vesme, Sardinia, with a lead capacity of 84,000 tons per year. The plant replaced an older ISF plant that had 14,000 tons per year less capacity. Société Italiana Minière (SIM) expanded an existing mine and brought on a new mine and mill at Monteponi, Sardinia, with a combined additional lead capacity of 13,000 tons per year. SIM was split from SAMIM to primarily control mining activity in the lead-zinc sector.

Japan.—Three lead-zinc mines representing 12,000 tons of lead per year, or about 30% of the nation's primary lead capacity, were shut down during the year in Miyagi, Fukui, and Akita.

Spain.—Boliden AB of Sweden acquired Andaluza de Piritas S.A. (APIRSA) from the Banco Central. APIRSA was the operator of the Aznacollar open pit mine in Sevilla, which has a capacity of 25,000 tons of lead per year, plus 40,000 tons of zinc, 12,000 tons of copper, and 60,000 tons of silver. Reportedly, it had become unprofitable in recent years. Two new lead-zinc-silver deposits in Cuidad Real and León were under study by Minas de Almaden y Arrayanes S.A. and Peñarroya S.A. with Empresa Nacional Adaro de Investigación Mineras S.A. (Enadimsa), respectively, reportedly to come on-stream in 1990 with an additional 28,000 tons of lead capacity.

Tunisia.—At Megrine, the only primary lead smelter-refinery, with a capacity of 30,000 tons per year, was closed in January.

Yugoslavia.—A new underground mine at Toranica operated by SOUR Zletovo-Sasa came on-stream with an initial lead capacity of 10,000 tons per year. Full capacity of 17,000 tons per year was scheduled to be reached in 1992. The Suplja Stijena Mine at Gradac, Montenegro, with an estimated lead capacity of 6,000 tons per year and one of 13 mines operated by SOUR Trepca, was closed.

TECHNOLOGY

A prototype, customer-side-of-the-meter, load-leveling system utilizing lead-acid batteries was established at Johnson Controls Inc.'s Milwaukee, WI, battery manufacturing plant. The new system, the first operating commercial-scale project of the concept in the United States, was to undergo extensive testing and modifications during 1988, including trials with zinc bromine and hydrogen-nickel oxide batteries. The "Advanced Load Management System" operates at 600 volts and has a capacity of 600 kilowatt hours, estimated to be sufficient to operate a typical home for 30 days or 300 homes for 2 hours taking advantage of time-of-use electricity rates. The prototype system was installed with 300 lead-acid, deep-discharge, stationary batteries modified for load management requirements and integrated with advanced digital controls and computerized analysis equipment. The system uses load profile simulations and energy management concepts as a means to develop the technology to anticipate and respond to peak demands for electricity.[4]

A comprehensive coverage of lead-related investigations and an extensive review of current world literature on the extraction and uses of lead and its products, including batteries, were published in quarterly issues of Leadscan, Lead Development Association, London, United Kingdom.

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[1]Physical scientist, Branch of Nonferrous Metals.
[2]International Lead and Zinc Study Group (London). Lead and Zinc Statistics. ILZSG Mon. Bull., v. 28, No. 10, Oct. 1988, pp. 17-18; v. 29, No. 11, Nov. 1988, pp. 17-18.
[3]Work cited in footnote 2.
[4]Advanced Battery Technology. V. 24, No. 1, Jan. 1988, pp. 4-5.

Table 3.—Mine production of recoverable lead in the United States, by State

(Metric tons)

State	1983	1984	1985	1986	1987
Alaska	W	--	--	--	--
Arizona	234	W	581	W	--
California	W	W	--	--	--
Colorado	W	W	W	W	W
Idaho	25,893	W	33,707	9,951	W
Illinois	W	W	W	W	W
Missouri	409,280	278,329	371,008	319,900	W
Montana	1,163	W	846	W	W
Nevada	14	W	([1])	--	--
New Mexico	258	--	W	10	W
New York	1,299	W	W	W	W
Oregon	W	--	--	--	--
Tennessee	--	W	W	--	W
Utah	--	W	--	--	--
Washington	--	--	--	--	--
Total	449,295	322,677	413,955	339,793	311,298

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1]Less than 1/2 unit.

Table 4.—Mine production of recoverable lead in the United States, by month

(Metric tons)

Month	1986	1987
January	40,392	24,194
February	36,277	23,910
March	38,216	27,859
April	33,984	23,628
May	25,038	26,957
June	23,763	26,302
July	25,168	29,022
August	23,420	24,114
September	24,186	28,178
October	24,301	28,447
November	20,800	23,195
December	24,248	25,492
Total	339,793	311,298

Table 5.—Production of lead and zinc, in terms of recoverable metal, in the United States in 1987, by State

(Metric tons)

State	Lead ore			Zinc ore			Lead-zinc ore		
	Gross weight (dry basis)	Lead	Zinc	Gross weight (dry basis)	Lead	Zinc	Gross weight (dry basis)	Lead	Zinc
Colorado	--	--	--	--	--	--	W	W	W
Idaho	--	--	--	--	--	--	--	--	--
Illinois	--	--	--	--	--	--	--	--	--
Kentucky	--	--	--	109	--	10	--	--	--
Missouri	W	W	W	--	--	--	W	W	W
Montana	--	--	--	--	--	--	--	--	--
New Mexico	--	--	--	--	--	--	--	--	--
New York	--	--	--	W	W	W	--	--	--
Tennessee	--	--	--	W	W	W	--	--	--
Total	W	W	W	4,702,226	W	153,384	1,405,635	W	W
Percent of total lead or zinc	XX	W	W	XX	W	71	XX	W	W

State	Copper-lead, copper-zinc, copper-lead-zinc ores			All other sources[1] [2]			Total		
	Gross weight (dry basis)	Lead	Zinc	Gross weight (dry basis)	Lead	Zinc	Gross weight (dry basis)	Lead	Zinc
Colorado	--	--	--	W	W	W	W	W	W
Idaho	--	--	--	W	W	W	W	W	W
Illinois	--	--	--	W	W	W	W	W	W
Kentucky	--	--	--	--	--	--	109	--	10
Missouri	1,020,071	32,404	604	--	--	--	W	W	34,956
Montana	--	--	--	W	W	W	W	W	W
New Mexico	--	--	--	W	W	--	W	W	--
New York	--	--	--	--	--	--	W	W	W
Tennessee	W	--	W	--	--	--	5,291,664	W	115,699
Total	W	32,404	W	W	13,911	15,984	13,225,706	311,298	216,981
Percent of total lead or zinc	XX	10	W	XX	4	7	XX	100	100

W Withheld to avoid disclosing company proprietary data; included in "Total." XX Not applicable.
[1]Includes lead and zinc recovered from copper, gold, gold-silver, and silver ores, from fluorspar and from mill tailings.
[2]Excludes tonnages of fluorspar in Illinois from which lead and zinc were recovered as byproducts.

Table 6.—Twenty-five leading lead-producing mines in the United States in 1987, in order of output

Rank	Mine	County and State	Operator	Source of lead
1	Buick	Iron, MO	The Doe Run Co	Lead-zinc ore.
2	Magmont	do	Cominco American Incorporated	Lead ore.
3	Viburnum No. 29	Washington, MO	The Doe Run Co	Do.
4	Casteel	Iron, MO	do	Copper-lead ore.
5	West Fork	Reynolds, MO	ASARCO Incorporated	Lead ore.
6	Fletcher	do	The Doe Run Co	Do.
7	Viburnum No. 28	Iron, MO	do	Do.
8	Leadville Unit	Lake, CO	ASARCO Incorporated	Lead-zinc ore.
9	Sunnyside	San Juan, CO	Sunnyside Gold Corp	Gold ore.
10	Lucky Friday	Shoshone, ID	Hecla Mining Co	Silver ore.
11	Montana Tunnels	Jefferson, MT	Montana Tunnels Mining Inc.	Gold ore.
12	Balmat	St. Lawrence, NY	Zinc Corporation of America	Zinc ore.
13	Sweetwater	Reynolds, MO	ASARCO Incorparated	Lead ore.
14	Black Pine	Granite, MT	Black Pine Mining Co	Silver ore.
15	Rosiclare	Hardin and Pope, IL	Ozark-Mahoning Co	Fluorspar.
16	Pierrepont	St. Lawrence, NY	Zinc Corporation of America	Zinc ore.
17	St. Cloud	Sierra, NM	St. Cloud Mining Co	Gold-silver ore.
18	Clayton	Custer, ID	Clayton Silver Mines	Silver ore.
19	New Market	Jefferson, TN	ASARCO Incorported	Zinc ore.
20	Young Mill	do	do	Do.
21	Immel	Knox, TN	do	Do.
22	Coy	Jefferson, TN	do	Do.
23	Silver King	Granite, MT	Stryker's Gold	Gold ore.
24	Pinos Altos	Grant, NM	Cyprus Minerals Co	Copper ore.
25	Cross	Boulder, CO	Hendricks Mining Co. Inc	Gold ore.

Table 7.—Refined lead produced at primary refineries in the United States, by source material[1]

(Metric tons unless otherwise specified)

Source material	1983[r]	1984[r]	1985[r]	1986[r]	1987
Refined lead:					
From primary sources:					
Domestic ores and base bullion	463,940	323,989	422,650	348,217	336,471
Foreign ores and base bullion	55,227	65,409	71,353	22,071	37,139
Total	519,167	389,398	494,003	370,288	373,610
Calculated value of primary refined lead[2] thousands	$248,142	$219,340	$207,689	$180,004	$296,026

[r]Revised.
[1]Total refined lead: American Bureau of Metal Statistics Inc. (ABMS). Domestic and foreign ores: Bureau of Mines calculations.
[2]Value based on average quoted price.

Table 8.—Stocks and consumption of new and old lead scrap in the United States, by type of scrap

(Metric tons, gross weight)

Type of scrap	Stocks, Jan. 1	Receipts	Consumption			Stocks, Dec. 31
			New scrap	Old scrap	Total	
1986						
Smelters, refiners, others:						
Soft lead[1]	1,476	27,729	--	28,017	28,017	1,188
Hard lead	694	8,572	--	9,052	9,052	214
Cable lead	620	2,243	--	2,398	2,398	465
Battery-lead plates	26,811	[r]689,723	--	[r]695,032	[r]695,032	21,502
Mixed common babbitt	298	1,241	--	1,406	1,406	133
Solder and tinny lead	2,856	22,718	--	23,179	23,179	2,395
Type metals	510	2,305	--	2,634	2,634	181
Drosses and residues	9,026	62,370	66,024	--	66,024	5,372
Total	42,291	[r]816,901	66,024	[r]761,718	[r]827,742	31,450
1987						
Smelters, refiners, others:						
Soft lead[1]	1,188	31,910	--	31,243	31,243	1,855
Hard lead	214	5,249	--	4,896	4,896	567
Cable lead	465	2,054	--	1,665	1,665	854
Battery-lead plates	21,502	799,442	--	792,360	792,360	28,584
Mixed common babbitt	133	1,593	--	1,631	1,631	95
Solder and tinny lead	2,395	21,908	--	22,527	22,527	1,776
Type metals	181	1,902	--	1,911	1,911	172
Drosses and residues	5,372	68,407	68,586	--	68,586	5,193
Total	31,450	932,465	68,586	856,233	924,819	39,096

[r]Revised.
[1]Includes remelt lead from cable sheathing plus other soft lead scrap processing.

Table 9.—Secondary metal recovered[1] from lead and tin scrap in the United States

(Metric tons)

	Lead	Tin	Antimony	Other	Total
1986					
Refined pig lead	[r]269,526	--	--	--	[r]269,526
Remelt lead	20,020	--	--	--	20,020
Total	[r]289,546	--	--	--	[r]289,546
Refined pig tin[2]	--	[r]1,140	--	--	[r]1,140
Lead and tin alloys:					
Antimonial lead	[r]291,943	891	9,950	621	[r]303,405
Lead-base babbitt	1,091	66	108	3	1,268
Solder	24,059	3,676	181	15	27,931
Type metals	1,369	197	210	2	1,778
Other alloys including cable lead	2,796	17	2	--	2,815
Total	[r]321,258	4,847	10,451	641	[r]337,197

See footnotes at end of table.

Table 9.—Secondary metal recovered[1] from lead and tin scrap in the United States —Continued

(Metric tons)

	Lead	Tin	Antimony	Other	Total
1986 —Continued					
Tin content of chemical products	--	W	--	--	W
Grand total	r610,804	r5,987	10,451	641	r627,883
1987					
Refined pig lead	334,844	--	--	--	334,844
Remelt lead	14,065	--	--	--	14,065
Total	348,909	--	--	--	348,909
Refined pig tin[2]	--	1,159	--	--	1,159
Lead and tin alloys:					
Antimonial lead	319,474	623	11,205	756	332,058
Lead-base babbitt	1,132	77	129	2	1,340
Solder	23,152	3,765	171	(3)	27,088
Type metals	919	66	130	4	1,119
Other alloys including cable lead	2,229	30	19	--	2,278
Total	346,906	4,561	11,654	762	363,883
Tin content of chemical products	--	W	--	--	W
Grand total	695,815	5,720	11,654	762	713,951

rRevised. W Withheld to avoid disclosing company proprietary data.
[1]Most of the figures herein represent actual reported recovery of metal from scrap.
[2]Includes remelt tin.
[3]Included with "Antimony" to avoid disclosing company proprietary data.

Table 10.—Lead recovered from scrap processed in the United States, by kind of scrap and form of recovery

(Metric tons)

	1986r	1987
KIND OF SCRAP		
New scrap:		
Lead-base	45,854	49,035
Copper-base	3,639	3,478
Tin-base	5	38
Total	49,498	52,551
Old scrap:		
Battery-lead plates	504,629	588,705
All other lead-base	60,284	57,947
Copper-base	10,358	11,014
Tin-base	--	--
Total	575,271	657,666
Grand total	624,769	710,217
FORM OF RECOVERY		
As soft lead	289,546	348,909
In antimonial lead	291,943	319,474
In other lead alloys	29,278	27,304
In copper-base alloys	13,997	14,492
In tin-base alloys	5	38
Total	624,769	710,217
Value[1] thousands	$303,712	$562,734

rRevised.
[1]Value based on average quoted price of common lead.

Table 11.—U.S. consumption of lead, by product

(Metric tons)

SIC code	Product	1986	1987
	Metal products:		
3482	Ammunition: Shot and bullets	44,382	46,835
	Bearing metals:		
35	Machinery except electrical	581	393
36	Electrical and electronic equipment	268	173
371	Motor vehicles and equipment	3,787	4,362
37	Other transportation equipment	889	334
	Total	5,525	5,262
3351	Brass and bronze: Billets and ingots	r9,057	9,868
36	Cable covering: Power and communication	17,061	20,140
15	Calking lead: Building construction	1,833	1,893
	Casting metals:		
36	Electrical machinery and equipment	1,198	970
371	Motor vehicles and equipment	1,357	(1)
37	Other transportation and equipment	6,790	14,299
3443	Nuclear radiation shielding	923	1,285
	Total	10,268	16,554
	Pipes, traps, other extruded products:		
15	Building construction	11,900	11,532
3443	Storage tanks, process vessels, etc	642	(2)
	Total	12,542	11,532
	Sheet lead:		
15	Building construction	12,572	13,746
3443	Storage tanks, process vessels, etc	2,038	(3)
3693	Medical radiation shielding	2,665	3,654
	Total	17,275	17,400
	Solder:		
15	Building construction	4,513	3,946
341	Metal cans and shipping containers	2,048	1,027
367	Electronic components and accessories	4,333	4,654
36	Other electrical machinery and equipment	2,196	2,658
371	Motor vehicles and equipment	8,212	7,473
	Total	21,302	19,758
	Storage batteries:		
3691	Storage battery grids, post, etc	488,932	529,362
3691	Storage battery oxides	364,878	424,236
	Total	853,810	953,598
371	Terne metal: Motor vehicles and equipment	3,497	2,286
27	Type metal: Printing and allied industries	306	(4)
34	Other metal products[5]	3,678	4,844
	Total	r1,000,536	1,109,970
	Other oxides:		
285	Paints	14,400	W
32	Glass and ceramic products	40,781	W
28	Other pigments and chemicals	14,346	W
	Total	69,527	68,094
2911	Gasoline additives	28,541	(6)
	Miscellaneous uses	26,917	52,323
	Grand total	r1,125,521	1,230,387

rRevised. W Withheld to avoid disclosing company proprietary data; included with "Other oxides: Total."
[1]Included with "Other transportation and equipment" to avoid disclosing company proprietary data.
[2]Included with "Building construction" to avoid disclosing company proprietary data.
[3]Included with "Building construction" to avoid diclosing company proprietary data.
[4]Included with "Other metal products" to avoid disclosing company proprietary data.
[5]Includes lead consumed in foil, collapsible tubes, annealing, galvanizing, plating, and fishing weights.
[6]Included with "Miscellaneous uses" to avoid disclosing company proprietary data.

Table 12.—U.S. consumption of lead, by month[1]

(Metric tons)

Month	1986[r]	1987
January	100,805	96,519
February	89,000	91,069
March	82,969	103,012
April	94,685	100,969
May	89,785	101,368
June	87,715	103,460
July	73,831	97,364
August	98,875	103,165
September	105,902	108,514
October	110,464	119,087
November	94,860	105,799
December	96,630	100,061
Total[2]	1,125,521	1,230,387

[r]Revised.
[1]Monthly totals include monthly reported consumption plus the prorated monthly distribution for companies that report on an annual basis only.
[2]Includes lead that went directly from scrap to fabricated products and lead contained in leaded zinc oxide.

Table 13.—U.S. consumption of lead in 1987, by State[1]

(Metric tons)

State	Refined soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
California	53,675	39,110	9,641	--	102,426
Connecticut	3,767	3,237	--	16	7,020
Florida	10,291	7,852	1,070	--	19,213
Georgia	23,841	8,767	2,516	--	35,124
Illinois	27,330	41,054	2,722	866	71,972
Indiana	221,045	33,720	11,921	606	267,292
Kansas	14,912	6,895	8,423	--	30,230
Kentucky	10,112	13,137	1,280	--	24,529
Massachusetts	785	133	46	54	1,018
Michigan	14,110	12,733	494	--	27,337
Missouri	10,599	19,798	--	--	30,397
New Jersey	45,883	203	1,669	236	47,991
New York	16,716	5,918	11,399	--	34,033
Ohio	15,027	15,104	4,110	209	34,450
Pennsylvania	105,999	33,079	30,922	1,451	171,451
Tennessee	1,365	10,140	2,306	--	13,811
Alabama and Mississippi	12,749	4,212	2,895	2,513	22,369
Arkansas and Oklahoma	1,365	359	74	--	1,798
Colorado and Nebraska	293	32	187	543	1,055
District of Columbia and Maryland	92	--	--	--	92
Hawaii and Oregon	4,039	8,595	938	--	13,572
Idaho, Montana, and Washington	12,114	970	--	--	13,084
Iowa and Minnesota	20,118	23,084	7,922	--	51,124
Louisiana and Texas	77,239	19,323	5,422	--	101,984
New Hampshire, Maine, Vermont, Delaware	13,370	14,917	--	19	28,306
North Carolina and South Carolina	37,332	24,209	7,809	--	69,350
Rhode Island and Wisconsin	3,650	296	32	43	4,021
Utah, Nevada, Arizona	1,370	153	1,333	--	2,856
Virginia and West Virginia	43	382	2,057	--	2,482
Total	759,231	347,412	117,188	6,556	1,230,387

[1]Includes lead that went directly from scrap to fabricated products and lead contained in leaded zinc oxide.

Table 14.—U.S. consumption of lead in 1987, by class of product[1]

(Metric tons)

Product	Soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
Metal products	64,108	59,375	26,333	6,556	156,372
Storage batteries	581,376	287,024	85,198	--	953,598
Other oxides	68,079	15	--	--	68,094
Gasoline additives	W	--	--	--	W
Miscellaneous	45,668	998	5,657	--	52,323
Total	759,231	347,412	117,188	6,556	1,230,387

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous."
[1]Includes lead that went directly from scrap to fabricated products and lead contained in leaded zinc oxide.

Table 15.—Production and shipments of lead pigments[1] and oxides in the United States

(Metric tons unless otherwise specified)

Product	1986				1987			
	Production		Shipments		Production		Shipments	
	Gross weight	Lead content	Quantity	Value[2]	Gross weight	Lead content	Quantity	Value[2]
White lead, dry	470	376	587	$794,640	W	W	W	W
Litharge and red lead	72,810	67,507	70,836	55,556,500	79,252	73,414	80,568	$72,292,620
Leady oxide	376,382	357,564	NA	NA	436,688	414,855	NA	NA
Total	449,662	425,447	NA	NA	515,940	488,269	NA	NA

NA Not available. W Withheld to avoid disclosing company proprietary data.
[1]Excludes basic lead sulfate; withheld to avoid disclosing company proprietary data.
[2]At plant, exclusive of container.

Table 16.—U.S. imports for consumption of lead pigments and compounds, by kind

Kind	1986		1987	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
White lead	540	$598	644	$939
Red lead	534	257	703	626
Litharge	11,270	4,810	14,263	10,290
Chrome yellow	1,934	3,061	3,354	5,573
Other lead pigments	r674	1,551	445	1,286
Other lead compounds	2,181	2,655	1,804	2,431
Total	r17,133	12,932	21,213	21,145

r Revised.

Source: Bureau of the Census.

Table 17.—Stocks of lead at consumers and secondary smelters in the United States, December 31

(Metric tons, lead content)

Year	Refined soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
1983	57,881	37,159	5,085	646	100,771
1984	53,802	37,015	5,326	934	97,077
1985	50,475	36,374	5,770	511	93,130
1986	47,589	30,442	5,524	269	83,824
1987	55,278	27,959	5,185	164	88,586

Table 18.—Average monthly and annual quoted prices of lead[1]

(Cents per pound)

Month	1986		1987	
	U.S. producer	London Metal Exchange	North American primary producer mean	London Metal Exchange
January	18.35	16.69	27.88	21.02
February	17.79	16.64	26.04	20.86
March	18.20	16.64	26.00	22.07
April	18.73	16.74	27.84	25.17
May	19.38	17.06	34.95	31.40
June	22.07	18.96	36.93	28.51
July	21.94	17.21	41.67	30.06
August	22.42	17.77	42.00	29.88
September	23.43	18.45	42.00	29.31
October	[2]25.55	19.69	42.00	27.25
November	[2]28.01	21.45	42.00	29.10
December	[2]28.68	23.48	42.00	29.86
Average	22.05	18.43	35.94	26.99

[1]Metals Week. Quotations for the United States on a nationwide, delivered basis. LME cash average.
[2]U.S. producer price through Sept. 1986. North American Mean (NAM) quotation (weighted) from October.

Table 19.—U.S. exports of lead, by country

Country	1986		1987	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Ore and concentrates (lead content):				
Australia	182	$68	187	$100
Belgium-Luxembourg	5	5	36	16
Canada	693	208	793	240
Germany, Federal Republic of	308	237	--	--
India	14	14	8	5
Japan	--	--	1,800	958
Mexico	3,146	942	5,326	1,597
Mozambique	--	--	90	83
Taiwan	24	12	466	291
Venezuela	--	--	18	10
Other	r8	r5	40	33
Total	4,380	1,491	8,764	3,333
Drosses and residues including flue dust (lead content):				
Austria	--	--	40	46
Belgium-Luxembourg	218	1,504	54	620
Canada	6,088	1,794	2,642	874
India	31	9	--	--
France	49	296	18	200
Germany, Federal Republic of	--	--	35	18
Mexico	11	4	11	4
Thailand	73	12	151	54
United Kingdom	707	1,253	519	773
Total	7,177	4,872	3,470	2,589
Unwrought lead and lead alloys (lead content):				
Australia	37	55	73	78
Belgium-Luxembourg	415	2,681	55	207
Brazil	1,993	392	--	--
Canada	3,225	2,058	526	706
Chile	164	173	76	98
China	84	94	--	--
Dominican Republic	148	90	111	122
Egypt	33	64	--	--
Germany, Federal Republic of	842	1,058	2	4
Haiti	38	25	--	--
Honduras	2	3	20	19
India	243	54	--	--
Indonesia	1	2	17	17
Israel	51	23	15	12
Italy	22	37	7	13
Japan	14	51	69	80
Korea, Republic of	466	407	1,267	1,166
Liberia	20	10	18	16

See footnotes at end of table.

Table 19.—U.S. exports of lead, by country —Continued

Country	1986 Quantity (metric tons)	1986 Value (thousands)	1987 Quantity (metric tons)	1987 Value (thousands)
Unwrought lead and lead alloys (lead content) —Continued				
Malaysia	35	$234	--	--
Mexico	1,194	569	347	$694
Netherlands	19	264	--	--
Panama	--	--	17	39
Philippines	--	--	25	59
Saudi Arabia	5	12	--	--
Singapore	1	3	83	117
South Africa, Republic of	3	15	16	86
Sudan	79	54	--	--
Taiwan	1,917	862	959	737
Trinidad	--	--	451	363
United Kingdom	80	84	146	138
Venezuela	2	7	4	15
Other	[r]57	[r]201	47	136
Total	11,190	9,582	4,351	4,922
Wrought lead and lead alloys (lead content):				
Argentina	--	--	11	13
Australia	3	28	18	41
Barbados	8	58	--	--
Belgium-Luxembourg	2	75	1	6
Brazil	16	24	2	17
Canada	211	163	4,374	3,413
Dominican Republic	9	8	34	46
France	20	29	62	115
Germany, Federal Republic of	8	23	4	64
Honduras	7	18	6	18
Hong Kong	5	14	1	29
Ireland	18	25	6	8
Israel	9	49	16	73
Italy	(1)	2	6	7
Jamaica	27	39	77	98
Japan	111	286	48	49
Korea, Republic of	15	75	2	6
Mexico	834	3,065	1,005	2,643
Netherlands	1	14	18	19
Panama	11	23	8	14
Philippines	2	4	(1)	2
Saudi Arabia	(1)	5	1	12
Singapore	20	35	3	25
Spain	22	34	--	--
Taiwan	6	36	8	36
United Kingdom	8	17	8	21
Venezuela	15	68	13	21
Other	[r]23	[r]198	33	227
Total	1,411	4,415	5,765	7,023
Grand total	24,158	20,360	22,350	17,867
Scrap (gross weight):				
Austria	--	--	183	40
Belgium-Luxembourg	29	99	659	110
Brazil	16,137	4,008	7,289	2,183
Canada	2,640	762	9,337	2,903
Colombia	--	--	451	87
Germany, Federal Republic of	770	333	1,469	431
India	1,423	813	617	184
Ireland	644	193	--	--
Italy	20	17	41	9
Japan	625	409	82	196
Korea, Republic of	5,570	1,521	4,507	1,032
Mexico	2,529	430	5,667	1,360
Netherlands	485	314	125	56
Pakistan	--	--	263	69
Portugal	99	28	--	--
South Africa, Republic of	--	--	204	45
Spain	14	2	1,268	225
Taiwan	21,688	2,914	8,953	1,669
Thailand	179	51	--	--
United Arab Emirates	--	--	800	205
United Kingdom	3,025	2,075	5,618	3,832
Venezuela	3,051	918	5,260	1,025
Other	[r]70	[r]34	30	9
Total	58,998	14,921	52,823	15,670

[r]Revised.
[1]Less than 1/2 unit.

Source: Bureau of the Census.

Table 20.—U.S. exports of lead[1]

Year	Blocks, pigs, anodes, etc.				Wrought lead and lead alloys				Scrap (gross weight)		Drosses, etc.	
	Unwrought[2]		Unwrought alloys		Sheets, plates, rods, other forms		Foil, powder, flakes					
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1985	23,468	$14,050	1,912	$2,150	1,870	$4,635	94	142	59,949	$12,963	9,978	$5,732
1986	8,869	6,036	2,321	3,546	1,200	4,183	211	232	58,998	14,921	7,177	4,872
1987	3,367	3,181	984	1,741	5,686	6,910	79	113	52,823	15,670	3,470	2,589

[1]Lead content, unless otherwise specified.
[2]Includes bullion.

Source: Bureau of the Census.

Table 21.—U.S. imports[1] of lead, by country

(Lead content)

Country	1985		1986		1987	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Ore and concentrates:[2]						
Australia	12,260	$2,407	11,497	$2,246	1,724	$456
Canada	5,195	1,246	62,900	7,325	201,165	50,683
Chile	765	106	3,106	914	3,231	985
China	--	--	--	--	3,568	2,203
Honduras	1,568	757	--	--	--	--
Mexico	4,321	1,356	827	287	1,070	628
Peru	15,176	4,017	8,417	1,174	19,098	10,309
South Africa, Republic of	3,381	1,316	--	--	--	--
Total	[3]42,665	11,205	86,747	11,946	229,856	65,264
Base bullion:						
Belgium-Luxembourg	--	--	--	--	1,414	955
Canada	713	375	121	67	--	--
France	--	--	--	--	1,699	1,136
Germany, Federal Republic of	--	--	--	--	350	258
Italy	--	--	--	--	1,250	904
Japan	--	--	--	--	1,800	1,165
Mexico	48	23	21	47	881	278
Netherlands	--	--	--	--	1,749	1,276
Spain	--	--	--	--	1,200	886
United Kingdom	--	--	--	--	401	284
Other	--	--	--	--	83	97
Total	[3]760	398	142	114	10,827	7,239
Pigs and bars:						
Australia	3,627	1,758	--	--	63	37
Belgium-Luxembourg	15	13	r ([4])	r1	4,950	3,299
Canada	90,056	33,783	105,281	44,080	92,643	61,384
China	--	--	77	31	574	357
France	20	9	--	--	3,193	2,102
Germany, Federal Republic of	542	3,080	496	658	8,824	5,755
Italy	--	--	--	--	1,800	1,232
Japan	--	--	1	2	906	704
Macao	--	--	--	--	403	298
Mexico	33,771	13,271	29,532	11,617	42,635	28,457
Morocco	--	--	--	--	1,500	1,001
Mozambique	--	--	--	--	87	66
Netherlands	10	23	--	--	6,317	3,939
Panama	--	--	47	19	--	--
Peru	5,150	1,770	1,053	449	350	189
Poland	--	--	--	--	2,500	1,535
Spain	--	--	--	--	5,999	3,887
Sweden	--	--	2,773	1,055	9,086	5,887
Switzerland	--	--	20	11	201	141
U.S.S.R	--	--	262	96	--	--
United Kingdom	337	807	679	1,153	4,039	3,180
Yugoslavia	--	--	--	--	1,020	634
Zambia	--	--	--	--	903	612
Other	--	--	r ([5])	r ([5])	83	146
Total	[3]133,529	54,514	140,221	59,172	188,076	124,842

See footnotes at end of table.

Table 21.—U.S. imports[1] of lead, by country —Continued

(Lead content)

Country	1985		1986		1987	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Reclaimed scrap, including drosses:[6]						
Canada	1,118	$454	1,444	$383	3,062	$1,600
Hong Kong	--	--	--	--	48	31
Japan	--	--	--	--	323	185
Malaysia	--	--	--	--	38	23
Mexico	2,035	720	1,831	1,060	3,034	1,230
Panama	--	--	--	--	44	23
Philippines	--	--	--	--	17	10
Other	15	34	15	28	21	26
Total	3,168	1,208	3,290	1,471	6,587	3,128
Grand total	180,122	67,325	230,400	72,703	435,346	200,473

[r]Revised.
[1]General imports include lead imported for immediate consumption plus material entering the country under bond.
[2]Also includes other lead-bearing materials containing greater than 5 troy ounces of gold per short ton or greater than 100 troy ounces of total precious metals per short ton.
[3]Data do not add to total shown because of independent rounding.
[4]Less than 1/2 unit.
[5]Revised to zero.
[6]Also includes other lead-bearing materials containing greater than 10% by weight of copper, lead, or zinc (any one).

Source: Bureau of the Census.

Table 22.—U.S. imports for consumption of lead, by country

Country	1985		1986		1987	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Ore and concentrates (lead content):[1]						
Australia	--	--	1,725	$380	--	--
Canada	--	--	--	--	696	$231
Chile	765	$106	2,052	677	--	--
Honduras	1,568	757	--	--	--	--
Mexico	317	116	827	287	177	77
Total[2]	2,649	979	4,604	1,344	873	308
Base bullion (lead content):						
Belgium-Luxembourg	--	--	--	--	1,414	955
Canada	713	375	121	67	--	--
France	--	--	--	--	1,699	1,136
Germany, Federal Republic of	--	--	--	--	350	258
Italy	--	--	--	--	1,250	904
Japan	--	--	--	--	1,800	1,165
Mexico	48	23	21	47	881	278
Netherlands	--	--	--	--	1,749	1,276
Spain	--	--	--	--	1,200	886
United Kingdom	--	--	--	--	401	284
Other	--	--	--	--	83	97
Total[2]	760	398	142	114	10,827	7,239
Pigs and bars (lead content):						
Australia	91	443	--	--	63	37
Belgium-Luxembourg	15	14	--	--	4,950	3,299
Canada	90,056	33,783	105,281	44,080	92,643	61,384
China	--	--	77	31	574	357
France	20	9	--	--	3,193	2,102
Germany, Federal Republic of	542	3,080	496	658	7,325	4,682
India	1,361	664	--	--	--	--
Italy	--	--	--	--	1,800	1,232
Japan	--	--	1	2	906	704
Macao	--	--	--	--	403	298
Mexico	33,771	13,271	29,532	11,617	42,635	28,457
Morocco	--	--	--	--	1,500	1,001
Mozambique	--	--	--	--	87	66
Netherlands	10	23	--	--	6,317	3,939

See footnotes at end of table.

Table 22.—U.S. imports for consumption of lead, by country —Continued

Country	1985 Quantity (metric tons)	1985 Value (thousands)	1986 Quantity (metric tons)	1986 Value (thousands)	1987 Quantity (metric tons)	1987 Value (thousands)
Pigs and bars (lead content) —Continued						
Peru	5,150	$1,770	1,053	$449	350	$189
Poland	--	--	--	--	2,500	1,535
Spain	--	--	--	--	5,999	3,887
Sweden	--	--	2,773	1,055	9,086	5,887
Switzerland	--	--	21	11	201	141
United Kingdom	337	807	679	1,153	4,039	3,180
U.S.S.R	--	--	262	96	--	--
Yugoslavia	--	--	--	--	1,020	634
Other	--	--	r46	r20	82	146
Total	131,353	53,864	140,221	59,172	185,673	123,157
Reclaimed scrap, etc. (lead content):[3]						
Canada	1,118	454	1,444	383	3,062	1,600
Hong Kong	--	--	--	--	48	31
Japan	--	--	--	--	323	185
Malaysia	--	--	--	--	38	23
Mexico	2,035	720	1,831	1,060	3,034	1,230
Panama	--	--	--	--	44	23
Philippines	--	--	--	--	17	10
Other	15	38	15	28	21	26
Total	3,168	1,212	3,290	1,471	6,587	3,128
Grand total	137,930	56,453	148,257	62,101	203,960	133,832
Sheets, pipe, shot, other forms (gross weight):						
Belgium-Luxembourg	44	57	454	418	18	38
Canada	419	627	299	293	352	414
Germany, Federal Republic of	149	576	132	422	256	827
Italy	1	13	18	40	55	110
Japan	18	197	20	241	128	2,338
Mexico	164	147	43	22	180	121
Peru	121	61	100	45	622	360
Spain	36	11	13	11	118	140
United Kingdom	1,027	809	228	255	1,047	895
Other	r2	r19	r37	r78	17	58
Total	1,981	2,517	1,344	1,825	2,793	5,301

rRevised.
[1]Also includes other lead-bearing materials containing greater than 5 troy ounces of gold per short ton or greater than 100 troy ounces of total precious metals per short ton.
[2]Data may not add to totals shown because of independent rounding.
[3]Also includes other lead-bearing materials containing greater than 10% by weight of copper, lead, or zinc (any one).

Source: Bureau of the Census.

Table 23.—U.S. imports for consumption of lead[1]

Year	Blocks, pigs, anodes, etc.: Unwrought[2] Quantity (metric tons)	Unwrought[2] Value (thousands)	Unwrought alloys Quantity (metric tons)	Unwrought alloys Value (thousands)	Wrought lead and lead alloys (gross weight): Sheets, plates, rods, other forms Quantity (metric tons)	Sheets, plates, rods, other forms Value (thousands)	Foil, powder, flakes Quantity (metric tons)	Foil, powder, flakes Value (thousands)	Scrap Quantity (metric tons)	Scrap Value (thousands)	Drosses, etc. Quantity (metric tons)	Drosses, etc. Value (thousands)
1985	119,633	$44,952	12,480	$9,310	1,684	$2,211	297	$306	2,550	$1,068	618	$144
1986	124,061	50,279	16,302	9,007	1,165	1,526	179	299	2,269	1,306	1,021	165
1987	182,852	119,444	13,648	10,952	2,483	2,768	310	2,533	6,088	2,805	499	323

[1]Lead content, unless otherwise specified.
[2]Includes bullion.

Source: Bureau of the Census.

Table 24.—U.S. imports for consumption of miscellaneous products containing lead[1]

Year	Gross weight (metric tons)	Lead content (metric tons)	Value (thousands)
1984	2,671	1,363	$17,299
1985	3,377	1,453	22,124
1986	1,016	517	3,810
1987	970	515	4,185

[1]Babbitt metal, solder, white metal, and other lead-containing combinations.

Source: Bureau of the Census.

Table 25.—Lead: World mine production of lead in concentrates, by country[1]

(Thousand metric tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Algeria[e]	3.0	4.0	3.8	3.6	3.6
Argentina	31.7	28.5	28.6	28.9	28.8
Australia	480.6	440.6	498.0	447.7	476.0
Austria	4.3	4.2	7.5	5.9	4.5
Bolivia	11.8	7.4	6.2	3.1	8.2
Brazil	18.8	16.7	19.2	[e]19.5	14.9
Bulgaria[e]	95.0	95.0	95.0	95.0	97.0
Burma	23.1	21.9	21.9	18.2	[3]27.1
Canada	251.5	264.3	268.3	349.3	413.4
Chile	1.7	4.3	2.5	1.5	.9
China	[e]160.0	[e]180.0	[e]200.0	227.0	[3]252.0
Colombia	.2	.1	.1	.2	[3].2
Congo (Brazzaville)	[e]4.0	1.7	1.5	[e]1.4	1.4
Czechoslovakia	3.2	3.1	[e]3.2	[e]3.2	3.2
Ecuador	.2	.2	[e].2	[e].2	.2
Finland	2.1	2.5	2.4	2.0	2.2
France	1.5	2.3	2.5	2.5	[3]2.2
Germany, Federal Republic of	23.5	21.0	20.5	16.7	[3]18.8
Greece[e]	20.0	22.0	19.4	20.0	20.0
Greenland	21.6	17.7	17.8	16.2	[3]20.5
Honduras	19.3	20.5	21.2	12.6	20.0
Hungary[e]	.7	.7	.7	.4	.5
India	[e]25.7	24.8	27.1	37.6	39.0
Iran	[r]18.5	19.9	21.6	20.0	21.6
Ireland	33.6	37.2	34.6	36.4	[3]33.8
Italy	23.6	20.8	15.6	11.1	20.0
Japan	46.9	48.7	50.0	40.3	[3]28.3
Korea, North[e]	75.0	110.0	110.0	110.0	110.0
Korea, Republic of	12.2	10.8	9.7	11.9	12.0
Mexico	184.3	202.6	197.5	207.0	200.0
Morocco	97.9	100.7	106.8	76.2	[3]75.7
Namibia	38.5	33.3	34.6	37.5	37.0
Nigeria[e]	.3	[r].3	.3	.1	.1
Norway	[r]4.3	4.0	3.6	[r e]3.5	3.0
Peru	207.4	193.7	201.5	194.4	204.0
Poland	47.0	52.8	51.3	50.3	50.2
Romania[e]	30.0	30.0	28.0	28.0	28.0
South Africa, Republic of	87.5	94.8	98.4	97.8	[3]93.6
Spain	82.0	96.6	85.6	82.1	84.0
Sweden	[r]85.8	[r]82.8	80.6	[r e]90.0	90.0
Thailand	21.0	16.7	19.7	26.3	[3]23.5
Tunisia	4.6	4.1	2.5	1.9	2.0
Turkey[e]	[r]9.0	[r]10.0	[r]10.0	[r]10.0	10.0
U.S.S.R.[e]	435.0	440.0	440.0	440.0	440.0
United Kingdom	3.8	2.4	4.0	3.6	3.6
United States	465.6	334.5	424.4	353.1	318.7
Yugoslavia	114.0	113.6	115.1	116.9	98.0
Zambia	25.9	18.1	15.0	14.9	12.0
Total[4]	[r]3,357.0	[r]3,261.9	3,427.9	3,375.7	3,453.8

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through June 24, 1988.
[2]In addition to the countries listed, Uganda may produce lead, but available information is inadequate to make reliable estimates of output levels.
[3]Reported figure.
[4]Data may not add to totals shown because of independent rounding.

Table 26.—Lead: World smelter production, by country[1]

(Thousand metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
Argentina:					
Primary (refined)	15.2	16.3	15.1	24.3	20.0
Secondary (refined)	16.0	15.0	13.6	15.0	15.0
Total	31.2	31.3	28.7	39.3	35.0
Australia:					
Primary:					
Bullion for export	182.6	179.5	183.2	188.4	[2]197.2
Refined	196.3	198.8	200.1	156.2	[2]201.3
Secondary (refined)[e]	27.0	21.5	15.6	[r]14.8	15.6
Total[e]	405.9	399.8	398.9	[r]359.4	414.1
Austria:					
Primary	4.2	1.7	1.9	1.5	1.5
Secondary	12.9	16.5	15.6	15.0	14.5
Total	17.1	18.2	17.5	16.5	16.0
Belgium:					
Primary[e] [3]	54.4	71.5	[2]67.0	70.0	70.0
Secondary[4]	30.0	30.0	8.3	[e]10.0	10.0
Total	84.4	101.5	75.3	[e]80.0	80.0
Brazil:					
Primary (refined)	20.6	26.0	29.8	32.7	[2]28.8
Secondary (refined)	28.9	[r]45.7	51.8	38.9	[2]45.4
Total	49.5	[r]71.7	81.6	71.6	[2]74.2
Bulgaria:[e]					
Primary	112.0	112.0	112.0	110.0	110.0
Secondary[4]	4.0	4.0	4.0	5.0	5.0
Total	116.0	116.0	116.0	115.0	115.0
Burma: Primary (refined)	7.6	7.0	9.6	5.4	[2]4.0
Canada:					
Primary (refined)	[r]178.0	173.0	173.2	169.9	[2]139.5
Secondary (refined)	63.9	79.0	68.4	87.7	[2]86.3
Total	[r]241.9	252.0	241.6	257.6	[2]225.8
China:[e]					
Primary (refined)	165.0	165.0	[r]170.0	[r]200.0	200.0
Secondary (refined)	30.0	30.0	[r]40.0	[r]40.0	40.0
Total	195.0	195.0	[r]210.0	[2]240.0	240.0
Colombia: Secondary (refined)[e]	3.0	3.0	3.0	4.0	4.0
Cyprus: Secondary (refined)[e]	2.5	2.5	2.0	2.0	2.0
Czechoslovakia: Secondary (refined)	21.0	21.1	21.4	23.6	20.0
Denmark: Secondary (refined)	10.0	13.0	4.5	.6	--
Finland: Secondary (refined)	6.0	4.5	4.4	1.2	1.2
France:					
Primary (refined)	[r]115.0	117.9	133.6	132.0	[2]115.6
Secondary	13.6	13.5	12.2	[e]12.5	12.3
Total	[r]128.6	131.4	145.8	[r] [e]144.5	127.9
German Democratic Republic: Secondary[e]	20.0	22.0	20.0	20.0	18.0
Germany, Federal Republic of:					
Primary	116.2	102.3	109.7	111.1	[2]113.6
Secondary	236.3	254.9	246.6	255.5	[2]229.4
Total	352.5	357.2	356.3	366.6	[2]343.0
Greece: Primary (refined)	--	--	15.0	16.0	16.0
Guatemala: Secondary (refined)	.1	.1	.1	.1	[2].1
Hungary: Secondary (refined)[e]	.1	.1	.1	.1	.1
India:					
Primary (refined)	15.0	15.2	15.6	19.9	[2]20.4
Secondary (refined)	6.6	[e]10.0	[e]10.0	11.3	[2]12.0
Total	21.6	[e]25.2	[e]25.6	31.2	[2]32.4

See footnotes at end of table.

Table 26.—Lead: World smelter production, by country[1] —Continued

(Thousand metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
Ireland: Secondary (refined)	8.0	9.1	9.0	10.2	10.4
Italy:					
Primary (refined)	37.0	37.6	29.5	29.3	66.0
Secondary (refined)	89.4	102.9	96.7	101.7	94.0
Total	126.4	140.5	126.2	131.0	160.0
Jamaica: Secondary (refined)[e]	1.0	1.0	1.0	1.0	1.0
Japan:					
Primary	198.9	207.9	218.3	220.4	[2]227.2
Secondary (refined)	118.3	129.2	133.3	128.7	[2]119.5
Total	317.2	337.1	351.6	349.1	[2]346.7
Korea, North: Primary (refined)[e]	60.0	95.0	95.0	95.0	95.0
Korea, Republic of:[e]					
Primary (refined)	[r]7.6	[r]11.4	[r]11.0	[r]32.1	32.4
Secondary (refined)	[r]10.2	[r]8.9	[r]9.2	[r]27.5	27.6
Total	17.8	20.3	[r]20.2	[r]59.6	60.0
Malaysia: Secondary (refined)	5.3	10.3	14.6	13.8	14.0
Mexico:					
Primary	166.8	174.8	203.0	197.3	200.0
Secondary (refined)[e]	31.0	30.0	31.0	[r]33.0	33.0
Total[e]	197.8	204.8	234.0	[r]230.3	233.0
Morocco:					
Primary (refined)	55.2	46.1	59.5	[e]60.0	62.5
Secondary (refined)[e]	2.0	2.0	2.0	2.0	2.0
Total[e]	57.2	48.1	61.5	62.0	64.5
Namibia: Primary (refined)	35.4	28.9	38.5	40.0	40.0
Netherlands:					
Primary	2.0	(5)	(5)	(5)	--
Secondary (refined)[e]	[2]23.6	25.0	25.0	25.0	30.0
Total[e]	[2]25.6	[r]25.0	[r]25.0	[r]25.0	30.0
New Zealand: Secondary (refined)[e]	6.0	6.0	6.0	6.0	6.0
Nigeria: Secondary	.4	.6	.8	[e]1.0	1.0
Peru:					
Primary (refined)	67.7	70.2	81.8	66.4	66.4
Secondary (refined)[e]	5.0	5.0	5.0	5.0	5.0
Total[e]	72.7	75.2	86.8	[r]71.4	71.4
Philippines: Secondary (refined)	6.0	4.0	7.0	7.0	7.0
Poland:[e]					
Primary (refined)	56.5	58.4	61.1	[r]63.3	60.0
Secondary (refined)[4]	24.5	25.0	26.2	25.0	25.0
Total	81.0	83.4	87.3	88.3	85.0
Portugal: Secondary (refined)	6.0	6.0	7.0	[e]6.5	6.5
Romania:[e]					
Primary (refined)	40.0	35.9	38.6	36.0	35.0
Secondary (refined)	9.3	10.0	10.0	[r]15.5	10.0
Total	49.3	45.9	48.6	51.5	45.0
South Africa, Republic of: Secondary (refined)	23.6	30.8	32.8	40.5	41.0
Spain:					
Primary (refined)[3]	107.8	110.1	112.8	88.0	77.0
Secondary (refined)	36.0	49.9	43.3	42.0	40.0
Total	143.8	160.0	156.1	130.0	117.0
Sweden:					
Primary	60.8	65.6	58.8	[e]65.0	65.0
Secondary	15.2	27.7	25.9	29.8	30.0
Total	76.0	93.3	84.7	[r e]94.8	95.0

See footnotes at end of table.

Table 26.—Lead: World smelter production, by country[1] —Continued

(Thousand metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
Switzerland: Secondary (refined)	2.0	2.0	2.0	2.5	2.4
Taiwan: Secondary (refined)[e]	38.0	44.3	44.4	[r]53.5	54.0
Thailand: Secondary (refined)	3.2	6.2	7.5	9.1	10.0
Trinidad and Tobago: Secondary (refined)[e]	2.0	2.0	2.0	2.0	1.8
Tunisia:					
Primary (refined)	10.4	8.4	2.0	2.2	2.2
Secondary (refined)[e]	.5	.5	.5	.5	.5
Total[e]	10.9	8.9	2.5	[r]2.7	2.7
Turkey:[e]					
Primary (refined)	2.0	--	--	--	--
Secondary (refined)	5.5	9.0	10.0	10.0	10.0
Total	7.5	9.0	10.0	10.0	10.0
U.S.S.R.:[e]					
Primary (refined)	490.0	495.0	500.0	500.0	505.0
Secondary (refined)	255.0	260.0	265.0	270.0	275.0
Total	745.0	755.0	765.0	770.0	780.0
United Kingdom:					
Primary	40.7	36.1	36.0	37.8	[2]34.4
Secondary (refined)[6]	185.3	191.3	179.1	172.5	[2]200.7
Total	226.0	227.4	215.1	210.3	[2]235.1
United States:					
Primary (refined)	[r]519.2	[r]389.4	494.0	370.3	[2]373.6
Secondary (refined)	503.5	633.4	615.7	624.8	[2]710.2
Total	[r]1,022.7	[r]1,022.8	1,109.7	995.1	[2]1,083.8
Venezuela: Secondary (refined)[e]	15.0	17.0	18.0	16.0	17.0
Yugoslavia:					
Primary	93.1	109.8	116.7	129.9	125.0
Secondary	34.0	[r]11.5	15.0	25.0	20.0
Total	127.1	121.3	131.7	154.9	145.0
Zambia: Primary (refined)	14.6	8.8	8.9	6.6	6.6
Grand total	[r]5,244.5	[r]5,422.6	5,587.9	5,541.4	5,646.7
Of which:					
Primary	[r]3,247.8	[r]3,175.6	3,401.3	3,277.0	3,311.2
Secondary	[r]1,996.7	[r]2,247.0	2,186.6	2,264.4	2,335.5

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

[1]Table includes data available through June 24, 1988. Figures presented represent, to the extent possible, production of unrefined lead, including bullion and impure lead derived from new and old scrap. The figures for secondary lead for a number of countries are undoubtedly high, but sufficient information is not available to separate reprocessed scrap lead from lead merely remelted. Countries for which this is the case have been footnoted (see footnote 4). For those countries from which unrefined lead production is not reported, but where available information suggests that there is little if any import or export of bullion for refining and refined lead output has been reported, it is so noted parenthetically because it is believed that the difference between smelter output and refined output is negligible.

[2]Reported figure.

[3]Data not reported, derived from reported primary refined lead output minus imports of lead bullion plus exports of lead bullion and checked against use of lead content of domestically produced ores plus lead content of imported ores (estimated) minus lead content of exported ores (estimated).

[4]Some part of the total entered may be merely remelt, and as such probably should not be included here, but a substantial part of the total presumably was reprocessed to qualify as a secondary smelter product. Available information is inadequate to permit differentiation, and the total has been included, although it is recognized that this produces a slightly inflated figure.

[5]Revised to zero.

[6]Includes a small amount of primary lead from domestic concentrate.

Table 27.—Lead: World refinery production, by country[1]

(Thousand metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
Argentina:					
Primary	15.2	16.3	15.1	24.3	20.0
Secondary	16.0	15.0	13.6	15.0	15.0
Total	31.2	31.3	28.7	39.3	35.0
Australia:					
Primary	196.3	198.8	200.1	156.2	[2]201.3
Secondary[e]	27.0	21.5	15.6	[r]14.8	15.6
Total[e]	223.3	220.3	215.7	[r]171.0	216.9
Austria:					
Primary	12.0	10.0	10.0	6.0	5.0
Secondary	11.5	16.2	15.5	19.0	15.0
Total	23.5	26.2	25.5	25.0	20.0
Belgium:					
Primary	96.3	89.6	84.3	64.0	63.0
Secondary	37.8	38.1	30.0	26.0	26.0
Total	134.1	127.7	114.3	90.0	89.0
Brazil:					
Primary	[r]20.6	26.0	29.8	32.7	[2]28.8
Secondary	[r]28.9	[r]45.7	51.8	38.9	[2]45.4
Total	[r]49.5	[r]71.7	81.6	71.6	74.2
Bulgaria:[e]					
Primary	98.6	98.6	98.0	97.0	98.0
Secondary	17.4	17.4	18.0	17.0	17.0
Total	116.0	116.0	116.0	114.0	115.0
Burma: Primary	7.6	7.0	9.6	5.4	[2]4.0
Canada:					
Primary	[r]178.0	173.0	173.2	169.9	[2]139.5
Secondary	63.9	79.0	68.4	87.7	[2]86.3
Total	[r]241.9	252.0	241.6	257.6	[2]225.8
China:[e]					
Primary	165.0	165.0	[r]170.0	[r]200.0	200.0
Secondary	30.0	30.0	[r]40.0	[r]40.0	40.0
Total	195.0	195.0	[r]210.0	[r]240.0	240.0
Colombia: Secondary[e]	3.0	3.0	3.0	4.0	4.0
Cyprus: Secondary[e]	2.5	2.5	2.0	2.0	2.0
Czechoslovakia: Secondary	21.0	21.1	21.4	23.6	20.0
Denmark: Secondary	10.0	13.0	4.5	.6	--
Finland: Secondary	6.0	4.5	4.4	1.2	1.2
France:					
Primary	115.0	117.9	133.6	132.0	[2]115.6
Secondary	99.4	88.8	90.0	98.4	[2]97.2
Total	214.4	206.7	223.6	230.4	212.8
German Democratic Republic: Secondary[e]	36.0	35.0	55.0	[r]46.0	45.0
Germany, Federal Republic of:					
Primary	217.0	191.9	181.0	182.1	160.7
Secondary	135.5	165.3	175.3	184.5	182.3
Total	352.5	357.2	356.3	366.6	343.0

See footnotes at end of table.

Table 27.—Lead: World refinery production, by country[1] —Continued

(Thousand metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
Greece: Primary	--	--	15.0	16.0	16.0
Guatemala: Secondary	.1	.1	.1	.1	[2].1
Hungary: Secondary[e]	.1	.1	.1	.1	.1
India:					
Primary	15.0	15.2	15.6	19.9	[2]20.4
Secondary	6.6	[e]10.0	[e]10.0	11.3	[2]12.0
Total	21.6	[e]25.2	25.6	31.2	[2]32.4
Ireland: Secondary	8.0	9.1	9.0	10.2	10.4
Italy:					
Primary	37.0	37.6	29.5	29.3	66.0
Secondary	89.4	102.9	96.7	101.7	94.0
Total	126.4	140.5	126.2	131.0	160.0
Jamaica: Secondary[e]	1.0	1.0	1.0	1.0	1.0
Japan:					
Primary	203.3	233.8	233.7	232.7	[2]218.8
Secondary	118.3	129.2	133.3	128.7	[2]119.5
Total	321.6	363.0	367.0	361.4	[2]338.3
Korea, North: Primary[e]	60.0	95.0	95.0	95.0	95.0
Korea, Republic of:[e]					
Primary	[r]7.6	[r]11.4	[r]11.0	[r]32.1	32.4
Secondary	[r]10.2	[4]8.9	[r]9.2	[r]27.5	27.6
Total	17.8	20.3	[r]20.2	[r]59.6	60.0
Malaysia: Secondary	5.3	10.3	14.6	13.8	14.0
Mexico:					
Primary	162.5	163.2	193.5	178.9	175.8
Secondary[e]	31.0	30.0	31.0	[r]33.0	33.0
Total[e]	193.5	193.2	224.5	[r]211.9	208.8
Morocco:					
Primary	55.2	46.1	59.5	60.0	62.5
Secondary[e]	2.0	2.0	2.0	2.0	2.0
Total[e]	57.2	48.1	61.5	62.0	64.5
Namibia: Primary	35.4	28.9	38.5	40.0	40.0
Netherlands:					
Primary	2.0	--	--	--	--
Secondary[e]	[2]23.6	[r]25.0	25.0	25.0	30.0
Total[e]	[2]25.6	[r]25.0	25.0	25.0	30.0
New Zealand: Secondary[e]	6.0	6.0	6.0	6.0	6.0
Nigeria: Secondary[e]	2.0	2.0	3.0	3.5	3.5
Pakistan: Secondary[e]	1.0	1.0	1.0	1.0	1.0
Peru:					
Primary	67.7	70.2	81.8	66.4	66.4
Secondary[e]	5.0	5.0	5.0	5.0	5.0
Total[e]	72.7	75.2	86.8	[r]71.4	71.4
Philippines: Secondary	6.0	4.0	7.0	7.0	7.0
Poland:					
Primary[e]	[r]56.5	58.4	61.1	[r]63.3	60.0
Secondary[e]	[r]24.5	25.0	26.2	[r]25.0	25.0
Total	81.0	83.4	87.3	[r]88.3	85.0
Portugal: Secondary	6.0	6.0	7.0	[e]6.5	6.5
Romania:					
Primary[e]	40.0	35.9	38.6	36.0	35.0
Secondary[e]	9.3	10.0	10.0	[r]15.5	10.0
Total	49.3	45.9	48.6	51.5	45.0
South Africa, Republic of: Secondary	23.6	30.8	32.8	40.5	41.0

See footnotes at end of table.

Table 27.—Lead: World refinery production, by country[1] —Continued

(Thousand metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
Spain:					
Primary	107.8	110.1	112.8	88.0	77.0
Secondary	36.0	49.9	43.3	42.0	40.0
Total	143.8	160.0	156.1	130.0	117.0
Sweden:					
Primary	34.8	49.8	43.2	50.0	50.0
Secondary	15.2	27.7	25.9	29.8	30.0
Total	50.0	77.5	69.1	79.8	80.0
Switzerland: Secondary	2.0	2.0	2.0	2.5	2.4
Taiwan: Secondary[e]	38.0	44.3	44.4	[r]53.5	54.0
Thailand: Secondary	3.2	6.2	7.5	9.1	10.0
Trinidad and Tobago: Secondary[e]	2.0	2.0	2.0	2.0	1.8
Tunisia:					
Primary	10.4	8.4	2.0	2.2	2.2
Secondary[e]	.5	.5	.5	.5	.5
Total[e]	10.9	8.9	2.5	[r]2.7	2.7
Turkey:[e]					
Primary	2.0	--	--	--	--
Secondary	5.5	9.0	10.0	10.0	10.0
Total	7.5	9.0	10.0	10.0	10.0
U.S.S.R.:[e]					
Primary	490.0	495.0	500.0	500.0	505.0
Secondary	255.0	260.0	265.0	270.0	275.0
Total	745.0	755.0	765.0	770.0	780.0
United Kingdom:					
Primary	136.9	147.1	148.1	156.1	[2]137.5
Secondary	185.3	191.3	179.1	172.5	[2]200.7
Total	322.2	338.4	327.2	328.6	338.2
United States:					
Primary	[r]519.2	[r]389.4	494.0	370.3	373.6
Secondary	503.5	633.4	615.7	624.8	710.2
Total	[r]1,022.7	[r]1,022.8	1,109.7	995.1	1,083.8
Venezuela: Secondary[e]	15.0	17.0	18.0	16.0	17.0
Yugoslavia:					
Primary	[r]85.0	[r]62.6	83.0	116.5	101.0
Secondary	[r]38.0	37.4	40.0	38.5	41.0
Total	[r]123.0	[r]100.0	123.0	155.0	142.0
Zambia: Primary	14.6	8.8	8.9	6.6	6.0
Grand total	[r]5,288.6	[r]5,456.2	5,661.4	5,583.2	5,629.8
Of which:					
Primary	[r]3,264.6	[r]3,161.1	3,369.6	3,229.0	3,176.6
Secondary	[r]2,024.0	[r]2,295.1	2,291.8	2,354.2	2,453.2

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through June 24, 1988. Data included represent the total output of refined lead by each country, whether derived from ores and concentrates (primary) or scrap (secondary), and include the lead content of antimonial lead, but exclude, to the extent possible, simple remelting of scrap.
[2]Reported figure.

Lime

By Joyce A. Ober[1]

Total lime sold or used by domestic producers, including that from Puerto Rico, increased from 14.5 million short tons in 1986 to 15.8 million tons in 1987. These products, valued at nearly $790 million, include quicklime and hydrated lime for commercial or captive consumption.

Lime is consumed primarily in chemical and industrial applications. The iron and steel industry was the largest consumer of lime. The resolution of a labor dispute at a major U.S. steel company and the increased production by other domestic steel producers were reflected in an increased demand for lime.

Consumption of lime increased in chemical, industrial, and agricultural industries. Consumption in the manufacture of refractory dolomite and for construction lime declined.

Domestic Data Coverage.—Domestic production data for lime are developed by the Bureau of Mines from two separate, voluntary surveys of U.S. operations. Typical of these surveys is the annual "Lime" survey. Of the 116 operations to which the annual survey request was sent, all responded, representing 100% of the total sold or used by producers shown in tables 1 and 2.

Table 1.—Salient lime statistics

(Thousand short tons unless otherwise specified)

	1983	1984	1985	1986	1987
United States:[1]					
Number of plants	139	129	115	116	116
Sold or used by producers:					
Quicklime	12,383	13,134	12,997	11,850	12,979
Hydrated lime	2,066	2,302	2,314	2,199	2,468
Dead-burned dolomite	418	487	378	424	285
Total[2]	14,867	15,922	15,690	14,474	15,733
Value[3] thousands	$757,611	$811,183	$809,000	$757,867	$786,125
Average value per ton	$50.96	$50.95	$51.56	$52.36	$49.96
Lime sold	12,083	13,064	13,409	12,097	13,105
Lime used	2,784	2,858	2,281	2,377	2,628
Exports[4]	28	25	19	16	13
Imports for consumption[4]	283	247	194	201	178
Consumption, apparent[5]	15,122	16,144	r15,865	14,658	15,898
World: Production	r121,365	r125,191	123,236	p120,964	e122,715

eEstimated. pPreliminary. rRevised.
[1]Excludes regenerated lime. Excludes Puerto Rico.
[2]Data may not add to totals shown because of independent rounding.
[3]Selling value, f.o.b. plant, excluding cost of containers.
[4]Bureau of the Census.
[5]Calculated by sold or used plus imports minus exports.

DOMESTIC PRODUCTION

The term "lime," as used throughout this chapter, refers primarily to six chemicals produced by the calcination of high-purity calcitic or dolomitic limestone followed by hydration where necessary. They are (1) quicklime, calcium oxide (CaO), (2) hydrated lime, calcium hydroxide ($Ca(OH)_2$), (3) dolomitic quicklime ($CaO \bullet MgO$), (4) two types of dolomitic hydrate, type N ($Ca(OH)_2 \bullet MgO$) and type S ($Ca(OH)_2 \bullet Mg(OH)_2$), and (5) dead-burned dolomite. Nondolomitic quicklime and hydrated lime are also called high-calcium lime. Lime can also be produced from a variety of calcareous materials such as aragonite, chalk, coral, marble, and shell. Lime was regenerated, i.e., produced as a byproduct, by paper mills, carbide plants, and water treatment plants; however, regenerated lime is beyond the scope of this report.

Total U.S. lime production from limestone, including that of Puerto Rico, increased 9%. Commercial lime, sold by producers, increased 8%, and captive lime, used by producers, increased 11%.

Seventy-two companies produced lime. Leading producing companies, in descending order, were Dravo Lime Co. with two plants in Kentucky and one plant each in Alabama, Louisiana, and Texas; Mississippi Lime Co. in Missouri; Marblehead Lime Co. with two plants in Illinois and one each in Indiana, Michigan, and Pennsylvania; Martin Marietta Corp. in Ohio; USG Corp. with one plant each in Louisiana, Ohio, Texas, and Virginia; Chemstar Inc. with two plants each in California and Nevada and one each in Arizona and Utah; Broyhill and Associates Inc. with two plants in Pennsylvania; Allied Products Co. with two plants in Alabama; LTV Steel Co. in Ohio; and Continental Lime Inc. with one plant each in Montana, Utah, and Washington. These 10 companies operated 30 plants and accounted for nearly 55% of total lime production.

A number of industry changes took place during the year. Bethlehem Steel sold its lime facilities in central Pennsylvania to Broyhill and Associates of Arlington, VA.[2] Marblehead Lime of Chicago, IL, sold its Utah plant to United States Pollution Controls Inc. of Oklahoma City, OK.[3]

USG announced plans to transfer its lime operations to a newly formed subsidiary of the company. The company intended to spin off A. P. Green Refractories and, in so doing, reassign the USG lime facilities in New Braumfels, TX, and Kimballton, VA, to APG Lime Co., a division of A. P. Green Refractories. The reorganization was expected to be completed early in 1988.[4]

Table 2.—Lime sold or used by producers in the United States, by State[1]

State	1986 Plants	1986 Hydrated (thousand short tons)	1986 Quicklime (thousand short tons)	1986 Total[2] (thousand short tons)	1986 Value (thousands)	1987 Plants	1987 Hydrated (thousand short tons)	1987 Quicklime (thousand short tons)	1987 Total[2] (thousand short tons)	1987 Value (thousands)
Alabama	5	96	1,084	1,180	50,377	5	100	1,132	1,232	52,200
Arizona	3	W	W	505	21,016	3	W	W	546	21,932
Arkansas, Louisiana, Oklahoma	4	227	110	337	21,962	4	108	240	348	22,989
California	11	W	W	371	24,187	11	W	W	465	25,745
Colorado, Nevada, Wyoming	8	W	W	211	16,648	7	W	W	227	15,999
Florida	1	W	W	W	W	--	--	--	--	--
Hawaii, Oregon, Washington	5	W	W	371	24,629	5	W	W	389	25,650
Idaho	3	--	89	89	4,729	3	--	97	97	5,149
Illinois, Indiana, Missouri	8	402	2,514	2,916	142,133	8	392	2,826	3,218	150,136
Iowa, Nebraska, South Dakota	5	W	W	W	W	4	W	W	W	W
Kentucky, Tennessee, West Virginia[3]	4	W	W	W	W	5	124	1,500	1,622	76,306
Maryland	1	3	6	10	546	1	3	6	9	486
Massachusetts	2	16	W	W	W	2	16	W	W	W
Michigan	8	W	W	556	27,257	8	W	W	569	30,320
Minnesota and Montana	7	10	261	271	15,494	7	--	W	W	13,142
North Dakota	3	--	74	74	7,359	3	W	W	127	11,912
Ohio	9	W	W	1,648	81,103	9	W	W	1,926	93,108
Pennsylvania	10	319	1,098	1,417	81,234	10	325	1,249	1,574	93,430
Puerto Rico	1	24	--	24	3,291	1	25	--	25	3,558
Texas	7	611	563	1,173	62,670	7	527	613	1,140	59,027
Utah	3	W	W	232	13,079	4	W	W	562	17,894
Virginia	4	68	556	624	27,362	5	123	576	699	29,435
Wisconsin	5	117	233	350	19,715	5	116	277	393	21,733
Other[4]	([5])	330	5,686	2,139	116,369	([5])	635	4,748	590	19,535
Total[2]	117	2,223	12,274	14,498	761,158	117	2,493	13,264	15,758	789,683

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Excludes regenerated lime. Includes Puerto Rico.
[2]Data may not add to totals shown because of independent rounding.
[3]1987 only.
[4]Includes data indicated by the symbol W.
[5]Included with data for each individual State.

Table 3.—Lime sold or used by producers in the United States,[1] by size of plant

Size of plant	1986			1987		
	Plants	Quantity (thousand short tons)	Percent of total	Plants	Quantity (thousand short tons)	Percent of total
Less than 10,000 tons	14	92	1	9	49	([2])
10,000 to 25,000 tons	23	340	2	22	372	2
25,000 to 50,000 tons	13	477	3	16	576	4
50,000 to 100,000 tons	22	1,671	11	24	1,761	11
100,000 to 200,000 tons	25	3,561	25	18	2,639	17
200,000 to 400,000 tons	16	4,612	32	22	5,797	37
More than 400,000 tons	4	3,745	26	6	4,564	29
Total	117	14,498	100	117	15,758	100

[1]Excludes regenerated lime. Includes Puerto Rico.
[2]Less than 1/2 unit.

CONSUMPTION AND USES

Lime was consumed in every State. Lime sold or used by producers was for chemical and industrial uses, 89%; construction, 8%; refractories, 2%; and a small amount for agriculture. Captive lime was used mainly in the production of steel in basic oxygen furnaces, and 24% of all captive lime was used in sugar refining.

In steel refining, quicklime was used as a flux to remove impurities such as phosphorus, silica, and sulfur. Dolomitic lime was often substituted for a fraction of the high-calcium lime to extend refractory life. Dead-burned dolomite, also called refractory lime, was used to line the bottom of open-hearth steel furnaces to extend the life of the brick lining. Dead-burned dolomite was a component in tar-bonded refractory bricks used in basic oxygen furnaces. Lime consumption for raw steel production increased 6% to 5.0 million tons and accounted for 32% of all lime consumed in the United States.

In nonferrous metallurgy, lime was used in the beneficiation of copper ores to neutralize the acidic effects of pyrite and other iron sulfides and maintain the proper pH in the flotation process. It was used to process alumina and magnesia, to extract uranium from gold slimes, to control pH and reduce cyanide loss in gold and silver leaching operations, and in the recovery of nickel by precipitation.

Lime was used in the softening and clarification of municipal potable water. In sewage treatment, lime was used to control pH in the sludge digester, which removes dissolved and suspended solids that contain phosphates and nitrogen compounds. It also aided clarification and the killing of bacteria in sewage treatment. Lime was used to neutralize acid mine and industrial discharges. In flue gas desulfurization systems serving utility and industrial plants, lime was used to react with sulfur oxides in the flue gas. Lime was used to stabilize sludges from sewage and desulfurization plants before disposal.

The paper industry used lime as a causticizing agent and for bleaching paper pulp to the desired degree of whiteness. Lime was also used in the clarification and color removal of paper mill wastes and to make precipitated calcium carbonate, a specialty pigment used in premium-quality coated and uncoated papers.

The chemical industry used lime in the manufacture of soda ash and bicarbonate of soda to recover and recycle ammonia. Quicklime was combined with coke to produce calcium carbide, which is used to make acetylene and calcium cyanamide. Lime was used to make calcium hypochlorite, citric acid, petrochemicals, and other chemicals.

In sugar refining, milk of lime, a suspension of hydrated lime in water, was used to raise the pH of the product stream, precipitating colloidal impurities. The lime itself is then removed by reaction with carbon dioxide to precipitate calcium carbonate. The carbon dioxide is often a byproduct of the lime production process.

Dolomitic quicklime was used as a flux in the manufacture of glass. Quicklime was used to make calcium silicate building products, i.e., sand-lime brick, and hydrated lime was used to produce silica refractory brick.

In construction, lime was used for soil stabilization to upgrade clay soils into satisfactory base and subbase materials. Common applications included the construction of roads, airfields, building foundations, earthen dams, and parking areas. Hydrated lime was used with fly ash to make base material, in asphalt mixes to act as an antistripping agent and to improve durability in plaster, stucco, and mortar. Other applications of lime included agricultural uses, leather tanning, plastics manufacture, and pigments.

Table 4.—Destination of shipments of lime sold or used by producers in the United States, by State[1]

(Thousand short tons)

State	1986			1987		
	Quicklime	Hydrated lime	Total[2]	Quicklime	Hydrated lime	Total[2]
Alabama	426	45	472	460	49	508
Alaska	(3)	1	1	(3)	1	1
Arizona	234	64	298	227	87	313
Arkansas	87	24	111	202	19	220
California	406	96	501	476	107	583
Colorado	72	9	82	65	11	76
Connecticut	15	10	25	5	9	14
Delaware	32	6	37	12	5	17
District of Columbia	22	26	48	23	14	38
Florida	361	34	395	307	30	337
Georgia	228	47	275	240	52	292
Hawaii	2	4	6	(3)	3	3
Idaho	97	3	100	103	2	105
Illinois	491	133	624	507	99	606
Indiana	1,322	33	1,356	1,562	31	1,593
Iowa	78	15	93	87	16	104
Kansas	62	17	79	60	23	83
Kentucky	489	18	508	448	22	470
Louisiana	245	96	341	235	104	339
Maine	13	1	13	(3)	1	1
Maryland	284	15	299	279	15	294
Massachusetts	39	15	54	2	15	17
Michigan	940	35	976	954	29	984
Minnesota	229	18	247	236	18	254
Mississippi	110	12	123	144	8	152
Missouri	125	49	174	140	51	191
Montana	42	8	50	44	10	54
Nebraska	51	6	57	57	5	61
Nevada	100	18	118	44	14	59
New Hampshire	2	(3)	2	1	(3)	1
New Jersey	107	54	160	100	48	148
New Mexico	156	38	174	177	35	212
New York	65	39	104	25	29	54
North Carolina	248	41	289	237	43	281
North Dakota	155	7	162	135	47	181
Ohio	1,287	118	1,404	1,372	154	1,526
Oklahoma	78	13	91	96	16	112
Oregon	77	12	90	117	20	136
Pennsylvania	1,416	203	1,619	1,620	239	1,859
Rhode Island	3	2	5	(3)	1	2
South Carolina	109	21	130	125	21	146
South Dakota	14	1	15	15	2	16
Tennessee	194	67	261	197	64	262
Texas	560	589	1,149	644	506	1,150
Utah	178	10	189	405	183	588
Vermont	(3)	1	1	(3)	1	1
Virginia	159	14	173	133	84	217
Washington	265	13	277	244	12	257
West Virginia	437	22	459	471	39	510
Wisconsin	97	47	144	137	43	180
Wyoming	39	22	62	55	17	72
Total[2]	12,250	2,191	14,441	13,225	2,454	15,680
Exports:						
Canada	19	8	28	26	8	34
Other countries	5	24	29	13	28	41
Total[2]	24	33	57	39	36	75
Grand total[2]	12,274	2,223	14,498	13,264	2,490	15,758

[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.

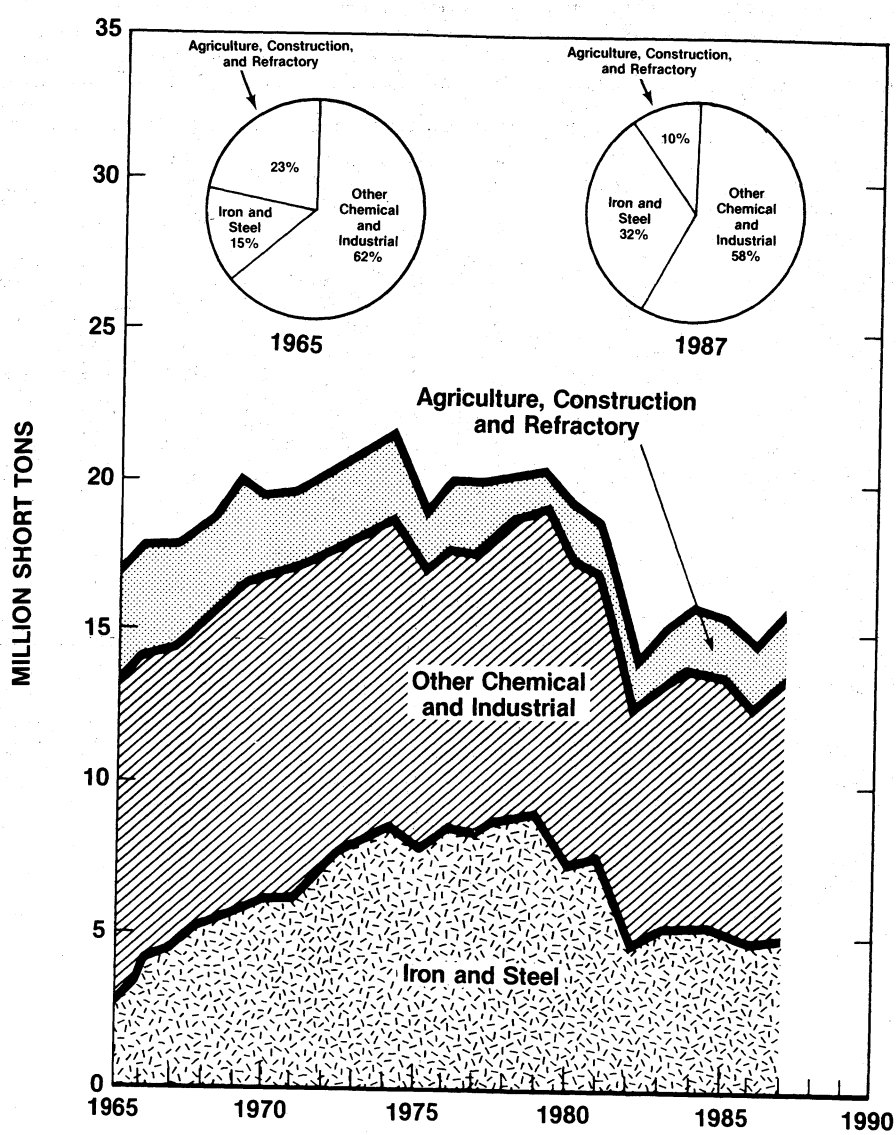

Figure 1.—Trends in major uses of lime.

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

(Thousand short tons and thousand dollars)

Use	1986				1987			
	Sold	Used	Total[2]	Value	Sold	Used	Total[2]	Value
Agriculture	51	(3)	51	3,169	89	--	89	6,877
Chemical and industrial:								
Acid water, mine or plant	W	W	286	14,715	W	W	342	16,294
Alkalies	W	W	118	7,015	W	W	118	7,790
Aluminum and bauxite	174	--	174	7,752	W	--	W	W
Brick, sand-lime, and slag	W	--	W	W	6	--	6	368
Copper ore concentration	W	W	335	13,978	W	W	677	20,340
Fertilizer	5	--	5	351	6	--	6	415
Food products, animal or human	17	--	17	878	17	--	17	914
Glass	142	--	142	7,020	129	--	129	6,221
Magnesia from sea water or brine	W	W	398	19,574	W	W	W	20,083
Metallurgy	W	W	10	467	5	--	5	208
Oil well drilling	11	--	11	902	W	--	W	W
Ore concentration, other	130	--	130	6,155	141	--	141	6,906
Paint	2	--	2	179	3	--	3	185
Paper and pulp	W	W	1,198	58,331	1,071	--	1,071	49,385
Petroleum refining	10	--	10	587	W	--	W	W
Sewage treatment	W	W	540	29,567	W	W	496	25,501
Steel, BOF	2,817	863	3,680	175,332	W	W	4,084	189,733
Steel, electric	W	W	883	41,527	W	W	760	35,242
Steel, open-hearth	W	W	122	5,939	W	W	145	6,733
Sugar refining	68	621	689	42,667	25	639	664	41,399
Sulfur removal from stack glasses	1,341	--	1,341	69,947	W	W	1,441	68,052
Tanning	22	--	22	1,377	20	--	20	1,218
Water purification	W	W	1,610	83,003	W	W	1,190	59,583
Wire drawing	W	--	W	W	17	--	17	863
Other[4]	5,643	762	906	50,490	10,161	1,861	2,769	125,009
Total[2]	10,383	2,246	12,629	637,753	11,599	2,501	14,101	682,442
Construction:								
Road stabilization	481	--	481	28,345	394	--	394	21,981
Soil stabilization	417	--	417	24,154	355	--	355	15,584
Finishing lime	221	--	221	20,899	203	--	203	20,121
Mason's lime	W	W	214	15,610	W	W	194	13,874
Other[5]	61	--	61	3,440	136	--	136	7,037
Total[2]	W	W	1,394	92,448	W	W	1,282	78,598
Refractory dolomite	W	W	424	27,788	W	W	285	21,766
Grand total[2]	12,121	2,377	14,498	761,158	13,129	2,628	15,758	789,683

W Withheld to avoid disclosing company proprietary data.
[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 briquetting, brokers, calcium carbide, chrome, citric acid (1987), commercial hydrators, desiccants, explosives, ferroalloys, fiberglass, glue, insecticides, ladle desulfurizing, magnesium metal, manganese, oil and grease, pelletizing, petrochemicals, pharmaceuticals, precipitated calcium carbonate, rubber, silica brick, soap, unspecified uses, and uses indicated by symbol W in "Chemical and industrial" lime only.
[5]Includes asphalt antistripping.

PRICES

The average value of lime sold or used by producers, as reported to the Bureau of Mines f.o.b. plant, excluding Puerto Rico, decreased 5% to $49.96 per short ton. Average values were $48.40 per ton for chemical and industrial lime, $76.35 for refractory dolomite, $61.31 for construction lime, and $76.97 for lime used in agriculture.

The average value of quicklime sold remained about the same at $47.63 per ton. Average values per ton were $47.47 for chemical lime, $45.50 for lime used in agriculture, $44.39 for construction lime, and $76.35 for refractory dead-burned dolomite.

The average value of hydrated lime sold decreased 16% to $63.20 per ton. Average values were $59.43 for chemical lime, $89.87 for lime used in agriculture, and $67.83 for construction lime.

FOREIGN TRADE

Exports and imports for consumption of lime decreased to 12,644 tons and 177,905 tons, respectively, insignificant quantities when compared with total domestic consumption of 15.9 million tons.

Table 6.—U.S. exports of lime

	Quantity (short tons)	Value[1] (thousands)
1984	24,714	$6,805
1985	19,383	5,155
1986	16,448	4,500
1987	12,644	2,971

[1]Customs value.

Source: Bureau of the Census.

Table 7.—U.S. imports for consumption of lime

	Hydrated lime		Other lime		Total	
	Quantity (short tons)	Value[1] (thousands)	Quantity (short tons)	Value[1] (thousands)	Quantity (short tons)	Value[1] (thousands)
1984	59,906	$3,669	187,579	$9,722	[2]247,484	$13,391
1985	48,827	3,407	145,230	8,810	194,057	12,217
1986	57,842	4,108	142,865	8,129	200,707	12,237
1987	39,734	3,021	138,171	7,558	177,905	10,579

[1]Customs value.
[2]Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

WORLD REVIEW[5]

The fortunes of international lime producers were similar to those in the United States in traditional end uses. Steel producers are the largest consumers of lime in most industrialized countries. World lime consumption declined proportionately along with the decline in steel production in recent years. Increased lime production in 1987 was driven by a modest recovery in the steel industry and development of new end-use technologies. The future growth of international and domestic markets for the lime industry depends on developing new markets, such as industrial air and water treatment, soil stabilization, and reinforcement of asphalt pavements.

Belgium.—The largest consumers of lime in Belgium were water treatment, construction, and chemical production. The majority of Belgian lime was exported to Luxembourg and the Netherlands for steel production.

Brazil.—Lime demand expanded with its growing steel, construction, and agricultural industries in 1986. Mineraçõ Lapa Vermelha expanded production capacity, Gramane-Cigar installed a new kiln, and Fabrica de Cal Votorantim began construction of two vertical kilns.

Canada.—The majority of Canadian lime producers operated for internal consumption. In 1987, 10 of 19 producers were captive producers that included 4 sugar companies, 4 steelmakers, 1 carbide producer, and 1 chemical manufacturer.

France.—Official French lime statistics listed 1986 consumption by end use as follows: steel industry, 55%; agriculture, 9%; roads, 7%; chemicals, 6%; water treatment, 6%; nonferrous metals, 5%; gas purification, 3%; building products, 3%; paper, 2%; calcium carbide, 2%; and the remaining 2%, other unspecified end uses.

Germany, Federal Republic of.—Lime sales have decreased steadily since 1980, responding to the decline in both the iron and steel industry and the construction industry.

Japan.—The decline in raw steel production was blamed for the 7.2% decrease in lime consumption in 1986.

South Africa, Republic of.—Because of the remoteness of high-grade limestone deposits to markets and the coal used to calcine limestone, transportation cost may represent 40% of the lime cost. Much of the lime produced in the Republic of South Africa had been used to remove uranium from gold processing slimes. As the demand for uranium has declined since 1982, lime production has remained depressed.

United Kingdom.—Although the steel industry was the largest consumer of lime at 33% in 1986, 26% was consumed in agriculture to increase the pH of farmland, streams, and lakes in order to offset the effects of acid rain.

Table 8.—Quicklime and hydrated lime, including dead-burned dolomite: World production, by country[1]

(Thousand short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Algeria[e]	45	45	45	45	45
Australia[e 3]	[4]1,120	[r]1,210	[r]1,210	[r]1,210	1,210
Austria	1,257	1,391	1,434	1,405	1,380
Belgium	1,951	2,392	1,997	1,944	2,090
Brazil	[e]5,500	5,053	5,255	5,411	5,510
Bulgaria	1,801	1,682	1,467	[e]1,500	1,500
Burundi	([5])	([5])	1	[r]([5])	1
Canada	2,460	2,498	2,438	2,472	2,500
Chile	797	858	882	[e]880	830
Colombia[e]	1,430	1,430	1,430	1,430	1,430
Costa Rica[e]	11	11	11	11	11
Cuba	169	166	187	[e]200	180
Cyprus	9	8	9	8	8
Czechoslovakia	3,417	3,436	3,557	3,670	[4]3,569
Denmark (sales)	119	141	142	147	[4]132
Dominican Republic[e]	44	44	37	37	40
Egypt[e]	[4]103	107	107	105	105
Fiji Islands	[e]3	[e]3	4	3	2
Finland	[r]255	266	278	288	287
France	3,247	3,450	3,417	3,200	3,300
German Democratic Republic	3,812	3,965	3,932	3,908	3,910
Germany, Federal Republic of	7,574	7,651	7,545	7,139	6,610
Guatemala	30	56	68	41	[4]88
Hungary	906	907	883	916	915
India[e]	440	550	550	[r]660	770
Iran[e]	700	700	700	700	700
Ireland	[e]65	75	93	97	[4]85
Israel[e]	[4]45	55	55	55	55
Italy	2,228	2,648	2,509	2,310	2,540
Jamaica	134	127	95	[e]100	100
Japan (quicklime only)	8,197	8,547	8,217	7,404	7,700
Jordan	294	247	[r e]250	[r e]250	250
Kenya	38	23	31	14	17
Korea, Republic of[e]	220	220	220	220	220
Kuwait	[e]15	17	58	63	63
Lebanon[e]	22	11	11	11	11
Libya[e]	[4]287	290	290	290	290
Malawi	2	2	[e]2	3	3
Malta[e]	[4]6	6	6	6	6
Martinique[e]	6	6	6	6	--
Mauritius[e]	8	8	8	8	8
Mexico[e]	4,000	4,400	4,400	[r]4,350	4,400
Mongolia[e]	[r]103	[r]105	[r]105	[r]105	105
Mozambique[e]	11	11	11	11	11
Namibia	1	--	--	--	--
Nepal	[e]11	8	[6]8	1	1
New Zealand[e]	180	165	175	175	175
Nicaragua	5	[e]3	4	[r e]4	4
Norway[e]	145	145	110	110	110
Paraguay	81	94	88	97	95
Peru[e]	40	40	40	40	40
Philippines	56	56	52	[e]50	50
Poland	4,543	4,686	4,546	[e]4,500	4,500
Portugal[e]	250	230	220	220	220
Romania	3,994	4,242	4,097	[e]4,100	4,000
Saudi Arabia[e]	10	[4]13	13	13	13
South Africa, Republic of (sales)	2,085	2,325	2,220	2,143	2,040
Spain[e]	1,100	[4]1,199	1,200	1,300	1,300
Sweden	672	714	715	[r e]720	720
Switzerland	47	45	41	[e]45	45
Taiwan	145	130	116	[e]120	115
Tanzania	3	[e]3	3	[e]3	3

See footnotes at end of table.

Table 8.—Quicklime and hydrated lime, including dead-burned dolomite: World production, by country[1] —Continued

(Thousand short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Tunisia[e]	640	660	660	720	720
Turkey[e]	[4]1,100	1,100	1,100	1,200	1,200
Uganda[e]	([4 5])	1	1	1	1
U.S.S.R	32,520	32,520	32,190	[e]32,190	32,190
United Arab Emirates[e]	50	50	50	50	50
United Kingdom[e]	2,750	2,750	2,750	2,750	3,100
United States including Puerto Rico (sold or used by producers)	14,902	15,956	15,713	14,498	[4]15,758
Uruguay	11	9	10	[e]11	11
Venezuela[e]	2	2	2	2	2
Yugoslavia[e]	[4]2,810	2,850	2,750	[r]2,850	2,850
Zaire	118	121	127	150	150
Zambia	213	256	282	268	265
Total	[r]121,365	[r]125,191	123,236	120,964	122,715

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through June 24, 1988.
[2]Lime is produced in many other countries in addition to those listed. Argentina, China, Iraq, Pakistan, and Syria are among the more important countries for which official data are not available.
[3]Data are for year ending June 30 of that stated.
[4]Reported figure.
[5]Less than 1/2 unit.
[6]Data for year ending mid-July of that stated.

TECHNOLOGY

Lime has been used successfully to stabilize medium, moderate, and fine-grained soils. Improved stability of these clay-type soils increases their load-bearing characteristics for new construction. The addition of lime to the soil creates a stable water layer, changes the texture, and strengthens the soil. A report was published by the National Lime Association describing the effect of lime additions for soil improvement.[6]

The U.S. Environmental Protection Agency developed a process to reduce the sulfur emissions from old coal-burning plants by as much as 50%. Limestone injection multistage burning (LIMB), tested at a powerplant in Ohio, involved injection of hydrated lime above the flame zone in boilers to convert sulfur dioxide to calcium sulfate. LIMB will represent a significant cost savings if large-scale tests prove that emissions are sufficiently reduced and more costly flue gas scrubbers are unnecessary. If new clean air legislation is enacted requiring reduced sulfur dioxide emissions from older powerplants, which are not controlled under existing laws, LIMB technology could be adopted and could open up a new market for the lime industry.[7]

[1]Physical scientist, Branch of Industrial Minerals.
[2]Rock Products. Bethlehem Selling Pennsylvania Limestone Operations. V. 90, No. 2, 1987, p. 9.
[3]———. Marblehead Lime Sells Utah Plant to Hazardous Waste Company. V. 90, No. 4, 1987, p. 9.
[4]Pit & Quarry. A. P. Green To Diversify. V. 80, No. 3, 1987, p. 15.
[5]O'Driscoll, M. Burnt Lime/Dolime, Seeking Markets Green. Ind. Miner. (London), No. 248, 1988, pp. 23-51.
[6]Little, D. N. Fundamentals of the Stabilization of Soil With Lime. National Lime Assoc. Bull. 332, 1987, 20 pp.
[7]Tarantino, T. Lime Injection May Be Alternative to Scrubbers. Pit & Quarry, v. 89, No. 12, 1987, p. 34.

Lithium

By Joyce A. Ober[1]

The United States remained the world's largest producer and consumer of lithium minerals and chemicals, although domestic production decreased. Imports of lithium mineral concentrates and lithium chemicals increased, essentially replacing most of the lost domestic production and causing a slight increase in estimated consumption over the level of 1986. The budding recovery of the domestic aluminum industry from its recent slump had the effect of increasing demand for lithium carbonate near year-end. Exports remained the same based on contained lithium and producers' stocks decreased slightly. World production experienced little change.

Domestic Data Coverage.—Domestic production data for lithium are developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the two operations to which a survey request was sent, both responded, representing 100% of total production. However, production and stock data were withheld from publication to avoid disclosing company proprietary data.

Legislation and Government Programs.—The General Services Administration reported sales of 52,000 pounds of lithium hydroxide monohydrate, valued at $43,000 from excess stocks of the U.S. Department of Energy (DOE). The stockpile originally contained 46,000 short tons of material, about 75% of which was depleted of lithium 6 and possibly contained 8 to 9 parts per million of mercury. The remainder of the material in the DOE account, 79,865,549 pounds, is designated for disposal.

Table 1.—Salient lithium statistics

(Short tons of contained lithium)

	1983	1984	1985	1986	1987
United States:					
Production[1]	W	W	W	W	W
Producers' stock changes[1]	W	W	W	W	W
Imports[2]	35	90	410	700	900
Shipments of Government stockpile surplus[3]	1	1	1	2	4
Supply[1 4]	6,000	6,600	5,500	4,100	4,000
Supply[e 5]	4,800	6,100	5,000	3,500	3,200
Exports[e 6]	2,600	2,900	2,500	2,000	2,000
Consumption:					
Apparent	W	W	W	W	W
Estimated	2,200	3,200	2,500	2,600	2,700
Rest of world: Production[e 1]	[r]1,800	[r]2,500	[r]3,300	[r]3,400	3,500

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Mineral concentrate and carbonate.
[2]Compounds, concentrate, ores, and metal.
[3]Lithium hydroxide monohydrate.
[4]Production minus inventory increase.
[5]Based primarily on monitoring at the carbonate stage and assuming a 15% lithium loss during conversion of concentrate to chemicals.
[6]Compounds.

DOMESTIC PRODUCTION

Two companies continued to produce lithium products in the United States. Lithium Corp. of America, (Lithco), a subsidiary of FMC Corp., mined spodumene, a lithium ore, from pegmatite dikes near Bessemer City, NC. The company produced lithium carbonate and downstream lithium compounds, including some organic lithium compounds, at a chemical plant near the mine. Foote Mineral Co., 87.5% owned by Newmont Mining Corp., recovered lithium carbonate from a subsurface brine deposit in Silver Peak, NV. Foote's lithium carbonate operation at Kings Mountain, NC, remained inactive throughout 1987, but some production of marketable ore concentrates continued. At yearend, Foote announced an agreement with Cyprus Minerals Co. to enter a cash merger with a new Cyprus subsidiary. The merger will be completed early in 1988.[2]

Foote operated processing facilities for downstream lithium products and metal in Frazer, PA; Sunbright, VA; and New Johnsonville, TN.

CONSUMPTION AND USES

The aluminum, ceramics and glass, lubricating grease, and synthetic rubber industries were the major consumers of lithium minerals and chemicals. These markets were primarily related to transportation, i.e., the aircraft and automotive industries. Ceramics and glass were also used in industrial and consumer applications. Estimated domestic consumption increased slightly, but U.S. production decreased. Imported lithium ores continued to replace lithium carbonate in some ceramics and glass applications.

The aluminum industry, which began to recover from its slump, maintained its edge as the leading end use for lithium in the United States. Lithium carbonate is added to the cryolite bath in aluminum potlines where it is converted to lithium fluoride. The lithium fluoride lowers the melting point of the bath, allowing a lower operating temperature for the potline and increasing the electrical conductivity of the bath. Operators use these factors to increase production, reduce power consumption, or increase current efficiency.

The second largest end use, the addition of lithium chemicals and ore concentrates to ceramics and glass manufacturing processes, is approaching that of the aluminum industry in volume of lithium consumption. Lithium additions, in the form of carbonate and mineral concentrates, lower process melting points, reduce the coefficient of thermal expansion and the viscosity, and eliminate the use of more toxic chemicals. The manufacture of thermal-shock-resistant cookware consumed the majority of lithium used in the ceramics and glass industry. Use of low-iron petalite and spodumene, two lithium ores, increased as a source of the lithium used to improve the physical properties of container and bottle glass, as well as a source of alumina (Al_2O_3), another important component of the glass. Lithium is being used increasingly in container and bottle glass, enabling glass manufacturers to produce lighter weight, thinner walled products.

The third largest end use for lithium was in the multipurpose grease industry. Lithium-based greases are favored because they retain their lubricating properties over a wide temperature range; have good resistance to water, oxidation, and hardening; and if liquefied, form a stable grease on cooling. These greases continued to be utilized in military, industrial, automotive, aircraft, and marine applications.

Lithium batteries represent an end use with the potential for dramatic growth. The 9-volt lithium-manganese dioxide battery announced by Eastman Kodak Co. in 1986, appeared on the consumer market in late 1987, indicating that lithium batteries had moved from specialty applications into everyday use. Although they represent a small percentage of total lithium consumption, sales of these batteries are expected to grow 13% per year until at least 1996.[3] Lithium batteries offer improved performance over the more traditional alkaline batteries, at a slightly higher cost. Lithium batteries have been used in cameras, microcomputers, and watches, and more recently in small appliances, electronic games, and toys. Large lithium batteries have been used in military applications.

Aircraft manufacturers in several countries have experimented with aluminum-lithium alloys as the material for wing and fuselage skin. Several U.S. companies have announced that they will use these alloys in their new airline models.[4] Use of aluminum-lithium alloys can reduce the weight of the aircraft by more than 10%, allowing significant fuel savings over the life of the aircraft. The alloys, which are 2% to 3% lithium by weight, are of interest to the aircraft and aerospace industry because of their reduced density and superior corrosion resistance compared with that of conventional aluminum alloys. These alloys face direct competition, however, from composite materials consisting of boron, graphite, or aramid fibers imbedded in plastic.

Small quantities of other lithium compounds were important to many industries. Butyllithium was used as a catalyst in synthetic rubber production. Lithium chloride and lithium bromide were used in industrial air-conditioning systems, commercial dehumidification systems, and in the production of sophisticated textiles. Sanitizers for swimming pools, commercial glassware, and public restrooms contained lithium hypochlorite, as did dry bleach for commercial laundries. Patients diagnosed as suffering from manic-depressive mental disorders were prescribed medication containing a pharmaceutical grade of lithium carbonate. Lithium metal was used as a scavenger to remove impurities from copper and bronze, and anhydrous lithium chloride was used in fluxes for hard-to-weld metals such as steel alloys and aluminum.

STOCKS

Yearend producers' stocks of lithium carbonate and marketable ore decreased slightly.

PRICES

Both domestic lithium-producing companies announced price increases for their large-volume products, lithium carbonate and lithium hydroxide monohydrate, for the first time since 1984. These increases were prompted by the fact that world production capacity for lithium reflected demand more closely than it had in recent years. This situation was due to the continued shutdown of operations at Kings Mountain, NC. In addition, the North American aluminum industry began to recover from its slump, promising an increase in demand for lithium carbonate from that sector. Additional price increases, averaging about 5%, were announced for most other lithium compounds.

Table 2.—Domestic yearend producers' average prices of lithium and lithium compounds

(Dollars per pound)

	1986	1987
Lithium bromide, 54% brine: 2,268-pound lots, delivered in drums	4.24	4.33
Lithium carbonate, technical: Truckload lots, delivered	1.50	1.55
Lithium chloride, anhydrous, technical: Truckload lots, delivered	3.49	3.66
Lithium fluoride	5.12	5.38
Lithium hydroxide monohydrate: Truckload lots, delivered	1.93	1.97
Lithium metal ingot, battery-grade: 1,000-pound lots, f.o.b	35.10	37.68
Lithium metal ingot, standard-grade: 1,000-pound lots, f.o.b	24.20	25.45
Lithium sulfate, anhydrous	3.21	3.51
N-butyllithium in n-hexane (15%): 3,000-pound lots, delivered	15.88	15.88

Source: U.S. lithium producers.

FOREIGN TRADE

In 1987, U.S. exports of lithium carbonate increased 10%, exports of lithium hydroxide remained about the same, and exports of other lithium compounds decreased 13%. U.S. imports for consumption of lithium ores increased 36% over the figures reported in 1986, and imports of lithium compounds increased 10%. Ninety-four percent of these imports were from Foote's joint venture with the Government of Chile at the Salar de Atacama. Lithium metal imports increased over 500%, which reflected growing demand for lithium batteries and alloys. Imports of lithium salts were also up significantly, but the 194% increase represents less than 1% of total lithium imports in terms of contained lithium.

Table 3.—U.S. exports of lithium chemicals, by compound and country

Compound and country	1986 Gross weight (pounds)	1986 Value	1987 Gross weight (pounds)	1987 Value
Lithium carbonate:				
Australia	72,220	$88,784	144,000	$201,240
Brazil	440	3,498	6,600	10,416
Canada	1,470,149	2,391,197	908,506	1,264,924
France	118,646	170,441	--	--
Germany, Federal Republic of	5,367,455	6,766,826	5,239,635	6,377,717
Hong Kong	38,801	51,764	1,067	1,600
India	25,877	72,943	14,722	23,589
Japan	2,180,837	3,129,384	2,703,248	3,644,631
Korea, Republic of	141,680	212,927	196,433	281,507
Mexico	371,011	547,580	186,114	283,317
Netherlands	455,875	657,101	476,551	653,764
New Zealand	1,100	5,071	4,409	8,780
Singapore	--	--	23,491	35,236
South Africa, Republic of	46,300	69,210	39,600	64,740
Taiwan	361,518	484,501	431,403	615,576
United Kingdom	918,601	1,314,335	2,344,063	3,237,207
Venezuela	8,800	12,341	20,009	30,812
Zimbabwe	--	--	9,700	15,833
Total	11,579,310	15,977,903	12,749,551	16,750,889
Lithium hydroxide:				
Argentina	386,916	668,863	262,732	436,559
Australia	204,883	350,940	167,000	278,238
Austria	950	1,030	--	--
Belgium	791	3,713	--	--
Brazil	953,925	1,626,832	649,345	1,125,288
Canada	19,481	31,630	136,000	257,980
Chile	39,457	75,396	34,394	65,200
Colombia	12,400	24,012	47,550	82,786
Ecuador	17,623	32,160	39,688	72,468
France	44,000	77,400	44,000	66,002
Germany, Federal Republic of	923,425	1,609,230	1,079,765	1,755,831
Greece	--	--	3,307	7,335
Honduras	6,600	13,530	4,400	8,395
India	503,498	842,238	420,336	762,876
Indonesia	92,000	187,264	76,000	152,065
Israel	40,344	70,373	48,492	87,025
Italy	6,614	12,831	--	--
Japan	1,459,124	2,600,737	1,135,087	2,043,074
Kenya	59,774	110,147	44,000	81,445
Korea, Republic of	203,987	338,728	240,393	389,534
Malaysia	--	--	8,818	15,432
Mexico	56,753	190,591	104,781	209,400
Netherlands	145,200	240,457	315,429	510,567
New Zealand	13,219	25,029	6,614	12,864
Pakistan	46,026	83,840	58,367	103,590
Peru	15,465	28,557	25,543	42,605
Philippines	45,000	74,360	50,325	91,460
Saudi Arabia	--	--	68,343	121,575
Singapore	88,148	160,264	70,437	121,662
South Africa, Republic of	139,360	246,716	206,271	352,096
Spain	44,000	79,200	--	--
Sweden	--	--	44,000	64,626
Taiwan	79,421	125,798	41,002	141,995
Thailand	17,931	32,573	36,000	63,665
Turkey	85,800	149,292	--	--
United Arab Emirates	5,292	9,633	37,239	65,313
United Kingdom	569,277	909,676	795,825	1,196,244
Uruguay	882	1,800	--	--
Venezuela	44,092	79,360	87,291	168,018
Yugoslavia	16,000	26,651	15,000	32,326
Zimbabwe	--	--	26,400	47,366
Total	6,387,658	11,140,851	6,430,174	11,032,905
Other:				
Argentina	124	2,632	12,202	587,602
Australia	27,480	66,771	64,956	155,299
Belgium	39,379	34,353	12,720	12,466
Bermuda	9,813	40,856	--	--
Bolivia	2,200	2,073	--	--

Table 3.—U.S. exports of lithium chemicals, by compound and country —Continued

Compound and country	1986 Gross weight (pounds)	1986 Value	1987 Gross weight (pounds)	1987 Value
Other —Continued				
Brazil	40,610	$122,174	34,259	$144,542
Canada	472,303	912,150	840,024	1,336,830
China	1,200	1,428	11,000	20,624
Colombia	4,792	14,825	1,615	12,840
Costa Rica	1,000	1,520	--	--
Denmark	--	--	14	1,596
Finland	9,211	16,120	--	--
France	122,773	291,491	48,624	128,216
Germany, Federal Republic of	338,142	1,466,270	175,230	240,100
Hong Kong	140	9,600	--	--
India	3,388	17,035	40	1,600
Israel	2,432	49,095	1,548	8,451
Italy	1,512	1,036	10,062	24,523
Jamaica	14,890	36,422	--	--
Japan	114,892	888,108	159,759	746,502
Jordan	--	--	1,704	1,879
Korea, Republic of	172,728	223,734	157,164	209,610
Mexico	181,155	420,718	534,796	1,463,046
Netherlands	321,200	488,612	66,000	97,662
Nigeria	--	--	73	4,440
Pakistan	20,041	41,157	12,042	31,835
Philippines	--	--	21,580	258,232
Saudi Arabia	75	12,588	--	--
Singapore	27,829	56,470	3,309	19,969
South Africa, Republic of	21,287	50,962	298	3,986
Sweden	--	--	1,561	155,365
Switzerland	156	3,588	--	--
Taiwan	8,927	43,404	31,487	97,666
United Arab Emirates	--	--	6,613	11,905
United Kingdom	1,126,018	2,657,074	474,780	1,157,173
Venezuela	5,978	11,861	4,758	23,038
Yugoslavia	551	75,742	486	105,080
Total	3,092,226	8,059,869	2,688,074	7,062,077

Source: Bureau of the Census.

Table 4.—U.S. imports for consumption of lithium-bearing materials, by commodity and country

Commodity and country	1986 Gross weight (pounds)	1986 Value (thousands) Customs	1986 Value (thousands) C.i.f.	1987 Gross weight (pounds)	1987 Value (thousands) Customs	1987 Value (thousands) C.i.f.
Lithium ores:						
Australia[1]	2,273,967	$247	$325	4,977,337	$491	$687
Brazil	--	--	--	30	1	2
Canada[1]	2,892,257	306	306	13,958,632	1,414	1,414
Japan	--	--	--	22	2	2
United Kingdom	--	--	--	496,000	57	57
Zimbabwe	21,488,181	2,639	2,985	16,914,565	1,627	1,825
Total	26,654,405	3,192	3,616	36,346,586	3,592	3,987
Lithium compounds:						
Belgium	--	--	--	132	4	4
Canada	--	--	--	55	1	1
Chile	4,125,042	5,239	5,525	4,347,930	4,845	5,121
China	5	2	2	4,409	6	8
France	12,200	3,161	3,178	6,013	593	598
Germany, Federal Republic of	51,787	330	342	34,014	249	257
Hong Kong	--	--	--	37,478	53	56
Japan	228	66	69	455	67	70
Switzerland	--	--	--	144,002	173	183
Taiwan	--	--	--	37,478	53	56
United Kingdom	381	49	50	6,129	130	131
Total	4,189,643	8,847	9,166	4,618,095	6,174	6,485

See footnote at end of table.

Table 4.—U.S. imports for consumption of lithium-bearing materials, by commodity and country —Continued

Commodity and country	1986			1987		
	Gross weight (pounds)	Value (thousands)		Gross weight (pounds)	Value (thousands)	
		Customs	C.i.f.		Customs	C.i.f.
Lithium salts:						
France	220	$8	$9	10,723	$9	$10
Germany, Federal Republic of	4,409	24	28	--	--	--
Japan	50	2	2	3,288	27	29
United Kingdom	90	4	4	--	--	--
Total	4,769	38	43	14,011	36	39
Lithium metal:						
France	--	--	--	3,340	7	8
Germany, Federal Republic of	4,333	24	25	10,482	21	23
Japan	--	--	--	50	2	3
United Kingdom	--	--	--	13,935	201	204
Total	4,333	24	25	27,807	231	238

[1]Spodumene concentrate.

Source: Bureau of the Census as adjusted by the Bureau of Mines.

WORLD REVIEW

Argentina.—Construction of a chemical plant to recover lithium, magnesium, and potassium salts from the Salar del Rincón was scheduled to begin before yearend. This brine deposit is near Campo Quijano in the Salta Province.[5]

Bolivia.—Brine-harvesting and mining concessions have been requested from Complejo Industrial de Recursos Evaporiticos del Salar de Uyuni, as well as permission to build a pilot plant for treatment of the brines of the Salar de Uyuni. Industria Minera Tierra Ltda. requested these concessions and planned to produce borax, boric acid, lithium, and magnesium salts and derivatives from the deposit, which reportedly contains higher concentrations of lithium than similar deposits in Chile. The company has also identified another deposit with high lithium concentrations as an alternative concession to the Salar de Uyuni request.[6]

Brazil.—Cia. Brasileira de Litio neared completion of its 1,700-ton-per-year lithium carbonate plant near Aracuai in Minas Gerais. The new facility was intended to make Brazil self-sufficient in lithium production; exports of lithium carbonate are also planned. The plant was designed to produce lithium carbonate from spodumene. Minas Gerais has proven reserves of lithium ores of 810,000 tons, including lepidolite, petalite, and spodumene. This is the second lithium operation to be built in Brazil. Nuclebras Monzanita e Associados Ltda. owns a lithium chemical plant, but the operation has been closed due to ore supply problems.[7]

Canada.—Tantalum Mining Corp. of Canada Ltd. (TANCO) announced plans to increase its spodumene concentrate capacity to 15,000 tons per year in 1988. The company also considered marketing a new product at its lithium operation in Bernic Lake, Manitoba. An amblygonite-spodumene concentrate containing about 6.5% lithium oxide and 8% to 10% phosphorous pentoxide would be produced as a byproduct of the company's spodumene concentrate. The amblygonite-spodumene concentrate would be targeted for specialty ceramics applications. TANCO also announced plans to resume tantalum production at the same location in 1988.[8]

Chile.—Sociedad Chilena de Litio Ltda., a joint venture between Foote and Corporación de Fomento de la Producción (CORFO), increased production to about 12 million pounds of lithium carbonate. This increase of more than 20% over that of 1986 approached the plant's design capacity of 16 million pounds. Investigations of the feasibility of a second operation at the Salar continued. AMAX Exploration Inc. (United States), CORFO, and Molibdenos y Metales S.A. (Chile) formed a consortium, Minera Salar de Atacama Ltda., to conduct a 3-year evaluation program, which began in 1986.[9]

Yugoslavia.—A lithium battery factory was built by the Trepca Enterprise in Gnjilane, Vojvodina. The factory, a joint venture with Battery Engineering Inc. of the United States, was planned to produce $3 million worth of batteries per year. Button, cylindrical, and spiral cells will be produced.[10]

Zimbabwe.—A new heavy-medium separation plant was built to recover petalite from a huge stockpile that had previously been considered waste material because it was impossible to separate by means of handpicking.[11] The ore concentrates recovered from the stockpile are expected to be produced with no additional mining expenses.

Table 5.—Lithium minerals and brine: World production, by country[1]

(Short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Argentina (minerals not specified)	168	24	[e]22	[e]22	22
Australia, spodumene	1,100	7,200	12,300	[e]12,100	13,000
Brazil:					
Amblygonite	125	54	130	[e]165	165
Lepidolite	1	--	--	--	--
Petalite	2,086	526	1,458	[r][e]1,270	1,380
Spodumene	128	317	118	[r][e]220	220
Canada, spodumene	--	[e]90	[e]330	688	820
Chile, carbonate from subsurface brine	--	2,326	4,969	4,914	4,960
China (minerals not specified)[e] [3]	16,500	16,500	16,500	16,500	16,500
Namibia:					
Amblygonite	56	67	55	57	55
Lepidolite	34	23	121	57	55
Petalite	770	880	1,984	1,230	1,200
Portugal, lepidolite	601	1,086	143	(4)	--
U.S.S.R. (minerals not specified)[e] [3]	60,600	60,600	60,600	60,600	60,600
United States, spodumene and subsurface brine	W	W	W	W	W
Zimbabwe (minerals not specified)	21,157	[r]24,855	30,765	36,117	37,500

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Table includes data available through Apr. 22, 1988.
[2]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.
[3]These estimates denote only an approximate order of magnitude; no basis for more exact estimates is available. Output by China and the U.S.S.R. has never been reported.
[4]Revised to zero.

TECHNOLOGY

The Bureau of Mines conducted research into the recovery of lithium from clays. The McDermitt caldera on the Nevada-Oregon border is estimated to contain more than 3 million tons of lithium. Lithium recovery of over 80% was achieved by limestone-gypsum roasting and selective chlorination techniques. Although the tests were successful, the costs of both processes were considered to be prohibitive. The limestone-gypsum process cost an estimated $2.02 to produce 1 pound of lithium carbonate, and the selective chlorination process costs were estimated at $3.85 per pound of lithium carbonate.[12]

A lithium-iron-sulfide battery developed by Argonne National Laboratories to power street vehicles delivered the equivalent of 200 miles of city driving in a bench-scale test. The test was conducted at a laboratory operated for DOE by the University of Chicago. Researchers have been working since the 1973 energy crisis to develop a battery-powered vehicle that would not require gasoline for its operation. The battery will be road tested in 1988 by the Tennessee Valley Authority in a cargo van adapted for its use.[13]

Research continued to determine the optimum concentration of lithium in aluminum-lithium alloys to minimize density without adversely affecting strength and stability. Scientists at Lawrence Berkeley Laboratory's Center for Advanced Materials were searching for the best materials to use in a proposed "space plane." The space plane is intended to take off from conventional runways and reach orbital speed. The laboratory is operated for DOE by the University of California.[14]

Foote has developed a lithium ceramic consisting of a mixture of lithium aluminate and lithium silicate solutions that hardens at room temperature to form a heat-resistant, ceramic-like material. The material shows compressive strengths of

6,000 (pounds per square inch) when hardened at room temperature. When fired, the strength of the material increases.[15]

Lithium carbonate has been used for decades to treat manic-depressive mental disorders. A study conducted at Ben Gurion University of the Negev, Beersheba, Israel, found that lithium blocks the activity of two types of protein that trigger many types of cell response to outside stimuli.[16]

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[1]Physical scientist, Branch of Industrial Minerals.
[2]Metals Week. Cyprus Dives Into Lithium. V. 58, No. 51, 1987, p. 3.
[3]Chemical Marketing Reporter. Lithium Sparks Batteries. V. 231, No. 26, 1987, p. 9.
[4]Haflich, F. Scrap Output Is Taking Off. Am. Met. Mark., v. 95, No. 151, 1987, p. 10.
[5]Industrial Minerals (London). Lithium—No Shortage in Supply. No. 237, 1987, p. 30.
[6]Crozier, R. D. Bolivia's Industrial Minerals An Update. Ind. Miner. (London), No. 241, 1987, p. 67.
[7]Industrial Minerals (London). Lithium Plant Nears Completion. No. 244, 1987, p. 8.
[8]Page 24 of work cited in footnote 6.
[9]Work cited in footnote 6.
[10]Industrial Minerals (London). Gnjilane Li Battery Factory. No. 234, 1987, p. 75.
[11]Page 29 of work cited in footnote 6.
[12]Crocker, L., and R. H. Lien. Lithium and Its Recovery From Low-Grade Nevada Clays. BuMines B691, 1988, 37 pp.
[13]Bishop, J. New Kind of Storage Battery Boosts Electric-Car Prospects. Wall St. J., v. 209, No. 85, 1987, p. 25.
[14]Yarris, L. LBL Studies Hypersonic Plane Material. Lawrence Berkeley Laboratory, Berkeley, CA, 1987, 2 pp.
[15]Chemical & Engineering News. Room-Temperature Lithium Ceramic Invented. V. 65, No. 20, 1987, p. 21.
[16]———. Lithium Ions May Inhibit G-Protein Activity. V. 66, No. 6, 1988, p. 16.

Magnesium

By Deborah A. Kramer[1]

Domestic primary magnesium production decreased slightly, but apparent consumption increased as producers drew down their stocks to meet demand. The largest U.S. producer increased its operating capacity near the end of 1987 to reduce its stock depletion. The United States remained a net exporter of magnesium, while both exports and imports increased.

New primary magnesium plant construction continued, principally in Canada, and expansion plans for a magnesium plant in Brazil were postponed. If announced capacity increases outside the United States occur as scheduled, a world oversupply of magnesium could occur by the end of the decade.

Development of new alloys and new casting and foundry techniques had the potential for increasing magnesium usage in large-volume applications, including automobiles and aircraft. Magnesium's high strength-to-weight ratio and its light weight were utilized in these and other applications.

Domestic Data Coverage.—Domestic consumption data for magnesium metal are developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the 114 operations to which a survey request was sent, 83% responded, representing 48% of the primary magnesium consumption shown in tables 1 and 3. Consumption for the 19 nonrespondents was estimated using reported prior year consumption levels.

Table 1.—Salient magnesium statistics

(Short tons unless otherwise specified)

	1983	1984	1985	1986	1987
United States:					
Production:					
Primary magnesium	115,431	159,207	149,614	138,493	137,123
Secondary magnesium	46,329	48,357	45,523	46,084	49,786
Exports	46,690	48,337	40,322	43,992	48,677
Imports for consumption	6,350	9,381	9,271	r9,210	11,961
Consumption, primary	81,976	89,887	83,502	77,119	93,000
Price per pound	$1.38	$1.43-$1.48	$1.48-$1.53	$1.53	$1.53
World: Primary production	286,755	360,459	362,381	p362,191	e354,740

eEstimated. pPreliminary. rRevised.

DOMESTIC PRODUCTION

Production of primary magnesium was about 81% of domestic capacity of 169,000 short tons. Three companies produced magnesium in 1987: AMAX Magnesium Corp., Rowley, UT; The Dow Chemical Co., Freeport, TX; and Northwest Alloys Inc., a subsidiary of Aluminum Co. of America (Alcoa), Addy, WA. AMAX recovered magnesium from purchased brines and Dow recovered magnesium from seawater; both companies used an electrolytic process for metal production. Northwest Alloys recovered magnesium from dolomite by a silicothermic process.

AMAX continued to purchase brine from two domestic companies, Kaiser Aluminum

& Chemical Corp. and Leslie Salt Div. of Cargill Inc., to replace brine from AMAX's solar ponds, which were destroyed in a June 1986 flooding of the Great Salt Lake. In June 1987, AMAX announced that it was constructing a new solar pond system in Knolls, UT, which would use highly concentrated brines from the State's west desert pumping station as feedstock. Construction of the ponds was expected to begin in the summer of 1988, and initial plant feedstock would be available by yearend 1988. AMAX planned to continue purchasing brine until the ponding operation is running at full capacity in late 1989.

Dow reportedly brought additional electrolytic cells on-line at its primary magnesium plant in November 1987. The additional cells increased Dow's operating capacity to 83,000 tons per year, or 86% of its 96,000-ton-per-year plant capacity. Increased production rates were because of a sharp decline in Dow's inventories, in response to increased magnesium demand from the U.S. aluminum industry, and increased use in Europe for iron and steel desulfurization. Dow also announced that, through an ongoing modernization program begun after the energy crisis of the 1970's, the company reduced the energy required to produce magnesium by 39%. Productivity and quality improvements were the result of the extensive modernization program, the introduction of statistical quality controls, computerized materials processing, and robotic materials handling.[2]

Table 2.—Magnesium recovered from scrap processed in the United States, by kind of scrap and form of recovery

(Short tons)

	1983	1984	1985	1986	1987
KIND OF SCRAP					
New scrap:					
Magnesium-base	2,873	3,192	1,664	1,092	932
Aluminum-base	18,718	18,402	17,915	19,645	23,002
Total	21,591	21,594	19,579	20,737	23,934
Old scrap:					
Magnesium-base	5,311	5,232	5,104	4,363	4,252
Aluminum-base	19,427	21,531	20,840	20,984	21,600
Total	24,738	26,763	25,944	25,347	25,852
Grand total	46,329	48,357	45,523	46,084	49,786
FORM OF RECOVERY					
Magnesium alloy ingot[1]	4,232	4,229	4,231	4,327	4,410
Magnesium alloy castings (gross weight)	952	980	483	r607	493
Magnesium alloy shapes	--	--	--	34	--
Aluminum alloys	39,451	41,072	39,459	r41,108	44,876
Zinc and other alloys	20	12	9	3	W
Chemical and other dissipative uses	4	9	3	W	W
Cathodic protection	1,670	2,055	1,338	W	--
Total	46,329	48,357	45,523	46,084	49,786

rRevised. W Withheld to avoid disclosing company proprietary data; included in "FORM OF RECOVERY: Total."
[1]Includes secondary magnesium content of both secondary and primary alloy ingot.

CONSUMPTION AND USES

Primary magnesium consumption increased from that of 1986 in most end uses, particularly aluminum alloying. Magnesium consumption for iron and steel desulfurization was estimated to be about 10,000 tons.

Introduction of magnesium components into the automotive market continued as Dow and Pontiac Motorsports Div. of General Motors Co. developed a sand-cast magnesium racing car engine block. The magnesium engine, with all components installed, weighed 226 pounds, a 96-pound weight savings when compared with cast-iron racing engines. After road tests were completed, Pontiac planned to market the engine in five standard displacements.

A complex magnesium extrusion produced by Dow was used in the agricultural industry as part of a laser system that prepares land for installation of irrigation systems. The magnesium extrusion, used in the Laserplane Analog system developed by Spectra-Physics Inc., supports a mast mounted on earth-moving equipment. A 360° laser beam in the field sends data on the terrain to a receiver mounted on the mast. The terrain data are used to guide the earth-moving equipment so that high, dry areas that do not get enough water are leveled off, and low areas that get too much water are filled in. Magnesium, 37% lighter than aluminum for this application, was used for the mast supports because the masts were designed to be moved by hand from one machine to another.[3]

Hughes Aircraft Co. used magnesium as a structural component in the antennas of airborne radar systems designed for use in military aircraft. Antennas fluctuate rapidly while sending and receiving data; therefore, they must be lightweight and strong, and the material used to fabricate the antennas must be easily machined. Magnesium's high strength-to-weight ratio and its ease of machinability were the reasons the metal was selected for the antennas. Special high-speed machining techniques were developed by Hughes to fabricate the AZ31B magnesium alloy plate into the antenna.

Table 3.—U.S. consumption of primary magnesium, by use

(Short tons)

Use	1983	1984	1985	1986	1987
For structural products:					
Castings:					
Die	1,937	595	2,457	4,019	4,090
Permanent mold	16	1,666	909	825	957
Sand	1,388	1,932	1,634	1,513	1,603
Wrought products:					
Extrusions	7,093	5,828	7,756	6,928	7,500
Other[1]	4,342	4,418	4,193	4,341	4,281
Total	14,776	14,439	16,949	17,626	18,431
For distributive or sacrificial purposes:					
Alloys:					
Aluminum	46,026	48,673	40,850	40,569	54,878
Other	7	8	8	6	9
Cathodic protection (anodes)	5,686	4,777	4,748	6,991	6,104
Chemicals	5,664	5,501	3,824	1,597	1,154
Nodular iron	2,200	2,408	1,698	1,788	1,996
Reducing agent for titanium, zirconium, hafnium, uranium, beryllium	4,711	6,689	8,126	5,771	5,827
Other[2]	2,906	7,392	7,299	2,771	4,601
Total	67,200	75,448	66,553	59,493	74,569
Grand total	81,976	89,887	83,502	77,119	93,000

[1]Includes sheet and plate and forgings.
[2]Includes scavenger, deoxidizer, and powder.

STOCKS

Yearend consumer stocks of primary magnesium ingot increased to 6,185 tons in 1987 from 5,473 tons in 1986. Magnesium alloy ingot stocks declined to 676 tons at yearend 1987 from 759 tons at yearend 1986. Producers' stocks of primary magnesium ingot decreased substantially to 24,516 tons at yearend 1987 from 37,078 tons at yearend 1986.

Table 4.—Stocks and consumption of new and old magnesium scrap[1] in the United States

(Short tons)

	Stocks, Jan. 1	Receipts	Consumption: New scrap	Consumption: Old scrap	Consumption: Total	Stocks, Dec. 31
1986	1,215	4,264	24	4,363	4,387	1,092
1987	1,092	4,452	234	4,252	4,486	1,058

[1]Cast scrap, solid wrought scrap, borings, turnings, and drosses.

PRICES

Throughout 1987, AMAX and Dow maintained the same price quotes for primary magnesium ingot and diecasting alloy as were quoted in 1986. The producers' primary magnesium ingot price was $1.53 per pound, AMAX's price for diecasting alloy was $1.29 per pound, and Dow's diecasting alloy price was $1.33 per pound.

FOREIGN TRADE

Imports and exports of magnesium increased in quantity from those of 1986. The United States remained a net exporter of magnesium, and Japan and the Netherlands were the destination of 55% of the U.S. magnesium exports. Imports increased by 30% from those in 1986. Canada and Norway were the principal import sources, accounting for 75% of domestic imports.

Table 5.—U.S. exports and imports for consumption of magnesium

EXPORTS

Year	Waste and scrap: Quantity (short tons)	Waste and scrap: Value (thousands)	Metals and alloys in crude form: Quantity (short tons)	Metals and alloys in crude form: Value (thousands)	Semifabricated forms, n.e.c.: Quantity (short tons)	Semifabricated forms, n.e.c.: Value (thousands)
1985	795	$2,071	37,484	$100,128	2,043	$11,401
1986	852	1,990	41,012	106,896	2,128	13,492
1987	1,417	3,623	44,315	110,898	2,945	16,151

IMPORTS FOR CONSUMPTION

Year	Waste and scrap: Quantity (short tons)	Waste and scrap: Value (thousands)	Metal: Quantity (short tons)	Metal: Value (thousands)	Alloys (magnesium content): Quantity (short tons)	Alloys (magnesium content): Value (thousands)	Powder, sheets, tubing, ribbons, wire, other forms (magnesium content): Quantity (short tons)	Powder, sheets, tubing, ribbons, wire, other forms (magnesium content): Value (thousands)
1985	2,874	$4,778	1,992	$5,525	3,651	$12,774	754	$2,010
1986	2,099	3,895	r3,093	r8,115	1,808	7,008	2,210	5,556
1987	2,873	5,391	3,959	10,832	2,921	8,624	2,208	6,117

rRevised.

Source: Bureau of the Census.

Table 6.—U.S. exports of magnesium, by country

Country	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)
1986:						
Argentina	10	$26	362	$905	115	$476
Australia	6	25	2,644	6,129	146	598
Austria	--	--	208	616	5	71
Bahrain	--	--	88	221	--	--
Belgium-Luxembourg	10	20	--	--	4	61
Brazil	--	--	961	2,358	4	24
Canada	355	833	3,348	8,046	497	2,458
China	--	--	3,228	8,351	2	8
Colombia	--	--	34	87	18	212
France	--	--	2	21	27	426
Germany, Federal Republic of	255	663	587	1,717	49	449
Ghana	--	--	969	2,359	--	--
Hong Kong	--	--	299	766	--	--
India	--	--	166	423	22	156
Italy	--	--	26	77	149	1,308
Japan	27	48	9,926	25,812	233	1,309
Korea, Republic of	--	--	570	1,927	33	406
Mexico	171	353	1,192	3,109	202	1,005
Netherlands	--	--	14,109	37,702	7	81
New Zealand	--	--	36	89	2	29
Norway	--	--	28	53	3	36
Singapore	--	--	44	88	34	329
South Africa, Republic of	--	--	590	1,690	17	102
Spain	--	--	789	2,004	15	231
Sweden	--	--	78	210	21	219
Taiwan	15	13	209	599	19	61
Turkey	--	--	9	26	--	--
United Kingdom	1	2	420	1,236	289	2,304
Venezuela	--	--	14	60	43	141
Other	2	7	r76	r215	r172	r992
Total	852	1,990	41,012	106,896	2,128	13,492
1987:						
Argentina	--	--	540	1,262	71	379
Australia	--	--	1,918	4,470	150	679
Austria	--	--	1	9	6	91
Bahrain	--	--	459	1,160	--	--
Belgium-Luxembourg	4	8	69	145	479	1,729
Brazil	11	27	764	1,902	2	10
Canada	505	1,170	5,170	12,076	185	1,549
China	--	--	2,275	5,368	289	722
Colombia	--	--	31	75	18	74
France	--	--	1	2	38	450
Germany, Federal Republic of	633	1,895	1,717	4,606	260	988
Ghana	--	--	930	2,315	--	--
Hong Kong	--	--	22	54	--	--
India	5	15	314	904	12	93
Italy	--	--	23	51	139	1,214
Japan	163	299	9,671	23,620	176	1,314
Korea, Republic of	3	6	637	2,188	77	243
Mexico	64	132	656	1,495	193	667
Netherlands	6	12	16,214	41,737	307	1,221
New Zealand	--	--	36	78	4	57
Norway	--	--	55	163	2	32
Singapore	--	--	45	89	15	137
South Africa, Republic of	--	--	20	55	69	356
Spain	--	--	2,103	5,360	30	487
Sweden	--	--	42	97	15	249
Taiwan	21	51	255	670	44	187
Turkey	--	--	118	298	--	--
United Kingdom	--	--	14	44	151	1,781
Venezuela	2	8	--	--	41	157
Other	--	--	215	605	172	1,285
Total	1,417	3,623	44,315	110,898	2,945	16,151

rRevised.

Source: Bureau of the Census.

WORLD REVIEW

Brazil.—Because of power supply problems, Brazileira do Magnesio S.A. (Brasmag) announced that some of its expansion plans would be delayed. Brasmag completed a 2,200-ton-per-year-capacity expansion in 1986, but an 11,000-ton-per-year expansion, originally scheduled for completion in July 1987, was postponed until mid-1988. The final phase of Brasmag's expansion of an additional 22,000 tons per year of capacity was awaiting Governmental approval at yearend. Although furnaces for the 11,000-ton-per-year expansion were completed, company officials cited problems with imports and delivery delays in equipment purchased in Brazil, coupled with the lack of power transmission lines, as reasons for the postponement of Brasmag's plant expansion.

Canada.—Norsk Hydro A/S reportedly began construction of its 66,000-ton-per-year primary magnesium facility in Becancour, Quebec. The plant was scheduled to come on-stream in 1989, and Norsk Hydro reportedly will phase in production slowly to keep pace with market development.

MPLC Holdings S.A. and Alberta Natural Gas Co. Ltd. announced the formation of a new company, Magnesium Co. of Canada Ltd. (MagCan), to construct a 69,000-ton-per-year primary magnesium plant near Aldersyde, Alberta. The joint venture was similar to the joint venture between MPLC and Alcoa, which Alcoa pulled out of in 1986. Construction was expected to begin in 1988 of one unit, with a production capacity of 13,800 tons per year, which was scheduled to be completed by August 1989. Two additional units of 27,600 tons per year each were to come on-stream by 1993. The plant was expected to use MPLC's direct-reduction technology to recover magnesium from magnesite, and MagCan also was expected to negotiate a contract with Baymag, Canada's sole magnesite producer, to provide the plant's feed material. MagCan planned to market its magnesium in North America.

Table 7.—Magnesium: World primary production, by country[1]

(Short tons)

Country	1983	1984	1985	1986[p]	1987[e]
Brazil	551	1,323	2,866	4,960	6,400
Canada[e]	6,600	8,800	7,700	7,700	7,700
China[e]	7,700	7,700	7,700	7,700	7,700
France	12,208	14,299	15,212	[e]15,400	15,400
Italy	8,473	8,257	8,667	13,687	12,100
Japan	6,643	7,830	9,321	8,946	[2]9,017
Norway	32,897	54,343	60,301	62,305	55,100
U.S.S.R.[e]	91,000	94,000	96,000	98,000	99,200
United States	115,431	159,207	149,614	138,493	[2]137,123
Yugoslavia[e]	[2]5,252	4,700	5,000	5,000	5,000
Total	286,755	360,459	362,381	362,191	354,740

[e]Estimated. [p]Preliminary.
[1]Table includes data available through July 1, 1988.
[2]Reported figure.

Table 8.—Magnesium: World secondary production, by country[1]

(Short tons)

Country	1983	1984	1985	1986[p]	1987[e]
Japan	14,343	17,258	23,032	15,890	[2]11,336
U.S.S.R.[e]	9,000	9,000	9,000	9,000	9,000
United Kingdom	[e]1,900	1,102	992	[e]1,100	1,000
United States	46,329	48,357	45,523	46,084	[2]49,786
Total	71,572	75,717	78,547	72,074	71,122

[e]Estimated. [p]Preliminary.
[1]Table includes data available through July 1, 1988.
[2]Reported figure.

TECHNOLOGY

Scientists at Dow developed a patented process and equipment to produce magnesium alloy parts by a technique similar to the injection-molding process used in the plastics industry. Room-temperature magnesium particles were fed to an atmosphere-controlled screw injection system, where the magnesium was turned into a soft mass. The mass can be injected into a die to form a die-cast metal part. The new process could eliminate the melting operation used in traditional diecasting operations. In addition, advantages of the injection-molding process were improved cycle rates, die and casting efficiency, and product quality, compared to hot-chamber or cold-chamber diecasting.[4]

In a review of magnesium alloys used in the aerospace industry, alloys with improved elevated temperature applications are described; high-strength alloys with useful properties up to 299° C were available. Adoption of resin-bonded sands for both molds and cores in the foundry industry, coupled with development of techniques for producing longer and narrower cored passageways, has enabled foundries to produce longer, more complex magnesium alloy castings. The production of castings with thinner sections was also possible, with the benefit of weight savings.[5]

Two new alloys for magnesium castings and wrought products were developed by Magnesium Elektron Ltd., using zinc and copper as the principal alloying elements. ZC63 combined moderate ambient temperature strength with useful elevated temperature properties up to at least 150° C. This alloy could be used in high-temperature automotive applications such as engine components and impellers. ZC71 had a range of room-temperature strengths depending on the heat treatment used after extrusion. This alloy should be useful for vehicle subframes, suspension arms, and body members. Optimum alloy compositions were defined for alloys for sand castings, permanent mold castings, and wrought products, but further development was required for the diecasting alloy.[6]

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[1]Physical scientist, Branch of Nonferrous Metals.

[2]Wilson, C. B. Dow Magnesium—A 10 Year Success Story. Paper in Magnesium in the Auto Industry: Prospects for the Future. Proceedings of 44th Annual World Magnesium Conference. Int. Magnesium Assoc., 1987, pp. 64-66.

[3]Modern Metals. Magnesium Extrusion Helps Laser System Level Farm Land. V. 43, No. 6, July 1987, pp. 46-48.

[4]Erickson, S. C. A Process for the Injection Molding of Thixotropic Magnesium Alloy Parts. Paper in Magnesium in the Auto Industry: Prospects for the Future. Proceedings of 44th Annual World Magnesium Conference. Int. Magnesium Assoc., 1987, pp. 39-45.

[5]Stevenson, A. Mg Casting Alloys for the Aerospace Challenge. J. Met., v. 39, No. 5, May 1987, pp. 16-19.

[6]Unsworth, W. A New Magnesium Alloy for Automobile Applications. Paper in Magnesium in the Auto Industry: Prospects for the Future. Proceedings of 44th Annual World Magnesium Conference. Int. Magnesium Assoc., 1987, pp. 22-27.

Magnesium Compounds

By Deborah A. Kramer[1]

Domestic shipments of caustic-calcined magnesia and refractory magnesia increased in 1987 following a 4-year decline to a record-low level in 1986. Upturns in the iron and steel and nonferrous metals industries were primarily responsible for an increase in demand. Increased imports helped in meeting the greater demand, while exports of magnesia declined. Technical developments in recovering magnesia from magnesite, seawater, or brines coupled with increasing product purity requirements have changed the magnesia market over the past several years.

Seawater and well and lake brines were the principal source of domestically produced magnesium compounds. One company mined magnesite in Nevada, and several olivine mines were operated in North Carolina and Washington.

Domestic Data Coverage.—Domestic data for magnesium compounds shipped and used are developed by the Bureau of Mines from a voluntary survey of U.S. operations entitled "Magnesium Compounds." Of the 21 operations to which a survey request was sent, 86% responded, representing 80% of the magnesium compounds shipped and used shown in table 3. Data for the three nonrespondents were estimated using prior year production levels and other factors.

Table 1.—Salient magnesium compound statistics

(Thousand short tons and thousand dollars)

	1983	1984	1985	1986	1987
United States:					
Caustic-calcined and specified magnesias:[1]					
Shipped by producers:[2]					
Quantity	143	142	100	95	113
Value	$57,416	$42,257	$33,772	$33,969	$27,565
Exports: Value[3]	$8,426	$14,026	$9,773	$13,295	$14,167
Imports for consumption: Value[3]	$5,476	$9,594	$10,407	$11,493	$4,575
Refractory magnesia:					
Shipped by producers:[2]					
Quantity	456	374	290	274	326
Value	$98,473	$87,945	$81,149	$73,172	$80,760
Exports: Value	$1,955	$3,641	$5,529	$5,488	$3,240
Imports for consumption: Value	$11,495	$23,715	$29,767	$36,718	$41,333
Dead-burned dolomite:					
Sold and used by producers:					
Quantity	418	487	376	424	[p]285
Value	$24,454	$29,391	$24,454	$27,789	[p]$21,766
World: Production (magnesite)	[r]13,412	[r]14,130	16,109	[p]16,313	[e]16,454

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Excludes caustic-calcined magnesia used in the production of refractory magnesia.
[2]Includes magnesia used by producers.
[3]Caustic-calcined magnesia only.

DOMESTIC PRODUCTION

After a 4-year decline in domestic magnesium compound shipments, both caustic-calcined and refractory magnesia shipments increased by 19% from those of 1986. Seawater and well and lake brines were the dominant source of magnesium compounds with some magnesia recovered from magnesite and dolomite. Olivine shipments from mines in North Carolina and Washington declined 7% from those of 1986, but the average value increased by 37%.

The Dow Chemical Co. reportedly sold its epsom salt assets and technology to PQ Corp. Under terms of the sale agreement, Dow would continue to produce epsom salt at its Midland, MI, facility through yearend 1988, while PQ would bring on additional capacity at its plants in California and Illinois. After this phaseout period, Dow's epsom salt plant would be dismantled.

Genentech Inc. reportedly purchased Merck & Co. Inc.'s south San Francisco, CA, magnesium compound facility. Although this plant was expected to be closed, Merck planned to produce magnesium compounds through most of 1988. As part of its restructuring, Kaiser Aluminum & Chemical Corp. announced the sale of its Wendover, UT, brine facility to Reilly Tar & Chemicals Corp.

Basic Magnesia Inc. reportedly completed improvements at its Port St. Joe, FL, magnesia plant. By adding enclosed burners to its multiple hearth furnace, fuel efficiency and product consistency were improved.

Table 2.—Magnesium compound producers, by raw material source, location, and production capacity in 1987

Raw material source and producing company	Location	Capacity (short tons of MgO equivalent)
Magnesite: Basic Inc	Gabbs, NV	110,000
Lake brines:		
Great Salt Lake Minerals & Chemicals Corp	Ogden, UT	100,000
Kaiser Aluminum & Chemical Corp	Wendover, UT	50,000
Well brines:		
The Dow Chemical Co	Ludington, MI	220,000
Do	Midland, MI	75,000
Martin Marietta Chemicals	Manistee, MI	330,000
Morton Chemical Co	do	10,000
Seawater:		
Barcroft Co	Lewes, DE	5,000
Basic Magnesia Inc	Port St. Joe, FL	55,000
The Dow Chemical Co	Freeport, TX	75,000
Merck & Co. Inc	South San Francisco, CA	15,000
National Refractories & Minerals Corp	Moss Landing, CA	150,000
Total		1,195,000

CONSUMPTION AND USES

Refractory products for use in the iron and steel and nonferrous metals industries were the principal applications for magnesia. Animal feed, accounting for 31% of domestic shipments, remained the dominant use of caustic-calcined and specified magnesias. Chemicals and pulp and paper represented the market for 27% of domestic shipments; and fuel additives, rubber, stack gas scrubbing, and refractories, in declining order, accounted for 23% of U.S. shipments. The following uses, in declining order, represented the remaining 19% of caustic-calcined magnesia shipments: sugar and candy, oxychloride and oxysulfate cements, medicine and pharmaceuticals, water treatment, ceramics, fertilizer, insulation and wallboard, electrical, uranium processing, and rayon.

Magnesium hydroxide was principally used in the pulp and paper and refractories industries; magnesium sulfate was used for chemicals, medicine and pharmaceuticals, and animal feed; and precipitated magnesium carbonate was used mainly in chemicals, medicine and pharmaceuticals, and fertilizer. Fifty-six percent of olivine shipments was used as foundry sands, 28% for refractories, and the remainder for slag control and soil conditioners.

Table 3.—U.S. magnesium compounds shipped and used

	1986		1987	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Caustic-calcined[1] and specified (USP and technical) magnesias	95,366	$33,969	113,460	$27,565
Magnesium hydroxide (100% $Mg(OH)_2$)[1]	228,917	56,305	263,187	52,578
Magnesium sulfate (anhydrous and hydrous)	51,295	15,388	61,294	19,447
Precipitated magnesium carbonate[1]	4,870	765	2,828	660
Refractory magnesia	274,429	73,172	325,634	80,760

[1]Excludes material produced as an intermediate step in the manufacture of other magnesium compounds.

PRICES

Magnesium compound prices at yearend were published in the Chemical Marketing Reporter as follows:

Magnesia, natural, technical, heavy, 85%, f.o.b. Nevada	per short ton	$232
Magnesia, natural, technical, heavy, 90%, f.o.b. Nevada	do	265
Magnesium chloride, hydrous, 99%, flake	do	290
Magnesium carbonate, light, technical (freight equalized)	per pound	$0.73- .83
Magnesium hydroxide, National Formulary, powder (freight equalized)	do	.78
Magnesium sulfate, technical	do	.14

FOREIGN TRADE

Imports for consumption of magnesia continued to increase in quantity as they have each year since 1982. Data in table 5 show that imports of caustic-calcined magnesia declined significantly in 1987, particularly from Canada. However, much of the magnesia classified as caustic-calcined magnesia imported from Canada prior to 1987 was reclassified as magnesium oxide in 1987. It accounted for the large increase in imports of magnesium oxide shown in table 6.

Imports of olivine were not separately identified by the Bureau of the Census, but through the Journal of Commerce Trade Information Service-PIERS, some olivine imports were identified. According to PIERS, which contains data on materials transported by ship, 163,241 tons of olivine were imported from Norway in 1987.

Table 4.—U.S. exports of magnesite and magnesia, by country

Country	Magnesite and magnesia, dead-burned				Magnesite, n.e.c., including crude caustic-calcined, lump or ground			
	1986		1987		1986		1987	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Argentina	--	--	--	--	13	$18	72	$74
Australia	--	--	--	--	1,250	410	191	214
Austria	3,308	$897	--	--	--	--	--	--
Belgium-Luxembourg	--	--	--	--	339	376	403	377
Brazil	7	6	--	--	175	400	397	624
Canada	16,593	3,747	4,337	$972	14,788	7,744	16,354	9,238
Chile	--	--	3,967	992	677	225	3	3
Colombia	822	118	1,774	290	91	138	72	105
Czechoslovakia	--	--	--	--	42	108	122	161
Dominican Republic	--	--	514	96	--	--	--	--
France	--	--	--	--	113	99	175	134
Germany, Federal Republic of	--	--	--	--	725	578	808	629
Guatemala	--	--	--	--	2	3	555	208
Italy	--	--	--	--	306	202	420	415
Japan	175	40	136	31	31	8	98	61

Table 4.—U.S. exports of magnesite and magnesia, by country —Continued

Country	Magnesite and magnesia, dead-burned				Magnesite, n.e.c., including crude caustic-calcined, lump or ground			
	1986		1987		1986		1987	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Korea, Republic of	--	--	50	$11	98	$58	37	$22
Mexico	620	$145	508	105	1,587	1,026	412	305
Netherlands	--	--	--	--	605	417	390	299
New Zealand	150	67	--	--	44	74	65	71
Peru	1,102	294	2,755	730	9	15	13	14
Saudi Arabia	824	152	--	--	--	--	11	12
Spain	--	--	--	--	175	109	229	202
Sweden	--	--	--	--	297	228	318	216
Taiwan	78	11	90	13	206	84	51	31
United Kingdom	--	--	--	--	226	369	157	214
Venezuela	19	2	--	--	853	387	741	237
Yugoslavia	--	--	--	--	27	64	149	73
Other	r48	r9	--	--	r122	r155	153	228
Total	23,746	5,488	14,131	3,240	22,801	13,295	22,396	14,167

rRevised.

Source: Bureau of the Census.

Table 5.—U.S. imports for consumption of crude and processed magnesite, by country

Country	1986		1987	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Lump or ground caustic-calcined magnesia:[1]				
Canada	44,230	$7,990	10,366	$1,547
China	796	84	9,677	685
Czechoslovakia	8,105	574	8,777	653
Greece	13,710	1,364	9,758	1,041
Mexico	1,037	154	502	64
Spain	7,431	836	432	104
Turkey	3,366	468	2,401	464
Other	67	23	98	17
Total	78,742	11,493	42,011	4,575
Dead-burned and grain magnesia and periclase:				
Not containing lime or not over 4% lime:				
Brazil	1,654	225	55	10
Canada	1,481	566	2,328	902
China	42,708	5,141	47,651	6,410
Czechoslovakia	3,858	262	--	--
Greece	84,317	11,933	50,190	7,787
Iceland	--	--	3,378	958
Ireland	24,088	6,959	24,431	6,730
Israel	20	4	9,211	3,638
Italy	--	--	591	139
Japan	9,255	3,878	25,081	5,202
Mexico	11,395	2,980	16,367	4,339
Netherlands	10,575	3,149	8,864	2,330
South Africa, Republic of	--	--	1,102	490
Turkey	1,689	243	--	--
United Kingdom	3,511	1,314	15,669	2,334
Other	r63	r64	149	64
Total	194,614	36,718	205,067	41,333
Containing over 4% lime:				
Austria	863	302	1,078	394
Canada	15,025	1,565	15,600	1,683
France	--	--	9	7
Germany, Federal Republic of	132	49	--	--
Greece	1,372	188	--	--
Mexico	1,109	80	1,801	122
United Kingdom	20	4	--	--
Total	18,521	2,188	18,488	2,206
Total dead-burned and grain magnesia and periclase	213,135	38,906	223,555	43,539

rRevised.

[1]In addition, crude magnesite was imported as follows, in short tons and thousand dollars: 1986—Canada, 37 ($15). 1987—Canada, 29 ($6); Italy, 3,176 ($695); Japan, 4 ($2); and the Netherlands, 109 ($30).

Source: Bureau of the Census.

Table 6.—U.S. imports for consumption of magnesium compounds

Year	Oxide or calcined magnesia		Magnesium carbonate[1] (precipitated)		Magnesium chloride (anhydrous)		Magnesium chloride (other)		Magnesium sulfate (epsom salts and kieserite)		Magnesium salts and compounds, n.s.p.f.[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)	Quantity (short tons)	Value (thousands)
1985	4,891	$5,638	247	$351	125	$21	2,975	$368	25,691	$1,902	2,822	$1,805
1986	5,702	5,804	217	346	15	5	3,633	381	27,174	1,711	3,066	2,791
1987	34,875	13,768	554	713	475	102	7,125	935	24,408	1,581	3,309	3,494

[1]In addition, magnesium carbonate, not precipitated, was imported as follows, in short tons and thousand dollars: 1985—110 ($125); 1986—23 ($48); and 1987—71 ($105).
[2]Includes magnesium silicofluoride or fluosilicate and calcined magnesia.

Source: Bureau of the Census.

WORLD REVIEW

Australia.—Queensland Metal Corp. NL, along with its partners Pancontinental Mining Ltd. and Radex Heraclith Group of Austria, reportedly installed a pilot beneficiation facility near its magnesite deposit in Kunwarara, central Queensland. The 3-ton-per-day facility was intended to provide dead-burned magnesite for customer testing before construction of a 110,000-ton-per-year plant. In addition, Queensland Metal drilled two deposits in the same area. The Oldman deposit contained an estimated 64 million tons of magnesite, and the Triple Four deposit contained 39 million tons of magnesite.[2]

Austria.—Veitscher Magnesitwerke AG reportedly planned to increase its annual production capacity of high-purity, caustic-calcined magnesia to 7,700 tons at its Brietenau facility. The expansion program was expected to provide material for the manufacture of 99.9%-pure magnesium hydroxide for use in the chemical industry.

General Refractories Co. of the United States reportedly agreed to sell its European operations to an Austrian investment group headed by Girozentrale Bank for about $62 million. Included in the sale were two magnesite mines in Austria and one in Greece.

France.—Pechiney S.A. reportedly planned to expand the annual capacity at its fused magnesia plant to 31,000 tons from 14,000 tons. Already the largest producer of fused magnesia in market economy countries, through this expansion, Pechiney planned to enter the magnesia-carbon refractories market. Fused magnesia's traditional market was electrical heating elements in home appliances.

Israel.—Dead Sea Periclase Ltd. (DSP) announced that it completed construction of a 5,500-ton-per-year plant for the production of specialty magnesia products. These included pharmaceutical and technical grades of magnesia and magnesium hydroxide, active magnesia for the plastics and rubber industries, and magnesia for electrical applications. Reportedly, DSP was also expanding its plant capacity for dead-burned magnesia from 55,000 tons per year to 77,000 tons.

Spain.—Empresa Auxiliar de la Industria planned to study the potential for extracting magnesia from dolomite. Dolomite, mined at 10 sites in Granada, was sold at a low price, and the company's study was aimed at producing a material of higher value.

Table 7.—Magnesite: World production, by country[1]

(Short tons)

Country	1983	1984	1985	1986[p]	1987[e]
Australia	22,640	73,900	63,421	42,986	55,100
Austria	1,108,668	1,304,484	1,383,446	1,195,301	1,157,400
Brazil[2]	254,634	259,043	299,576	[r] [e]308,600	308,600
Canada[e] [3]	74,000	76,000	150,000	160,000	165,000
China[e]	2,200,000	2,200,000	2,200,000	2,200,000	2,200,000
Colombia[e]	1,800	1,800	1,800	[4]16,464	16,500
Czechoslovakia	729,729	[r]727,525	[e]739,000	[r] [e]750,000	770,000
Greece	981,618	1,173,111	932,431	[r] [e]990,000	990,000
India	478,482	456,388	460,117	465,175	510,000
Iran[5]	936,964	914,917	2,469,174	[r] [e]2,470,000	2,470,000
Kenya[e]	330,000	[4]343,098	330,000	330,000	330,000
Korea, North[e]	2,095,000	2,095,000	2,095,000	2,095,000	2,095,000
Mexico	25,559	33,537	21,274	[e]22,000	22,000
Nepal	16,552	16,097	21,882	69,655	66,100
Pakistan	2,202	[r]4,578	2,329	1,937	4,400
Philippines	683	689	745	[e]715	715
Poland[e]	[4]17,747	18,000	18,000	18,000	18,000
South Africa, Republic of	24,868	36,441	31,855	67,446	67,200
Spain	658,230	762,294	763,015	[e]770,000	780,000
Turkey	[r]690,667	[r]849,415	1,244,465	1,448,174	1,540,000
U.S.S.R.[e]	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000
United States	W	W	W	W	W
Yugoslavia	335,064	[r] [e]360,000	[r] [e]460,000	466,277	463,000
Zimbabwe	26,534	23,856	21,368	24,966	25,400
Total	[r]13,411,641	[r]14,130,173	16,108,898	16,312,696	16,454,415

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

[1]Figures represent crude salable magnesite. In addition to the countries listed, Bulgaria produced magnesite, but output is not reported quantitatively, and available general information is inadequate for formulation of reliable estimates of output levels. Table includes data available through May 13, 1988.

[2]Series reflects output of marketable concentrates. Production of crude ore was as follows, in short tons: 1983—536,135 (revised); 1984—798,381 (revised); 1985—687,103; 1986—720,000 (revised, estimated); and 1987—720,000 (estimated).

[3]Magnesitic dolomite and brucite. Figures are estimated on the basis of reported tonnage dollar value.

[4]Reported figure.

[5]Year beginning Mar. 21 of that stated.

TECHNOLOGY

In a review of the magnesia industry from 1970 to 1986, technical and commercial developments in production were presented, as well as changes in the markets for refractory and caustic-calcined magnesias.[3] The most significant process improvements were aimed at cutting costs by improving fuel efficiency. New calcining and sintering techniques and improvements in filtration steps have increased energy efficiency in recovering magnesia from seawater and brines. Improvements in beneficiation techniques and introduction of chemical processing methods have improved magnesia purity and recovery from natural magnesite, particularly in centrally planned economies.

Improvements in mining and beneficiation methods at A/S Olivin in Norway coupled with development of new markets are highlighted in a review of the Norwegian olivine industry.[4] Olivin was the largest producer of olivine in market economy countries, with an estimated production of 3 million tons in 1986. Most of the growth in olivine demand over the past decade was for use as a slag conditioner in iron and steelmaking to lower the viscosity of the slag, substituting for dolomite when low-silica ores were treated. Other new uses for olivine were as ballast for North Sea oil platforms and covering for undersea pipelines.

[1]Physical scientist, Branch of Nonferrous Metals.

[2]Industrial Minerals (London). Queensland Magnesite Interest Intensified. No. 234, Mar. 1987, p. 8.

[3]Coope, B. The World Magnesia Industry—Smaller but Fitter...and Purer! Ind. Miner. (London), No. 233, Feb. 1987, pp. 21-48.

[4]Suttill, K. Norwegian Olivine. Eng. and Min. J., v. 188, No. 9, Sept. 1987, pp. 34-39.

Manganese

By Thomas S. Jones[1]

World production of manganese ore declined slightly to the lowest total since 1983, according to preliminary data. Several countries among major market economy country producers had lower outputs, most notably the Republic of South Africa. The United States again produced only a small quantity of manganiferous material for brick coloring.

Price trends in manganese were negative for ores and positive for ferroalloys. Ore delivered to the United States and Japanese consumers was priced about 3% less, so that the U.S. price in 1987 succeeded that in 1986 as the lowest in constant dollars since 1974. In contrast, prices in the United States for imports of key manganese ferroalloys were up significantly to levels last reached in 1982. For U.S. imports, the price rose in 1987 by over one-fifth for high-carbon ferromanganese and about one-third for silicomanganese. One factor cited for higher ferroalloy prices was change in foreign currency exchange rates.

Greater than expected steel production also was considered a factor behind advances in ferroalloy prices. U.S. raw steel production increased 8%, bringing with it an increased consumption of manganese ferroalloys and metal. Unit consumption of these materials in steelmaking was about the same as that of 1986.

U.S. imports declined for all principal forms of manganese, resulting in a decrease of over 12% in overall quantity of manganese imported to nearly the same amounts as in 1984-85. For manganese dioxide the quantity imported was the least since 1981, but that for low-carbon ferromanganese was a record high.

Table 1.—Salient manganese statistics

(Thousand short tons, gross weight)

	1983	1984	1985	1986	1987
United States:					
Manganese ore (35% or more Mn):					
Imports for consumption	368	338	387	463	340
Consumption	531	615	e545	e500	e521
Manganiferous ore (5% to 35% Mn):					
Production (shipments)	34	88	20	14	W
Ferromanganese:					
Production	86	W	W	W	W
Exports	8	7	7	4	3
Imports for consumption	342	409	367	396	368
Consumption	446	492	466	376	409
World: Production of manganese ore	24,147	r26,100	26,742	p26,158	e25,101

eEstimated. pPreliminary. rRevised. W Withheld to avoid disclosing company proprietary data.

Manganese was certified by the U.S. Department of State as a strategic mineral essential for the economy or defense of the United States and unavailable in adequate quantities from reliable and secure suppliers. It was therefore unrestricted for importation into the United States from the Republic of South Africa under terms of the Comprehensive Anti-Apartheid Act of 1986. The Government's program of upgrading ore in the National Defense Stockpile into high-carbon ferromanganese was continued through awarding of further contracts for such domestic conversion. Accordingly, the Government inventory of high-carbon ferromanganese was to be increased by 117,000 tons[2] by the end of 1988.

Domestic Data Coverage.—Domestic production data for manganese are developed by the Bureau of Mines from three separate, voluntary surveys of U.S. operations. Typical of these surveys is the "Manganese and Manganiferous Ores" survey. All four operations to which a survey request was sent responded, representing 100% of production.

Legislation and Government Programs.—The General Services Administration contracted further with Elkem Metals Co. to upgrade stockpiled metallurgical manganese ore into high-carbon ferromanganese. This latest award was valued at about $56 million and, in approximate quantities, called for converting 215,000 tons of ore into 117,000 tons of high-carbon ferromanganese, of which 59,000 tons was to have been produced in 1987 and 57,600 tons in 1988. The contract contained an option for additionally converting 103,000 tons of ore into 58,600 tons of high-carbon ferromanganese in 1989.

The only sale of excess stockpile manganese material was in support of the ferroalloys upgrading project, consisting of 2,500 tons of stockpile-grade natural battery ore. Changes in stockpile inventories of manganese materials in 1987 are shown in the following table.

Material	Short tons, gross weight: Sales: Stockpile grade	Sales: Nonstockpile grade	Change in yearend inventory
Natural battery ore	2,500	--	-4,539
Chemical ore	--	--	-232
Metallurgical ore	--	--	-223,109

Table 2.—U.S. Government stockpile goals and yearend inventories for manganese materials in 1987

(Short tons, gross weight)

Material	Stockpile goals	Physical inventory, Dec. 31: Uncommitted: Stockpile grade	Uncommitted: Nonstockpile grade	Uncommitted: Total	Sold, pending shipment	Grand total
Natural battery ore	62,000	169,093	33,561	202,654	3,009	205,663
Synthetic manganese dioxide	25,000	3,011	--	3,011	--	3,011
Chemical ore	170,000	171,717	89	171,806	417	172,223
Metallurgical ore	2,700,000	2,078,606	919,204	2,997,810	21,803	3,019,613
High-carbon ferromanganese	439,000	704,952	--	704,952	--	704,952
Medium-carbon ferromanganese	--	29,057	--	29,057	--	29,057
Silicomanganese	--	23,574	--	23,574	--	23,574
Electrolytic metal	--	14,172	--	14,172	--	14,172

On January 7, pursuant to section 303(a)(2) of the Comprehensive Anti-Apartheid Act of 1986, the U.S. Department of State certified manganese to be 1 of 10 strategic minerals essential for the economy or defense of the United States that were unavailable in adequate quantities from reliable and secure suppliers. Manganese was defined in this context to include ferromanganese and silicomanganese. The certification, published on page 4454 of the February 11, 1987, issue of the Federal Register, had the effect of allowing manganese to be imported into the United States from parastatal organizations in the Republic of South Africa.

The U.S. Department of Defense included manganese among 22 high-technology metals and metal groups considered required in future defense systems and having uncertainties as to supply and/or applications. These materials were candidates for increased research and attention. The form of manganese under consideration was high-purity manganese as electrolytic manganese metal, some of which is used in making superalloys.

The possible benefits of seabed mining in the U.S. Exclusive Economic Zone (EEZ) were studied by the U.S. Congress, Office of Technology Assessment, which concluded that considerably more exploration is required before a definitive assessment can be made. Because of its strategic importance, manganese was regarded as one of several minerals for which national security concerns might override economic considerations in a future decision on whether to engage in extraction from such marine deposits. Otherwise, commercialization of marine minerals within the EEZ was viewed as remote for the foreseeable future except possibly for sand and gravel and precious metals.[3]

DOMESTIC PRODUCTION

Ore and Concentrate.—The only production and shipment of material containing 5% or more manganese was that mined in Cherokee County, SC, by brick manufacturers or contractors for use in coloring brick. This consisted of manganiferous material associated with the Battleground Schist of the Kings Mountain area. This material has a natural manganese content ranging from 5% to 15%. Shipments in 1987 approached the 20,000-ton level that has been generally typical of the 1980's. Consolidation of ownership of the few companies involved precluded publication of proprietary shipments data.

Ferroalloys and Metal.—Publication of statistics continued to be precluded to avoid disclosing proprietary data. There were only two producers each of manganese ferroalloys and metal: Elkem Metals and SKW Alloys Inc. for ferroalloys and Elkem Metals and Kerr-McGee Chemical Corp. for metal.

Chemetals Inc. started a new facility at its Baltimore, MD, plant for producing nitrided ferromanganese and manganese powders. This expansion resulted from relocation and rebuilding of equipment from the Kingwood, WV, plant that Chemetals operated until that plant was disabled by a flood in 1985. Product lines of the new facility included nitrided medium-carbon ferromanganese, nitrided "Massive Manganese," and weld-grade powders of ferromanganese and manganese oxide. These products were in addition to continuing production of various manganese chemicals and ground and reduced manganese ore at the Baltimore plant.

Globe Metallurgical Inc., which had been a producer of silicomanganese in a plant at Beverly, OH, was sold by Moore McCormack Resources Inc. on June 24 to private interests that included members of Globe Metallurgical's management. Moore McCormack had acquired Globe Metallurgical in 1984 through Pickands Mather & Co., then a subsidiary of Moore McCormack.

Table 3.—Domestic producers of manganese products in 1987

Company	Plant location	Products[1]				Type of process
		FeMn	SiMn	Mn	MnO_2	
Chemetals Inc	Baltimore, MD	--	--	--	X	Chemical.
Do	New Johnsonville, TN.	--	--	--	X	Electrolytic.
Elkem Metals Co	Marietta, OH	X	X	X	--	Electric furnace and electrolytic.
Kerr-McGee Chemical Corp	Hamilton, MS	--	--	X	--	Electrolytic.
Do	Henderson, NV	--	--	--	X	Do.
Ralston Purina Co.: Eveready Battery Co.	Marietta, OH	--	--	--	X	Do.
RAYOVAC Corp.: Materials Div.	Covington, TN	--	--	--	X	Do.
SKW Alloys Inc	Calvert City, KY	--	X	--	--	Electric furnace.

[1]FeMn, ferromanganese; SiMn, silicomanganese; Mn, electrolytic manganese metal; MnO_2, synthetic manganese dioxide.

CONSUMPTION, USES, AND STOCKS

Ironmaking and Steelmaking.—The average rate at which manganese was consumed as manganese ore in making pig iron or equivalent hot metal increased to 1.0 pound per ton of raw steel. This rate was calculated from an estimated consumption of 102,000 tons of manganese-bearing ore, all of which contained more than 35% manganese and was of foreign origin. According to preliminary data, production of raw steel as ingots, continuous- or pressure-cast blooms, billets, slabs, etc., was 88.5 million tons. No manganese ore containing 35% or more manganese was reported to have been used directly in steelmaking.

Unit manganese consumption in steelmaking as ferroalloys and metal changed insignificantly. For reported consumption in the production of 89.3 million tons of raw steel and steel castings in 1987, the pounds of manganese consumed per ton of raw steel was 7.0 as ferromanganese, 1.6 as silicomanganese, and 0.1 as metal, for a total of 8.7. In 1986, the corresponding unit consumption in production of 82.5 million tons of raw steel and steel castings totaled 8.6, of which ferromanganese accounted for 6.9; silicomanganese, 1.6; and metal, 0.1. The results for both years included less than a full year of steelmaking by USX Corp., which resumed steel production late in the first quarter of 1987. With the nation's largest steelmaking capacity, USX correspondingly had a significant effect on consumption of manganese ferroalloys.

The pattern of manganese ferroalloy consumption by the U.S. steel industry showed a preference for ferromanganese or silicomanganese that depended on type of facilities being used. According to an industry source, integrated producers were obtaining manganese units almost entirely from ferromanganese, particularly the high-carbon grade, whereas the quantity of silicomanganese being used by minimills was over twice that of ferromanganese. To some extent, steelmakers were evaluating use of high-carbon ferromanganese containing 76% manganese, a content less than the traditional 78%, in terms of nominal percentage. A continuing increase in the number of ladle refining units being installed augured for lower unit consumption of manganese ferroalloys in the future because of the high and predictable ferroalloy recoveries associated with use of such equipment. For example, one steel company reported a typical ferromanganese recovery of 98% when practicing ladle metallurgy.

Battery and Miscellaneous Industries.—Dioxide in natural ore and that synthetically produced were being used in dry-cell batteries. Natural material continued to be the basis of carbon-zinc cells and synthetic, the basis of the alkaline-manganese dioxide type. Historical aspects of manganese-containing batteries, particularly those in which synthetic dioxide is used, were reviewed in a publication of The Electrochemical Society.[4]

On June 1, Chemetals acquired the manganese facilities and businesses operated by Foote Mineral Co. in New Johnsonville, TN, thus ending Foote Mineral's role for over 60 years as a domestic supplier of manganese materials. Included in the transaction were a 10,200-ton-per-year electrolytic manganese dioxide (EMD) plant, roasting and grinding facilities for manganese ore, and a marketing arrangement for distributing in the United States electrolytic manganese metal produced in the Republic of South Africa. The purchase price stated when Chemetals and Foote Mineral signed the sales agreement was $12.7 million plus assumption of certain liabilities.

RAYOVAC Corp. realigned its EMD production and ore-grinding plant at Covington, TN, to Materials Div. of the corporation. The plant had formerly been a subsidiary operating as ESB Materials Co.

The ore-grinding activities of N. K. Industries Inc. in Phenix City, AL, were acquired by Prince Manufacturing Co., already a processor of manganese ore in plants at Bowmanstown in eastern Pennsylvania and at Quincy in western Illinois.

Table 4.—U.S. consumption and industry stocks of manganese ore,[1] by use

(Short tons, gross weight)

Use	Consumption		Stocks, Dec. 31	
	1986	1987	1986	1987
Manganese alloys and metal	W	W	197,639	189,444
Pig iron and steel[e]	74,000	102,000	64,300	83,600
Dry cells, chemicals, miscellaneous[2]	W	W	193,544	196,548
Total[e]	500,000	520,000	455,483	469,592

[e]Estimated. W Withheld to avoid disclosing company proprietary data; included in "Total."
[1]Containing 35% or more manganese (natural).
[2]Natural ore, including that consumed in making synthetic manganese dioxide.

Table 5.—U.S. consumption, by end use, and industry stocks of manganese ferroalloys and metal in 1987

(Short tons, gross weight)

End use	Ferromanganese			Silico-manganese	Manganese metal
	High carbon	Medium and low carbon	Total		
Steel:					
Carbon	238,522	71,435	309,957	81,812	3,052
Stainless and heat-resisting	16,279	(1)	16,279	3,770	1,505
Full alloy	26,468	9,177	35,645	17,505	975
High-strength, low-alloy	27,025	5,102	32,127	5,310	794
Electric	(1)	(1)	(1)	(1)	(1)
Tool	303	(1)	303	(1)	66
Unspecified	694	802	1,496	416	114
Total steel[2]	309,291	86,516	395,807	108,813	6,506
Cast irons	8,204	635	8,839	2,555	W
Superalloys	W	W	W	W	154
Alloys (excluding alloy steels and superalloys)	W	W	W	W	18,373
Miscellaneous and unspecified	4,658	75	4,733	3,177	536
Total consumption	322,153	87,226	409,379	[3]114,545	25,569
Total manganese content[4]	251,000	70,000	321,000	76,000	25,600
Stocks, Dec. 31: Consumers and producers	37,634	10,429	48,063	13,757	2,983

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified" where applicable.
[1]Withheld to avoid disclosing company proprietary data; included with "Steel: Unspecified."
[2]Includes estimates.
[3]Internal evaluation indicates that silicomanganese consumption is considerably understated.
[4]Estimated based on typical percent manganese content (rounded).

PRICES

Manganese Ore.—Prices depend primarily on manganese content but are also influenced by other factors including other chemical constituents, physical character, quantity, delivery terms, ocean freight rates, insurance, inclusion or exclusion of duties if applicable, buyers' needs, and availability of ores having the specifications desired. Trade journal quotations reflect the editors' evaluation of the market.

Metallurgical manganese ore underwent a price decline on international markets, as did iron ore. Manganese ore contracts negotiated between Japanese ferroalloy producers and Australian and South African suppliers about the April 1 start of the Japanese fiscal year called for a 5.8% price reduction f.o.b. basis. The cost of ocean freight was rising. Thus, reductions on a c.i.f. basis were in the 3% to 4% range. These terms were negotiated for an overall contract volume about one-third less than in fiscal year 1986. In early February, Metal Bulletin of London lowered by 7% its figure for the price of ore delivered to Western European ports. It made no further change but noted in June sluggish demand and delay in settling annual contracts. The price for ore delivered to U.S. customers decreased about 3%, with customers paying somewhat above or below the average depending on volume purchased. The average price, c.i.f. U.S. ports, for metallurgical ore containing 48% manganese was $1.29 per long ton unit, compared with $1.34 in 1986; per metric ton unit, these prices were $1.27 and $1.31, respectively. These prices convert to 5.8 cents and 6.0 cents per pound of manganese in ore, respectively.

Manganese Ferroalloys.—Upward price trends were apparent in the price developments of imported material. The price of imported high-carbon ferromanganese containing 78% manganese, f.o.b. Pittsburgh or Chicago warehouse, began rising in late March from a low reached in the latter part of 1986, ranging from $305 to $320 per long ton of alloy. Frequent incremental increases thereafter led, as of mid-December, to a final price of $380 to $390, the highest range reached since mid-1982. This equated to a price rise of over one-fifth in 1987 and a price average about 7% greater than in 1986. For imported silicomanganese containing 2% carbon, the corresponding increases were relatively greater, a price rise of about one-third in 1987 and a price average over 8% greater than in 1986. Per pound of alloy, f.o.b. Pittsburgh or Chicago warehouse, the price of imported silicomanganese started the year at 17 to 18.25 cents, decreased early in January to 17 to 18 cents, and then in mid-February began a succession of changes. All but one were increases, bringing the final price as of mid-December to 22.5 to 24 cents. This final level had not been attained since briefly in January 1982.

Factors cited by trade journals as possibly being behind price rises in manganese ferroalloys were changes in foreign currency exchange rates, greater than expected steel production, uncertainty of supply from the Republic of South Africa, and a desire by producers and marketers to recoup from comparatively low prices in recent years. The extent of increase in the price of imported silicomanganese nearly matched that in the price of imported ferrosilicon. Current list prices of domestic producers for the most widely used manganese ferroalloys were not available in trade publications.

Manganese Metal.—During the first part of the year the list price of domestic suppliers was 80 cents per pound for bulk shipments, f.o.b. shipping point, although a trade journal spoke of transaction prices nearer 78 cents per pound. List prices subsequently were raised twice by 3 cents per pound, first as of August 1 and then as of December 1, to give a yearend price of 86 cents per pound. Timing of the increases was the same for the two domestic producers as well as for Chemetals, a supplier of material imported from the Republic of South Africa.

FOREIGN TRADE

Most of the reported ore exports and all ore reexports were presumed to have been metallurgical ore, and apparently consisted of both stocks from industry and material obtained from excess Government stocks. Of 13,237 tons of reexports, 11,675 tons went to Mexico and 1,562 tons went to Canada. About 1,000 tons of exports apparently was imported manganese dioxide ore, possibly ground, blended, or otherwise classified in the United States, of which about 600 tons went to Canada and the balance to destinations other than Canada and Mexico. Relatively small exports of ferromanganese and silicomanganese were even less than in 1986, by about one-third and two-thirds, respectively. Rising exports of manganese metal were about two-thirds as large as imports.

The overall quantity of manganese contained in the principal forms imported decreased more than 12%, as imports of all major categories declined. Ore imports were down to the range for 1983-85, whereas the average grade for imported ore of 50.1% was the highest yet of the 1980's. Only 5 tons of manganiferous ore was imported, all from Mexico, with an average manganese content of 31%.

The total of ferromanganese imports was slightly less than the average for 1983-86, although imports of low-carbon ferromanganese increased to a record high. The average manganese content of all ferromanganese imports advanced slightly to 78.7%. High-carbon ferromanganese from Japan, in the amount of 5,511 tons, was an unusual receipt for the 1980's. Reported imports of spiegeleisen were 209 tons, all from the Federal Republic of Germany, at a relatively high unit value.

Imports of manganese dioxide decreased for the second consecutive year to the lowest level since 1981. All but 139 tons were apparently synthetic dioxide for battery or chemical applications.

Tariffs.—As of April 1 at U.S. ports open to public navigation, the U.S. Customs Service commenced collecting a harbor maintenance fee of 0.04% ad valorem on cargo loaded or unloaded from water-borne vessels. This fee was assessed on import, export, and domestic movements of cargo at all ports at which Federal funds have been used since 1977 for construction, maintenance, or operation, other than inland waterway harbors or channels. The Water Resources Development Act of 1986 (Public Law 99-662) mandated collection of this fee for deposit into the Harbor Maintenance Trust Fund in the U.S. Treasury. Collection of the fee proceeded according to interim regulations (52 FR 10198).

Table 6.—U.S. exports of manganese ore, ferroalloys, and metal, by country

(Gross weight)

Country	1986		1987	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Ore and concentrates containing 5% or more manganese:				
Canada	7,669	$613	7,496	$630
Colombia	3,616	295	65	15
Mexico	29,307	2,085	54,884	3,353
Other	1,374	285	825	227
Total[1]	41,966	3,278	63,270	4,225
Ferromanganese:				
Canada	2,433	1,676	1,877	1,351
Germany, Federal Republic of	1,274	554	428	347
Other	[2]616	[2]420	546	447
Total[1]	4,323	2,650	2,851	2,144
Silicomanganese:				
Canada	277	190	249	160
Germany, Federal Republic of	1,169	199	--	--
Mexico	42	54	309	160
Trinidad and Tobago	496	214	4	2
Other	[2]20	[2]30	135	170
Total[1]	2,004	687	697	493
Metal including alloys and waste and scrap:				
Belgium-Luxembourg	702	1,061	701	1,053
Canada	580	1,055	1,208	2,028
Japan	1,705	2,330	1,492	2,606
Netherlands	371	519	706	1,320
Other	[2]1,788	[2]2,927	1,668	2,742
Total[1]	5,146	7,892	5,775	9,748

[1]Data may not add to totals shown because of independent rounding.
[2]Unspecified group of countries differs from the 1986 Minerals Yearbook.

Source: Bureau of the Census; adjusted by the Bureau of Mines.

Table 7.—U.S. imports for consumption of manganese ore, ferroalloys, metal, and selected chemicals, by country

Country	1986 Gross weight (short tons)	1986 Manganese content (short tons)	1986 Value (thousands)	1987 Gross weight (short tons)	1987 Manganese content (short tons)	1987 Value (thousands)
ORE AND CONCENTRATES						
35% or more manganese:						
Australia	68,131	35,539	$3,305	93,205	48,747	$3,819
Belgium-Luxembourg[1]	252	[2]151	27	--	--	--
Brazil	82,702	38,728	3,221	62,903	29,673	2,196
Gabon	239,132	119,068	11,435	175,695	88,413	8,282
Germany, Federal Republic of[1]	5	[2]2	1	--	--	--
Mexico	34,717	[2]14,771	3,603	8,678	3,712	769
Morocco	316	[2]186	36	58	[2]30	14
Panama	6,612	3,174	275	--	--	--
South Africa, Republic of	31,376	13,988	1,219	--	--	--
Total[3]	463,242	225,608	23,122	340,539	170,576	15,079
Of which, more than 35% but less than 47% manganese:						
Brazil	17,492	7,532	541	10,758	4,626	357
Mexico	33,443	[2]14,156	3,391	5,911	2,395	292
South Africa, Republic of	12,044	4,577	430	--	--	--
Total[3]	62,979	26,265	4,362	16,669	7,021	649
FERROMANGANESE						
All grades:						
Australia	13,423	10,401	2,816	8,185	6,072	1,885
Belgium-Luxembourg	4,952	4,465	4,864	2,474	2,150	1,490
Brazil	20,392	15,418	4,945	5,512	4,189	1,400
Canada	52,049	39,907	12,733	24,022	18,861	6,290
France	86,728	68,573	27,546	121,817	95,629	38,426
Germany, Federal Republic of	25,775	21,043	11,181	12,775	10,674	5,947
Italy	--	--	--	412	367	338
Japan	2,803	2,277	1,334	8,331	6,607	2,682
Mexico	28,152	22,540	10,836	17,910	14,562	7,463
Norway	6,663	5,603	4,439	21,830	18,167	12,530
South Africa, Republic of	145,549	113,043	35,944	144,407	112,101	35,180
Spain	9,164	7,775	3,845	--	--	--
Total[3]	395,650	311,045	120,482	367,675	289,379	113,630
Of which, 1% or less carbon:						
Belgium-Luxembourg	4,952	4,465	4,864	823	746	761
France	8,950	8,034	8,180	9,553	8,677	8,965
Germany, Federal Republic of	8	6	8	--	--	--
Italy	--	--	--	412	367	338
Japan	37	34	34	20	18	18
Norway	4,128	3,588	3,633	9,323	8,044	7,122
South Africa, Republic of	54	51	64	--	--	--
Total[3]	18,129	16,178	16,782	20,132	17,852	17,203
More than 1% to 4% or less carbon:						
Belgium-Luxembourg	--	--	--	1,651	1,404	729
Canada	410	315	76	--	--	--
France	2,800	2,226	1,363	6,151	4,997	2,944
Germany, Federal Republic of	25,767	21,037	11,173	12,775	10,674	5,947
Japan	2,766	2,243	1,300	2,800	2,240	1,262
Mexico	20,477	16,572	8,689	15,761	12,864	6,811
Norway	882	709	404	10,743	8,729	5,000
South Africa, Republic of	3,960	3,191	1,633	559	452	259
Spain	9,164	7,775	3,845	--	--	--
Total[3]	66,225	54,068	28,483	50,440	41,359	22,951

See footnotes at end of table.

Table 7.—U.S. imports for consumption of manganese ore, ferroalloys, metal, and selected chemicals, by country —Continued

Country	1986 Gross weight (short tons)	1986 Manganese content (short tons)	1986 Value (thousands)	1987 Gross weight (short tons)	1987 Manganese content (short tons)	1987 Value (thousands)
SILICOMANGANESE						
Australia	17,363	11,525	5,310	17,142	11,180	4,527
Brazil	19,563	12,850	5,675	7,334	4,676	2,541
Canada	1,822	1,067	320	6,446	4,171	1,969
Chile	176	117	47	--	--	--
Italy	766	473	469	1,105	696	683
Mexico	19,339	12,930	5,649	39,704	24,866	11,072
Netherlands[1]	--	--	--	413	250	251
Norway	16,602	10,917	5,596	26,136	17,159	8,877
Portugal	9,125	5,925	2,755	--	--	--
South Africa, Republic of	88,642	59,114	24,931	66,105	43,736	19,625
Spain	2,694	1,730	1,595	1,663	1,056	1,031
Yugoslavia	22,553	14,777	6,491	25,369	16,525	7,884
Total[3]	198,645	131,425	58,839	191,418	124,315	58,461
METAL						
Unwrought:						
South Africa, Republic of	9,641	XX	9,760	8,925	XX	9,600
Other	27	XX	40	--	XX	--
Total	9,668	XX	9,800	8,925	XX	9,600
Waste and scrap:						
Canada	6	XX	3	60	XX	8
United Kingdom	--	XX	--	6	XX	6
MANGANESE DIOXIDE						
Belgium-Luxembourg	1,375	XX	1,329	1,252	XX	1,508
Brazil	734	XX	845	884	XX	970
Greece	575	XX	645	62	XX	71
Ireland	2,778	XX	3,133	358	XX	401
Japan	10,335	XX	12,440	13,279	XX	14,719
South Africa, Republic of	3,230	XX	3,243	830	XX	889
Other	347	XX	390	180	XX	134
Total[3]	19,374	XX	22,025	16,845	XX	18,692
MANGANESE SULFATE						
Australia	529	XX	123	1,565	XX	289
Belgium-Luxembourg	--	XX	--	127	XX	32
China	--	XX	--	555	XX	95
Germany, Federal Republic of	68	XX	113	30	XX	129
Japan	46	XX	105	27	XX	76
Other	16	XX	34	12	XX	7
Total[3]	659	XX	375	2,317	XX	629
POTASSIUM PERMANGANATE						
China	318	XX	312	803	XX	791
German Democratic Republic	259	XX	290	176	XX	206
Spain	1,283	XX	2,153	918	XX	1,587
Other	10	XX	124	101	XX	290
Total[3]	1,870	XX	2,879	1,998	XX	2,874

XX Not applicable.
[1]Country of transshipment rather than original source.
[2]Includes Bureau of Mines conversion of part of reported data (from apparent MnO_2 content to Mn content).
[3]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census; adjusted by the Bureau of Mines.

Table 8.—U.S. import duties on manganese materials[1]

Item	TSUS No.	Rate of duty effective Jan. 1, 1987	
		Most favored nation (MFN)	Non-MFN
Manganese dioxide	419.4420	4.7% ad valorem[2]	25% ad valorem.
Ore and concentrate	601.27	Free	1 cent per pound Mn.
Ferromanganese:			
Low-carbon	606.26	2.3% ad valorem[2]	22% ad valorem.
Medium-carbon	606.28	1.4% ad valorem[2 3]	6.5% ad valorem.
High-carbon	606.30	1.5% ad valorem[4 5]	10.5% ad valorem.
Silicomanganese	606.44	3.9% ad valorem[2 6]	23% ad valorem.
Metal	632.30	14% ad valorem[5 7]	20% ad valorem.

[1]All subject to ad valorem user fee of 0.22% through Sept. 30, 1987, and 0.17% thereafter, except for products from beneficiary countries under the Carribean Basin Economic Recovery Act (CBERA) and least developed developing countries.
[2]Free from certain countries under Generalized System of Preferences, including Israel.
[3]Not duty free for Mexico.
[4]Free for products of Israel.
[5]Free from beneficiary countries under the CBERA.
[6]Not duty free for Brazil.
[7]5.6% ad valorem for products of Israel.

WORLD REVIEW

Argentina.—A gravity concentration plant for manganese ore was inaugurated in the latter part of the year at Pozo Nuevo, Cordoba Province, in the north-central part of the country. The plant was to be capable of processing about 275 tons per day of low-grade ore containing 12% to 15% manganese from mines in Cordoba and the neighboring Province of Santiago del Estero. This material was to be upgraded into concentrates containing at least 34.5% manganese at a mill recovery of 75%. The product was intended for domestic consumption by the steel industry and others, and would reduce Argentina's dependence on imported ore.

Australia.—Manganese ore production by Groote Eylandt Mining Co. Pty. Ltd. (GEMCO) increased nearly one-eighth to about the same level as in 1984 while GEMCO's exports gained by a slightly greater percentage, according to preliminary data of the Australian Bureau of Mineral Resources. Exports of about 1,440,000 tons plus decreased domestic shipments of about 410,000 tons produced a small advance in total shipments to about 1,850,000 tons.[5]

Programs to increase capacities were completed by this mining subsidiary of The Broken Hill Pty. Co. Ltd. (BHP) and by BHP's manganese smelting subsidiary, Tasmanian Electro Metallurgical Co. Pty. Ltd. (TEMCO). Capacity of GEMCO's ore concentration plant was brought to 2,650,000 tons per year. At TEMCO's plant in Tasmania, rating of two of the three manganese ferroalloy furnaces was raised to 29 megavolt amperes (MVA) and the third to 36 MVA. Because all three furnaces were capable of producing either ferromanganese or silicomanganese, capacity of the plant was upgraded to about 200,000 tons per year for high-carbon ferromanganese or 120,000 tons per year for silicomanganese, or to an intermediate level for a mix of ferromanganese and silicomanganese. TEMCO's ore-sintering capacity was about 275,000 tons per year.

BHP announced through its BHP-Utah Minerals International subsidiary that it planned to build an EMD plant in Australia to be fed with ore from GEMCO. Plant capacity was to be 16,500 tons per year, and production was to begin in 1990. Newcastle, New South Wales, on the southeastern coast north of Sydney subsequently was chosen as the plant site.

Brazil.—Overall shipments of manganese ore from the Serra do Navio, Amapá Territory, operations of Indústria e Comércio de Minérios S.A., all via Porto de Santana on the Amazon River, rose marginally to 807,000 tons. Shipments to Europe rebounded 40% to 430,000 tons. Shipments to other markets decreased, respective quantities being, in tons, to export destinations in North America, 124,000; South America, 39,000; and in coastal vessels to Brazilian consumers, 214,000.[6]

Cia. Vale do Rio Doce (CVRD) shipped a total of 315,000 tons of manganese ore from the Azul Mine in the Carajás region. Shipments were via the Ponta da Madeira iron ore terminal and the commercial dock at

Itaqui, both near São Luís. Exports of 163,000 tons in 11 shipments exceeded somewhat the 152,000 tons making up 14 cargoes sent in coastal vessels to the Brazilian market.[7] Total shipments increased over those of 1986, because exports were nearly one-half greater, whereas domestic shipments declined slightly.

Production of manganese ferroalloys advanced slightly to a new record total of nearly 380,000 tons, according to preliminary data. A drop in production of high-carbon ferromanganese was more than compensated for by increased production of silicomanganese and refined ferromanganese. Problems in such areas as energy cost and supply, labor cost, and Government price control reportedly affected producers at various times during the year.

Diverse proposals for producing manganese ferroalloys in the Carajás region from ore from that region appeared to have culminated in the so-called Provale project. This was a $110 million joint venture in which Brazilian financing was split 60:40 between Prometal Prodútos Metalurgicos S.A. and CVRD. The Soviet Union was the third participant in the project through extension of a $60 million credit line to be used for equipment. The Soviet Union was to receive one-half of the projected annual shipments of 165,000 tons of manganese ferroalloys for 12 years beginning with the start of production in 1990.

Gabon.—Compagnie Minière de l'Ogooué S.A. took steps to further manganese ore shipping via the Trans-Gabon Railroad. This included letting contracts for constructing a manganese ore port at Owendo, targeted for completion by the end of 1988, and for installing ore-handling systems to transfer shipments at Moanda from the mine to the railway and at the port from the railway to the ore terminal.

The contribution of manganese ore to Gabon's total export earnings more than doubled in 1986 to over 13% because of a large drop that year in the value of oil exports. In 1984 and 1985, the corresponding contribution had been nearly 6%.

Ghana.—Exports of 269,000 tons of ore from the Nsuta Mine of Ghana National Manganese Corp. were shipped through the Port of Takoradi to the Far East and Europe, western and eastern sectors.[8] This second year of declining shipments brought the annual export total about 8% below that for 1985, the peak year so far in the 1980's.

India.—Hand sorting and picking remained the most common method of beneficiating crushed manganese ore, especially for small mines in remote areas. Ore-washing practices included manual washing in a basket to remove mud as well as mechanical washing at some mines in Madhya Pradesh and Orissa States. Hand or mechanical jigging was the technique most extensively used for gravity concentrating ore. Sandur Manganese and Iron Ores Ltd. practiced jigging plus tabling and low-intensity magnetic separation to treat its ferruginous ore at Sandur in Karnataka State. Manganese Ore India Ltd. remained the only Indian manganese producer having a heavy-medium separation plant. However, this plant, installed over 30 years ago at Dongri-Buzurg Mine in Maharastra State to process ore in dumps, has not been in service for a number of years.[9]

Japan.—Production of manganese ferroalloys decreased about one-sixth to only about 40% of yearend 1986 capacity. Silicomanganese production declined nearly 40% to 101,000 tons. A drop in ferromanganese production to 366,000 tons was not as severe.

Ferromanganese exports of over 21,000 tons were nearly three times as great as in 1986; over 40% of 1987 exports were to the United States. No exports of silicomanganese were reported. Imports of ferromanganese almost quadrupled to 30,200 tons whereas those of silicomanganese declined about 15% to 166,000 tons. The most pronounced changes among sources for silicomanganese imports were increases in quantities from China and the Soviet Union and decreases in those from Brazil and the Republic of South Africa.

The variety of manganese materials being employed in some degree by Japanese steelmakers extended to ferromanganese fines. The effect was to lower consumption of more costly lump ferromanganese, which is also the case with such other recent innovations such as the use of manganese ore in hot-metal pretreatment technology.

In electrolytic materials, production of synthetic manganese dioxide was a near-capacity 73,600 tons and exports rebounded to 48,600 tons. Production and exports of the dioxide were at record highs. Production of 4,050 tons of electrolytic manganese metal was a further decrease from the reduced 1986 output of 4,200 tons.

Mexico.—Cía. Minera Autlán S.A. de C.V. (Autlán) announced in December that an affiliate, Industrias Sulfamex S.A. de C.V., had completed a plant at Tamos, Veracruz State, with a capacity of 22,000 tons per year for manganese sulfate. Autlán further stated that an EMD plant would be built adjacent to the sulfate plant and would obtain its raw materials from that plant. The EMD plant was projected to have an annual capacity of 13,200 tons and to begin producing in the first half of 1990, largely for export markets.

Norway.—Importing of manganese ore was excluded from economic sanctions against the Republic of South Africa that became effective in July. Under a sanctions program that had been considered for some time, Norwegian ferroalloy producers were allowed to continue importing South African manganese ore for at least 2 more years. In the 1980's, such imports have been the major item in imports by Norway from the Republic of South Africa and were the source of approximately 40% of Norway's manganese feed material in 1986.

South Africa, Republic of.—Following 3 years of progressive increases, ore production decreased over one-fifth to approximately the 1983 level. Production of the various categories of ore was as follows:

	Quantity (thousand short tons, gross weight)
METALLURGICAL ORE	
30% to 40% Mn	734
Over 40% to 45% Mn	852
Over 45% to 48% Mn	483
Over 48% Mn	980
Total	[1]3,050
CHEMICAL ORE	
35% MnO_2 and less	6
Over 35% to 65% MnO_2	129
Over 65% to 75% MnO_2	3
Total	138

[1]Data do not add to total shown because of independent rounding.

Reduced demand in Europe for ore used in making ferromanganese lowered ore sales of The Associated Manganese Mines of South Africa Ltd. nearly 30%, to 968,000 tons compared with about 1,370,000 tons in 1986.

Equipment being installed or tested by Samancor Ltd. to improve its ore production operations included, at the Mamatwan Mine, an ore sintering plant and a heavy-medium separation plant and, at the Wessels Mine, a mechanized ore-sorting plant based on the use of X-ray fluorescence. Construction of the commercial-scale sintering plant progressed, whereas the separation and sorting plants were run at pilot scale. Throughout the year, Samancor found it expedient to respond to ferroalloy market changes by shifting production mix back and forth between ferromanganese and silicomanganese at its Metalloys Works at Meyerton in Transvaal Province. The company reacted to a labor protest at the Meyerton plant by discharging over 1,000 workers.

U.S.S.R.—Total concentrate production was unchanged. A slight increase in output from the Nikopol' Basin in the Ukraine compensated for a further decline to 2.3 million tons from the Chiatura Basin in Georgia. This reduced the Chiatura Basin's production to only three-fourths of that region's 1980's peak production of 3.1 million tons in 1984. Considering that the Soviet Union's high-grade concentrates come mainly from the Chiatura Basin, declining production from that region appeared connected both with the Soviet Union's importing of high-grade ore in recent years and its participation in a ferromanganese project in Brazil. A new plant there was to provide the Soviet Union with over 80,000 tons of ferromanganese per year beginning in 1990, according to arrangements previously discusseed. (See "Brazil" section of this chapter.)

Ore exports of 1,214,000 tons in 1986 made that the fifth consecutive year in which such exports totaled about 1.2 million tons. Principal destinations for 1986 exports, accounting for 91% of the total, were, in tons, Poland, 637,000; Czechoslovakia, 303,000; German Democratic Republic, 93,000; and Bulgaria, 69,000.

Table 9.—Manganese ore: World production, by country[1]

(Thousand short tons unless otherwise specified)

Country[2]	Range percent Mn[e 3]	Gross weight					Metal content				
		1983	1984	1985	1986[p]	1987[e]	1983	1984	1985	1986[p]	1987[e]
Australia[4]	37-53	1,510	2,038	2,208	1,818	[5]2,043	754	969	1,056	865	974
Brazil[6 7]	30-50	2,306	2,969	2,781	[r e]2,866	2,650	922	1,187	997	1,032	950
Bulgaria	29	50	50	42	[e]44	44	14	14	12	[e]13	13
China[e 8]	30	1,760	1,760	1,760	1,760	1,760	530	530	530	530	530
Gabon[6 9]	50-53	2,047	2,336	2,579	2,767	2,650	945	1,078	1,191	1,277	1,220
Ghana[6]	30-50	191	296	348	375	325	76	118	139	150	130
Hungary[6 10]	30-33	65	74	69	69	71	20	22	21	21	21
India[6 9 11]	10-54	1,412	1,246	1,367	1,337	[5]1,436	530	464	509	502	539
Japan	26-27	83	68	23	7	--	22	18	6	2	--
Mexico	27-50	[e]386	[e]525	[e]437	[e]506	425	147	199	166	192	[5]161
Morocco[6]	50-53	81	65	48	44	47	43	35	26	24	25
Romania[6 10]	30	86	73	73	[e]72	72	26	22	22	21	21
South Africa, Republic of[6 9]	30-48+	3,181	3,361	3,969	4,100	[5]3,188	1,225	1,341	1,587	1,663	1,310
Thailand[6]	46-50	7	10	5	5	6	4	5	2	3	3
Turkey[6]	27-46	4	47	12	8	8	1	17	4	3	3
U.S.S.R.	29-30	10,890	11,100	10,900	10,300	10,300	3,280	3,300	3,200	3,100	3,100
Yugoslavia	25-45	35	23	[e]28	[e]28	28	12	7	[e]10	[r e]8	8
Other[e 12]	XX	54	[r]61	92	[r]53	51	20	23	[r]38	[r]19	18
Total[13]	XX	24,147	[r]26,100	26,742	26,158	25,101	8,571	[r]9,350	9,516	9,424	9,027

[e]Estimated. [p]Preliminary. [r]Revised. XX Not applicable.
[1]Table includes data available through June 10, 1988.
[2]In addition to the countries listed, Colombia, Cuba, Panama, and Peru 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 thousand short tons, gross weight: Argentina (19% to 30% Mn), 1983—8, 1984—7, 1985—8, 1986—11, and 1987—11 (estimated); and Czechoslovakia (about 17% Mn), an estimated 1 in each year.
[3]May be for average content of each year's production rather than for content of typical products.
[4]Metallurgical ore.
[5]Reported figure.
[6]Gross weight reported; metal content estimated. Estimated metal content figures have been revised as necessary.
[7]Reported gross-weight figures are the sum of (1) sales of direct-shipping manganese ore and (2) production of beneficiated ore, both as reported in Anuário Mineral Brasiliero.
[8]Includes manganiferous ore.
[9]Calculated metal content includes allowance for assumed moisture content.
[10]Concentrate.
[11]Much of India's production grades below 35% Mn; average content was reported as 38.3% Mn in 1983.
[12]Category represents the combined totals of Bolivia (exports), Chile, Greece, Indonesia, Italy (from wastes), the Republic of Korea, Pakistan, the Philippines, and Sudan.
[13]Data may not add to totals shown because of independent rounding.

TECHNOLOGY

The Bureau of Mines performed a laboratory evaluation of a dual leaching method for recovering silver and manganese from refractory domestic manganiferous silver ores. Samples large enough to simulate in situ and/or heap leaching were column-leached in succession. The leaching sequence was relatively dilute aqueous sulfur dioxide (SO_2), an intervening neutralization rinse with sodium hydroxide solution, and finally, caustic cyanide solution. The SO_2 leaching step extracted 65% to 96% of the manganese and 2% to 43% of the silver. Subsequent cyanide leaching brought total silver extraction up to 25% to 82%. Silver extraction was only 0.7% to 8.5% when an SO_2 preleach was not used. The tests were conducted on samples of a hydrothermal vein origin from Arizona, Colorado, and Nevada, in which the manganese content ranged from 2% to 28% and silver content from 1.8 to 7.0 troy ounces per ton.[10]

The Bureau screened sulfuric acid oxidation pressure leaching, aqueous sulfur dioxide leaching, and acid sulfation processes for extracting cobalt, nickel, and manganese from cobalt-manganese crust ores and concentrates derived from the seabed. All three methods gave extractions of 95% or better for all three metals. Sulfuric acid pressure leaching was regarded the most likely process for this application. Test materials originated mostly from the Necker Ridge and Cross Seamount areas of the Central Pacific Basin in the EEZ.[11] South of Necker Ridge in the EEZ, the Bureau identified a manganese resource potential in crusts in the vicinity of Horizon Guyot and S. P. Lee Guyot of about 20 million and 8 million tons, respectively.[12]

Manganese was one of several strategic and critical metals whose potential recovery from domestic sources by carbonyl processing was investigated in the laboratory by the Bureau. Hydrogen reduction followed by carbonylation at 140° C and 1,500 pounds per square inch carbon monoxide pressure removed most of the iron from a sample of manganiferous ore from Aroostook County, ME, and upgraded the content of such material from 11% Mn, 35% Fe to 20% Mn, 3% Fe.[13]

Calorimetric methods were used by the Bureau in determining thermodynamic properties for pyroxmangite, a Mn-Ca silicate, and fowlerite, a Mn-Zn-Ca silicate.[14]

The Bureau investigated composition and generation rate of fume from shielded metal arc welding with electrode materials typical of those used in mines, with emphasis on the more highly alloyed filler metals. As expected, the data showed manganese in the electrodes to have a relatively high fume propensity. Exposure indices were developed to guide users in selecting electrode materials and avoiding excessive exposure to metals in fume from them.[15]

The Bureau analyzed the role of manganese in the economy of the U.S.S.R., beginning with the origins of the Soviet manganese industry and concluding with the outlook that this industry is likely to experience increased difficulties. Details were presented on reserves, mining, ferroalloy production, technology, trade, and consumption.[16]

Manganese was one of a number of mineral commodities for which the Bureau updated its previous assessment of availability from market economy countries. The indication for manganese continued to be that mine producers active as of 1987 could meet market economy countries' requirements throughout the remainder of the 20th century without expanding capacity, assuming no significant demand increase in the same period.[17]

A classification of the world's principal manganese deposits was put forth from the perspective of a field geologist. The classification was based on the geological environments that gave rise to manganese sediments, the minerals and rock formations associated with them, and secondary deposits formed from the original accumulations.[18]

A computer control system for electric furnaces used to smelt manganese ferroalloys was described. The system was developed by Elkem Metals and commissioned for use at the Bell Bay, Tasmania, plant of TEMCO in 1986 and at the Beauharnois, Canada, plant of Elkem Metals Canada Inc. in 1987. At the latter plant, operation of the system was observed to produce improvements in power level requirements and quality control and cost reductions in electrical energy and labor.[19]

Inclusion of manganese sulfide (MnS) in iron powder metallurgy (PM) mixes improved machinability of PM parts without producing detrimental effects. Tests with a 0.5% MnS addition showed reduced tool friction and wear, thereby leading to longer tool life.[20]

Values were recommended for such thermodynamic properties of manganese metal as heat capacity and enthalpy for the temperature range of 0.5 to 2,400 K and for its vapor pressure from room temperature to 2,400 K, based on a review of data available through March 1985.[21]

Concerns about deleterious environmental effects from mercury in dry-cell batteries have led to efforts to develop schemes for recycling such batteries to recover their manganese, mercury, and zinc contents. Tests of battery recycling and the attendant difficulties were discussed for various hydrometallurgical and/or pyrometallurgical methods. These tests were conducted in Japan, where two plants have begun recovering manganese and zinc from batteries in municipal waste.[22]

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[1]Physical scientist, Branch of Ferrous Metals.

[2]Unless otherwise specified, the unit of weight in this chapter is the short ton (2,000 pounds).

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Mercury

By Linda C. Carrico[1]

With the McDermitt Mine closed most of 1987, mercury recovered as a byproduct from gold-mining operations played a significant role in domestic primary production. The Paradise Peak gold deposit in Nevada was the largest producer of byproduct mercury. With primary production decreasing, mercury produced from scrap (industry and Government) rose substantially.

Although U.S. imports for consumpton of mercury and mercury-bearing waste and scrap decreased, they continued to be a major domestic source of supply. China became the leading U.S. import source of mercury.

Although total reported U.S. consumption decreased for the third consecutive year, the chlorine and caustic soda manufacturers increased their mercury consumption dramatically. The battery industry continued to be the dominant consumer of mercury, even though the amount of mercury in each dry-cell battery was reduced.

New York and London prices started the year at relatively low levels and slowly increased throughout most of the year but remained low by historical standards. The averages for the year were about $60 per flask[2] above that of 1986. Foreign mine producers continued to meet intermittently during the year to review the weak market conditions, and in response, they withdrew spot sales in an attempt to bolster prices.

Table 1.—Salient mercury statistics

	1983	1984	1985	1986	1987
United States:					
Producing mines	^{r}5	^{r}5	^{r}6	^{r}8	9
Mine production ---- flasks	25,070	19,048	16,530	W	W
Value ---- thousands	W	W	W	W	W
Secondary production:					
Industrial ---- flasks	13,751	5,673	5,358	6,362	7,692
Government[1] ---- do.	--	--	585	3,078	3,404
Industry stocks, yearend[2] ---- do.	31,018	27,255	27,985	W	W
Shipments from the National Defense Stockpile[3] ---- do.	6,000	4,092	4,534	463	3,700
Imports for consumption ---- do.	12,786	25,327	18,890	20,187	18,451
Consumption ---- do.	49,138	54,669	49,846	^{r}46,060	41,939
Price: New York, average per flask	$322.44	$314.38	$310.96	$232.79	$295.50
Employment, mine and mill, average	45	41	35	22	9
World:					
Mine production ---- flasks	180,835	^{r}195,031	197,688	^{p}179,263	^{e}178,800
Price: London, average per flask	$313.33	$306.40	$288.56	$193.80	$250.56

^{e}Estimated. ^{p}Preliminary. ^{r}Revised. W Withheld to avoid disclosing company proprietary data.
[1]Secondary mercury released from U.S. Department of Energy stocks.
[2]Stocks at mines, consumers, and dealers.
[3]Primary mercury.

Domestic Data Coverage.—Domestic data for mercury are developed by the Bureau of Mines from three separate, voluntary surveys of U.S. operations. Typical of these surveys is "Mercury," a survey of mercury consumption. Of the 339 firms to which this survey report was sent, 95% responded, representing an estimated 99.95% of the reported U.S. consumption shown in tables 1 and 3. Consumption for the nonrespondents was estimated using prior years consumption levels.

Legislation and Government Programs.—Under Public Law 99-661, Department of Defense Authorization Act, 1986, the General Services Administration (GSA) was authorized to dispose of 3,700 flasks of primary mercury from the National Defense Stockpile (NDS). GSA auctioned a maximum of 750 flasks of primary mercury per month, commencing January 1987; the mercury was offered instead of cash to pay contractors for services performed on the ferroalloy upgrading program. During the first half of 1987, GSA sold and shipped the total quantity of primary mercury authorized for disposal (3,700 flasks). Total inventory at yearend was 165,526 flasks, and the goal remained at 10,500 flasks.

GSA continued its monthly auctions of surplus secondary mercury stocks, which were managed by the U.S. Department of Energy (DOE) in Oak Ridge, TN. On the third Tuesday of each month, GSA offered a maximum of 750 flasks per month during January through July, and 1,500 flasks per month through the remainder of the year on an "as-is" basis. On July 17, GSA announced the elimination of a deposit with each bid and changed the removal periods as follows: 1 to 500 flasks, 90 days; 501 to 900 flasks, 150 days; and 901 to 1,500 flasks, 180 days. GSA sold 3,402 flasks and shipped 3,404 flasks during 1987, leaving 28,238 flasks available for disposal at yearend.

Under section 307 of the Clean Air Act, the Environmental Protection Agency (EPA) reviewed the national emission standards for mercury, which limit emissions from mercury ore-processing facilities, sludge incineration and drying plants, and mercury-cell chloralkali plants. The review by EPA determined that revisions to the monitoring, record keeping, and reporting requirements on the amount of mercury emitted by each plant was warranted and became effective on March 19.[3]

EPA, under the Resource Conservation and Recovery Act, restricted land disposal of some hazardous liquid wastes, including free liquids associated with any solid or sludge, of which mercury and/or mercury compounds were included. The liquid waste cannot contain mercury equal to or greater than 20 milligrams per liter, effective July 8.[4] A liquid waste was defined as any item containing a free liquid. For example, when the liquid waste is placed in a paint filter, any portion of the material passing through the filter within 5 minutes is considered a liquid waste.

Under the Comprehensive Environmental Response, Compensation, and Liability Act (Superfund), as amended, EPA and the Agency for Toxic Substance and Disease Registry (ATSDR) of the U.S. Department of Health and Human Services prepared a list of 100 hazardous substances commonly found at facilities on the Superfund list that pose a significant potential threat to human health as a result of known or suspected toxicity. The list was broken down into 4 groups, each consisting of 25 substances, in order of priority, of which mercury was No. 23 in the second group. ATSDR will prepare toxicological profiles on each listed hazardous substance in order of its priority. The profiles will be developed in detail to meet the obligations of health officials for current toxicological information.[5]

The Safe Drinking Water Act Amendments of 1986 require EPA to review and promulgate the maximum permissible levels for 83 contaminants by 1989, 1 of which is mercury. At yearend, the maximum permissible level of mercury in drinking water remained at 0.002 milligram per liter.

DOMESTIC PRODUCTION

Nevada remained the principal mercury-producing State in 1987. The figure for 1987 mine production, reported by nine mines—seven in Nevada and one each in California and Utah—and including byproduct mercury from gold operations, was withheld by the Bureau of Mines to avoid disclosing company proprietary data. An average of 8 pounds of mercury was produced per ton of ore treated over the last 5 years. Mine production decreased compared with that in the previous year, owing to the availability of low-cost foreign material, sales of mercury from Government stockpiles, and the closing of the McDermitt Mine.

Placer Dome U.S. Inc. (formerly Placer U.S. Inc.), operator of the McDermitt Mine in Nevada, closed its mine in early 1987 after 11 consecutive years of operation, stating that the depressed domestic price of mercury made it difficult for the company to compete against low-cost imports and sales of Government stocks. Placer met its sales obligations from its stockpile.

According to the Alaska Division of Geological and Geophysical Surveys,[6] the Mountain Top mercury mine produced about 12 flasks of mercury in 1986 and was active in 1987. The mine and retort are in a remote area southwest of Sleetmute, AK.

Mercury produced as a byproduct from eight gold-mining operations in 1987 accounted for more than 60% of the total reported production. The mines, operators, and locations were as follows: Alligator Ridge, Amselco Minerals Inc., Ely, NV; Borealis, Echo Bay Minerals Co. (formerly CanAm Minerals Co.), Hawthorne, NV; Carlin, Newmont Gold Co., Carlin, NV; Jerritt Canyon, Freeport-McMoRan Gold Co., Elko, NV; McLaughlin, Homestake Mining Co., Lower Lake, CA; Mercur, Barrick Mercur Gold Mines Inc., Tooele, UT; Paradise Peak, FMC Paradise Peak Corp., Gabbs, NV; and Pinson, Pinson Mining Co., Winnemucca, NV.

The following five companies redistilled purchased primary and/or processed purchased scrap mercury: Adrow Chemical Co., Wanaque, NJ; Bethlehem Apparatus Co. Inc., Hellertown, PA; D. F. Goldsmith Chemical and Metal Corp., Evanston, IL; Mercury Refining Co. Inc., Albany, NY; and Troy Chemical Corp., Newark, NJ.

Total secondary production from industry and Government materials was equivalent to 26% of the reported mercury consumption. Secondary mercury was salvaged from obsolete items and waste products such as amalgams, batteries, and industrial and control instruments. It was also retrieved from operating chlorine and caustic soda plants and from DOE shipments of mercury.

Table 2.—Production of secondary mercury in the United States

(Flasks)

Year	Industrial production	GSA releases	Total
1983	13,751	--	13,751
1984	5,673	--	5,673
1985	5,358	585	5,943
1986	6,362	3,078	9,440
1987	7,692	3,404	11,096

CONSUMPTION AND USES

Consumption of mercury was reported by about 200 plants. Prime virgin mercury accounted for 75% of the total reported consumption, followed by secondary mercury, 16%, and redistilled mercury,[7] 9%.

Total reported domestic mercury consumption decreased 9% compared with that of 1986. The battery industry reported a 29% decline in mercury consumption but continued to be the dominant consumer, followed by industries producing chlorine and caustic soda, paint, wiring devices and switches, and measuring and control instruments.

Mercury consumed by the battery industry decreased for the third consecutive year owing to a reduction in the amount of mercury used in each dry cell. Also, the producers of mercury-cell batteries have turned to foreign producers for their mercuric oxide instead of producing it themselves.

Consumption of mercury by the chlorine and caustic soda manufacturing industry increased dramatically in 1987 owing to a steady demand and resulting in a decrease in caustic soda stocks. During 1987, 20 mercury-cell plants operated in the United States; 16 were east of the Mississippi River.

Table 3.—Mercury consumed in the United States, by use

(Flasks)

SIC code	Use	1983	1984	1985	1986[r]	1987
28	Chemical and allied products:					
2812	Chlorine and caustic soda manufacture	8,054	7,347	6,804	7,499	9,014
2816	Pigments	W	W	W	W	W
2819	Catalysts, miscellaneous	484	359	488	515	402
2821	Catalysts for plastics	W	W	W	W	W
2819	Laboratory uses	280	269	413	571	589
283	Pharmaceuticals	--	--	--	W	W
2851	Paints	6,047	4,651	4,892	5,179	5,755
--	Other chemicals and allied products	W	W	478	W	W
36	Electrical and electronic uses:					
3641	Electric lighting	1,273	1,487	1,147	1,197	1,299
3643	Wiring devices and switches	2,316	2,730	2,762	2,981	3,811
3692	Batteries	23,350	29,700	27,622	21,764	15,462
--	Other electrical and electronic uses	W	W	W	215	W
38	Instruments and related products:					
382	Measuring and control instruments	2,465	2,856	2,300	1,820	1,717
3843	Dental equipment and supplies	1,597	1,432	1,444	1,507	1,613
--	Other instruments and related products	W	W	W	W	W
--	Other	1,356	1,404	267	349	420
	Total	49,138	54,669	49,846	46,060	41,939

[r]Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."

STOCKS

Reported stocks of mercury held by mine producers were withheld to avoid disclosing company proprietary data. Consumer and dealer-broker stocks increased dramatically owing to declining consumer demand. The NDS and DOE stockpile data are reported under the "Legislation and Government Programs" section in this chapter.

Table 4.—Stocks of mercury in the United States, December 31

(Flasks)

Year	Producer (mine)	Consumer and dealer	Total
1983	18,323	12,695	31,018
1984	19,964	7,291	27,255
1985	19,398	8,587	27,985
1986	W	[r]6,792	W
1987	W	9,287	W

[r]Revised. W Withheld to avoid disclosing company proprietary data.

PRICES

The domestic price of primary mercury increased gradually during most of the year owing to the setting of floor prices by foreign mine producers and the suspension of spot sales, which caused tight supplies. As reported in Metals Week, the New York dealer price for primary mercury was $220 to $230 per flask at the beginning of the year, reached a low of $201 to $211 per flask on February 20; thereafter, the price started a steady increase that continued throughout most of the year. The reported high range of $355 to $375 per flask for the year was set on October 23.

According to Metal Bulletin (London), the price range of mercury (minimum 99.99% pure) reached a low for the year on January 1 of $158 to $170 per flask. Thereafter, it gradually increased throughout most of the year, reaching a high for the year of $305 to $312 per flask on September 17.

Table 5.—Average prices of mercury at New York and London

(Per flask)

Period	New York	London
1983	$322.44	$313.33
1984	314.38	306.40
1985	310.96	288.56
1986	232.79	193.80
1987:		
January	217.25	165.56
February	208.11	179.00
March	239.77	204.50
April	272.73	230.00
May	313.00	272.17
June	307.27	257.78
July	295.65	238.89
August	313.33	266.56
September	342.14	302.38
October	355.00	306.44
November	349.74	295.50
December	332.05	287.94
Average	295.50	250.56

Sources: Metals Week (New York) and Metal Bulletin (London).

FOREIGN TRADE

Imports for consumption of mercury and mercury-bearing waste and scrap, which include imports for immediate consumption plus material withdrawn from bonded warehouses, decreased 9% owing to cutbacks in shipments by several foreign mine producers. In 1987, China became the leading U.S. supplier for the first time, followed by Spain.

The U.S. rate of duty on imported mercury, TSUS 632.3440, and mercury-bearing waste and scrap, TSUS 632.3420, as of January 1, 1987, from countries with most-favored-nation status was 6.4 cents per pound ($4.86 per flask).[8] A duty of 25 cents per pound ($19.00 per flask) applied to other countries. During 1987, mercury and mercury-bearing waste and scrap imported from Brazil, Hong Kong, and Turkey were eligible for duty-free status under the Generalized System of Preferences.

Philipp Bros. Inc., once quoted as the largest domestic trader of mercury, has ceased its mercury trading business at its New York office. Mercury transactions will be handled through its London office.

In a move to increase trade, China National Nonferrous Metals Imports and Exports Corp. (CNIEC), Beijing, established a permanent New York office, Nonferrous Metals (U.S.A.) Inc., 70 Pine Street, Suite 5016, New York, NY 10270. With a New York office, CNIEC officials stressed that this should improve the consistency of its mineral and metal exports and improve shipment timing. In 1987, China exported 11,771 flasks of mercury and mercury-bearing waste and scrap to the United States, an increase of 150% over the 1986 level.

Table 6.—U.S. imports for consumption of mercury and mercury-bearing waste and scrap, by country

Country	1985		1986		1987	
	Flasks	Value (thousands)	Flasks	Value (thousands)	Flasks	Value (thousands)
Algeria	1,938	$580	1,251	$208	--	--
Australia	--	--	39	7	--	--
Canada	5	26	10	53	156	$59
China	2,382	662	4,741	863	11,771	2,235
France	1	7	1,003	255	7	29
Germany, Federal Republic of	500	148	--	--	2	1

Table 6.—U.S. imports for consumption of mercury and mercury-bearing waste and scrap, by country —Continued

Country	1985 Flasks	1985 Value (thousands)	1986 Flasks	1986 Value (thousands)	1987 Flasks	1987 Value (thousands)
Hong Kong	--	--	--	--	500	$62
Japan	2,502	$630	2,202	$318	1,000	238
Malaysia	380	81	--	--	--	--
Mexico	214	38	655	150	10	3
Netherlands	--	--	--	--	1	3
Spain	7,955	2,322	5,824	1,310	5,002	1,230
Turkey	3,012	842	4,328	975	--	--
United Kingdom	(1)	1	2	2	--	--
Venezuela	--	--	132	35	--	--
Total[2]	18,890	5,337	20,187	4,176	18,451	3,860

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

Source: Bureau of the Census.

WORLD REVIEW

Mine producers in Algeria, Spain, and Turkey continued to meet during 1987 to review the mercury market situation and to try to stabilize the international price. The producers agreed to suspend spot sales throughout most of the year and set a floor price for contractual sales in an attempt to bolster prices to $400 per flask. Reportedly, these producers adopted a passive role in the past allowing the published free-market quotations to influence their selling prices. They agreed to refrain from making sales based on a formula linked to free-market prices.

The Council of the European Communities (EC) continued its investigation into the antidumping claim filed by Spain in 1986 against the U.S.S.R. Spain claimed that the U.S.S.R. exported about 15,000 flasks of mercury to European countries at "dumping prices." The EC Council imposed a duty of 70 European Currency Units ($90 per flask),[9] effective December 11, on U.S.S.R. mercury entering the European Communities.

Japan.—The All-Japan Cleaning Council operated a plant for the disposal and recycling of mercury-containing waste, especially dry cell batteries. The plant was in Itomuka, Hokkaido Prefecture. Reports indicated that the plant could recover as much as 1,450 flasks of mercury per year.

Kenya.—The Kenya Bureau of Standards banned the use of mercury as an active ingredient in shampoos, nail polish, and skin lightening creams. The ban was in response to a study conducted at the University of Nairobi that determined mercury caused poisoning, and even death, among users of cosmetics in Kenya.

Spain.—Minas de Almadén y Arrayanes S.A. (MAYASA), a mining company owned by the Spanish Government, and the largest mercury producer in the market economy countries, operated the Almadén, El Entredicho, and Las Cuevas Mines. MAYASA announced the discovery of a major mercury deposit near its 2,000-year-old Almadén Mine in southern Spain. Reportedly, the open pit deposit has an average ore grade of 20.5% mercury and exploitable reserves of over 135,000 flasks. Because of the extremely high grade of ore, mine operating costs for this deposit were estimated at $87 per flask, a significant difference from the $190 per flask for the El Entredicho open pit mine and over $300 per flask for the Almadén Mine. The new open pit was planned to begin in 1990, although production at the Almadén Mine will be phased out by 1989. Development work on Las Cuevas underground mine continued and was to be brought on-stream after the closure of the Almadén Mine.

MAYASA built a mercury-bearing recovery facility and ran it on a pilot basis during 1987. The plant had a production capacity of 15,000 flasks per year and employed about 30 workers. It consisted of four furnaces, each of which could treat about 6 tons of waste per day. In late 1987, only one furnace was operating. The material treated contained between 16% to 18% mercury with a recovery of 75% to 80%. The plant was to process large quantities of residues obtained from zinc-processing plants, battery scrap, and mercury recovered from mercury-cell chloralkali plants.

Table 7.—Mercury: World mine production, by country[1]

(Flasks)

Country	1983	1984	1985	1986[p]	1987[e]
Algeria[e]	10,000	[2]23,000	23,000	[r]22,000	22,000
China[e]	20,000	20,000	20,000	20,000	20,000
Czechoslovakia	4,177	4,409	4,583	4,873	4,700
Dominican Republic[e]	60	80	[2]121	120	100
Finland	1,857	2,292	3,630	4,235	4,000
Germany, Federal Republic of	2,005	--	--	--	--
Mexico	6,411	11,140	11,430	10,008	10,000
Spain	41,075	44,090	45,042	42,653	43,000
Turkey	4,680	5,272	6,552	7,574	6,000
U.S.S.R.[e]	64,000	64,000	65,000	66,000	67,000
United States	25,070	19,048	16,530	W	W
Yugoslavia[e]	1,500	[r]1,700	[r]1,800	[r]1,800	2,000
Total	180,835	[r]195,031	197,688	179,263	178,800

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

[1]Table includes data available through May 6, 1988.

[2]Reported figure.

TECHNOLOGY

The Luys Association's Yerevan electric bulb plant in the U.S.S.R. tested a new production process that reportedly reduces emission of mercury vapors into the atmosphere. Under the current process, an average of 100 milligrams of mercury was introduced into each bulb. The high output and extensive use of mercury-laden luminescent bulbs in the U.S.S.R. have consistently required that designers and developers find ways to reduce the level of environmental pollution. Scientists at the plant investigated the potential for replacement of liquid mercury by mercury compounds in the bulb. The use of compounds containing mercury, such as a titanium-mercury compound, was introduced. At normal temperatures, this compound released virtually no mercury. The weight amount of mercury product introduced into a bulb is several times less than that in the standard process. Experiments on test samples of luminescent bulbs using titanium-mercury showed that mercury evaporation reportedly declined, and bulb quality improved.[10]

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[1]Mineral specialist, Branch of Nonferrous Metals.

[2]Flask, as used throughout this chapter, refers to the 76-pound flask.

[3]Federal Register. Environmental Protection Agency. National Emission Standards for Hazardous Air Pollutants; Review and Revision of the Standards for Mercury. V. 52, No. 53, Mar. 19, 1987, pp. 8724-8728.

[4]———. Land Disposal Restrictions for Certain "California List" Hazardous Wastes and Modifications to the Framework. V. 52, No. 130, July 8, 1987, pp. 25760-25792.

[5]———. Notice of the First Priority List of Hazardous Substances That Will Be the Subject of Toxicological Profiles. V. 52, No. 74, Apr. 17, 1987, pp. 12866-12874.

[6]Bundtzen, T. K., C. B. Green, J. Deagen, and C. L. Daniels. Alaska's Mineral Industry, 1986. Spec. Rep. No. 40, Fairbanks, AK, 1987, pp. 29, 66.

[7]Redistilled mercury is primary mercury further processed or refined to a higher grade and is sometimes referred to as triple distilled mercury.

[8]Federal Register. Proclamation of Trade Agreement With Japan and Spain Providing Compensatory Concession. V. 48, No. 247, Dec. 22, 1983, pp. 56553-56559.

[9]Value has been converted from European Currency Units (ECU's) to U.S. dollars at the rate of ECU1.2857=US$1.00 as of Dec. 11, 1987.

[10]Foreign Broadcast Information Service. Science & Technology USSR: Materials Science, New Technology Reduces Mercury Pollution. Joint Publication Research Service, Washington, DC, JPRS-UMS-88-001, Jan. 8, 1988, pp. 37-38.

Mica

By Lawrence L. Davis[1]

In 1987, about 161,000 short tons of scrap and flake mica was produced in the United States, an increase of 9% from 1986 production.

Nearly all sheet mica supply continued to be imported. Consumption of muscovite mica block increased 15% to 57,900 pounds. Consumption of mica splittings decreased 5% to 2.1 million pounds. The value of sheet mica exports increased 4% to $4.9 million. Imports for consumption of sheet mica increased slightly to 4.1 million pounds.

Domestic Data Coverage.—Domestic production and consumption data for mica are developed by the Bureau of Mines by means of three separate, voluntary surveys and one mandatory survey. Of the 17 operations to which the crude scrap and flake mica production form was sent, 16 operations, or 94%, responded, representing 93% of the production shown in table 1. Of the 15 operations to which the ground mica form was sent, all responded, representing 100% of the production in table 1. Of the eight canvassed operations to which the mica block and film consumption form was sent, seven operations, or 88%, responded, representing 98% of the consumption shown in table 1. Of the 11 canvassed operations to which the mica splittings consumption form was sent, 9 operations, or 82%, responded, representing 94% of the splittings consumption shown in table 1. Consumption for the nonrespondents was estimated using prior year production data.

Table 1.—Salient mica statistics

	1983	1984	1985	1986	1987
United States:					
Production (sold or used by producers):					
Scrap and flake mica thousand short tons	140	161	138	148	161
Value thousands	$6,479	$7,139	$6,330	$7,108	$8,201
Ground mica thousand short tons	130	146	136	r123	124
Value thousands	$18,702	$21,334	$21,256	r$21,872	$22,376
Consumption:					
Block, muscovite thousand pounds	74	62	51	50	58
Value thousands	$961	$842	$751	$755	$982
Film thousand pounds	W	W	W	W	W
Value thousands	W	W	W	W	W
Splittings thousand pounds	2,120	2,366	2,361	2,226	2,116
Value thousands	$1,394	$1,679	$1,610	$1,252	$1,417
Exports thousand short tons	11	9	10	8	6
Imports for consumption do	8	13	11	13	13
World: Production thousand pounds	535,231	r609,595	560,701	p636,207	e654,531

eEstimated. pPreliminary. rRevised. W Withheld to avoid disclosing company proprietary data.

Legislation and Government Programs.—With the resumption of sales of natural sheet mica in 1987, the Government inventory of stockpile-grade mica was reduced slightly to 22.2 million pounds. The General Services Adminstration sold 141,000 pounds of muscovite splittings and 3,000 pounds of muscovite film.

Table 2.—Stockpile goals and Government inventories for mica, December 31, 1987

(Thousand pounds)

Material	Goal	Inventory: Stockpile grade	Inventory: Non-stock-pile grade	Available for disposal	1987 sales
Block:					
Muscovite, Stained and better	6,200	5,008	207	--	--
Phlogopite	210	17	114	--	--
Film: Muscovite, 1st and 2d qualities	90	1,176	1	1,032	3
Splittings:					
Muscovite	12,630	14,513	--	121	141
Phlogopite	930	1,519	--	--	--

DOMESTIC PRODUCTION

Scrap and Flake Mica.—North Carolina remained the major producing State with 62% of the total production. The remainder was produced in Connecticut, Georgia, New Mexico, Pennsylvania, South Carolina, and South Dakota. Most mica was recovered from mica schist, high-quality sericite schist, and as a byproduct of kaolin, feldspar, and lithium beneficiation.[2] The five largest producers were, in alphabetical order, The Feldspar Corp., Spruce Pine, NC; KMG Minerals Inc., Kings Mountain, NC; Lithium Corp. of America, Gastonia, NC; Pacer Corp., Custer, SD; and Unimin Corp., New Canaan, CT. These companies produced 68% of the national total.

Ground Mica.—Twelve companies operated fifteen grinding plants. Eleven plants produced dry-ground and four produced wet-ground mica. The five largest producers accounted for 76% of the total. They were, in alphabetical order, KMG Minerals, Kings Mountain, NC; Mineral Industrial Commodities of America Inc., Santa Fe, NM; Pacer, Custer, SD; Unimin, New Canaan, CT; and USG Corp., Chicago, IL.

Cyprus Minerals Co. agreed to purchase Foote Mineral Co. from Newmont Mining Corp. The agreement, reached late in the year, includes Foote's byproduct mica production facilities at Kings Mountain, NC.

In May, J. M. Huber Corp. broke ground for a new muscovite mica plant at Kings Mountain, NC. The plant, scheduled to open in 1988, will produce dry-ground products from mica ore mined at a nearby site.

Production of low-quality sericite, used primarily in brick manufacturing, was 34,000 tons valued at $129,000. Approximately 32,000 tons of ground sericite valued at $281,000 was sold or used. Low-quality sericite is excluded from tabulated data contained in this report.

Table 3.—Scrap and flake mica[1] sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	Quantity	Value
1983	140	6,479
1984	161	7,139
1985	138	6,330
1986	148	7,108
1987:		
North Carolina	100	5,607
Other States[2]	61	2,594
Total	161	8,201

[1]Includes finely divided mica recovered from mica schist and high-quality sericite schist, and mica that is a byproduct of feldspar, kaolin, and lithium beneficiation.
[2]Includes Connecticut, Georgia, New Mexico, Pennsylvania, South Carolina, and South Dakota.

Table 4.—Ground mica sold or used by producers in the United States, by method of grinding[1]

(Thousand short tons and thousand dollars)

Year	Dry-ground		Wet-ground		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
1983	118	13,907	12	4,795	130	18,702
1984	133	16,269	13	5,065	146	21,334
1985	123	15,993	13	5,263	136	21,256
1986[r]	109	14,682	14	7,190	123	21,872
1987	111	15,140	13	7,237	124	[2]22,376

[r]Revised.
[1]Domestic and some imported scrap. Low-quality sericite is not included.
[2]Data do not add to total shown because of independent rounding.

CONSUMPTION AND USES

Sheet Mica.—Consumption of muscovite block (ruby and nonruby) totaled 57,900 pounds, a 15% increase over that of 1986. Of the total muscovite block fabricated, 58% went into electronic uses; of this, the majority was used in vacuum tubes. Consumption of Stained quality decreased 5%, although it remained in greatest demand, accounting for 57% of consumption. Consumption of grades No. 5 and smaller increased 24%, while consumption of grades No. 4 and larger decreased 9%.

Eight companies continued to consume muscovite block and film in eight plants in seven States: two in North Carolina and one each in Massachusetts, New Jersey, New York, Ohio, Pennsylvania, and Virginia. The New York, Pennsylvania, and Virginia companies consumed 61% of the total.

Consumption of mica splittings decreased 5% to 2.1 million pounds. The decrease was caused by lower demand for built-up mica products. Muscovite splittings from India accounted for 97% of the consumption. The remainder was phlogopite splittings from Madagascar. The splittings were fabricated into various built-up mica products by 10 companies operating 10 plants in 8 States.

Built-Up Mica.—The primary use of this mica-base product, made by mechanical or handsetting of overlapping splittings and alternate layers of binders and splittings, was as electrical insulation material. Total production, sold or used, of built-up mica decreased 6% from that of 1986. The decrease continued the long-term decline caused by substitute materials and imported built-up mica products. Molding plates and segment plates were the major end products, accounting for 33% and 28% of the total, respectively. Other end products included flexible plates, heater plates, and tapes.

Reconstituted Mica (Mica Paper).—Four companies consumed 3.7 million pounds of scrap mica to produce 2.4 million pounds of mica paper. The principal source of this scrap mica was India. Primary end uses for mica paper were the same as those for built-up mica. Manufacturing companies were Corona Films Inc., West Townsend, MA; General Electric Co., Schenectady, NY; Kirkwood-Acim Corp., Hempstead, NY; and US Samica Corp., Rutland, VT.

Ground Mica.—The major end uses were joint cement, 57%; paint, 12%; and well-drilling muds, 6%. Other end uses included agricultural products, molded electical insulation, plastics, roofing, rubber, and welding rods.

Table 5.—Fabrication of muscovite block mica in the United States in 1987, by quality and end product use

(Pounds)

Quality	Electronic uses	Nonelectronic uses	Total
Good Stained or better	1,400	2,700	4,100
Stained	W	W	33,300
Lower than Stained[1]	W	W	20,500
Total	33,600	24,300	57,900

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1]Includes punch mica.

Table 6.—Fabrication of muscovite block mica in the United States in 1987, by quality

(Pounds)

Quality	No. 4 and larger	No. 5 and smaller	Total
Good Stained or better	3,700	400	4,100
Stained	6,500	26,800	33,300
Lower than Stained	1,900	18,600	20,500
Total[1]	12,000	45,900	57,900

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

Table 7.—Consumption and stocks of mica splittings in the United States, by source

(Thousand pounds and thousand dollars)

	India		Madagascar		Total[1]	
	Quantity	Value	Quantity	Value	Quantity	Value
Consumption:						
1983	2,079	1,257	41	137	2,120	1,394
1984	2,323	1,537	42	141	2,366	1,679
1985	2,327	1,485	34	125	2,361	1,610
1986	2,197	1,136	29	116	2,226	1,252
1987	2,050	1,231	67	185	2,116	1,417
Stocks on Dec. 31:						
1983	1,187	NA	148	NA	1,335	NA
1984	877	NA	77	NA	954	NA
1985	1,085	NA	41	NA	1,126	NA
1986	1,249	NA	95	NA	1,344	NA
1987	899	NA	9	NA	908	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	1986		1987	
	Quantity	Value	Quantity	Value
Flexible (cold)	190	803	177	626
Heater plate	63	132	51	88
Molding plate	624	2,326	680	2,397
Segment plate	686	2,940	571	2,211
Tape	253	1,559	161	1,197
Other	392	1,741	429	1,758
Total[2]	2,209	9,501	2,069	8,277

[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 end use

(Thousand short tons and thousand dollars)

End use	1986		1987	
	Quantity	Value	Quantity	Value
Joint cement	63	10,499	71	11,352
Paint	22	3,676	15	3,012
Plastics	1	252	2	338
Well-drilling mud	5	576	7	797
Other[1]	r32	r6,868	28	6,877
Total[2]	r123	r21,872	124	22,376

rRevised.
[1]Includes mica used for agricultural products, molded electrical insulation, plastics, rubber, textile and decorative coatings, and welding rods.
[2]Data may not add to totals shown because of independent rounding.

STOCKS

Reported yearend consumer stocks of sheet mica decreased 31% to 1.0 million pounds; of this, mica splittings represented 87% and mica block represented 13%.

PRICES

Average reported values of consumed muscovite sheet mica changed as follows: Block decreased 43% to $11.19 per pound; film increased 178% to $13.66 per pound; and splittings increased 15% to $0.60 per pound. The average value of phlogopite block increased 30% to $6.08 per pound, while the value of phlogopite splittings decreased 31% to $2.78 per pound. The large changes in average value are more a reflection of the quality of mica consumed during the year than actual changes in price. For example, much more lower quality, lower valued muscovite block mica was consumed in 1987 than in 1986.

The average value of crude scrap (flake) mica, including high-quality sericite, was $51 per ton. The average value per ton for North Carolina scrap (flake) mica, predominantly a flotation product, was $56.

Table 10.—Average reported price for dry- and wet-ground mica sold or used by U.S. producers in 1987

(Dollars per short ton)

Kind	Price
Wet-ground	544
Dry-ground	136
End uses:	
Joint cement	159
Paint	200
Plastics	153
Well-drilling mud	107
Other[1]	243

[1]Includes mica used for agricultural products, molded electrical insulation, roofing, rubber, textile and decorative coatings, welding rods, and miscellaneous.

FOREIGN TRADE

The United States continued to rely on imports, mostly from India, for nearly all of its unmanufactured sheet mica and paper-quality scrap mica. Imports for consumption of unmanufactured block, film, and splittings increased 32% to 2.5 million pounds. The increase was a reflection of lower than average sales of mica from the Government stockpile. About 6,000 tons of ground mica was imported, mostly from Canada, while about 5,000 tons was exported to 27 countries. The combined value of all mica imports increased 13% to $10.3 million, while the combined value of all mica exports decreased 7% to 6.4 million.

Table 11.—U.S. exports of mica and manufactures of mica in 1987, by country

(Thousand pounds and thousand dollars)

Country	Scrap and flake mica				Sheet mica		
	Ground or pulverized		Waste and scrap[1]		Unmanufactured block, film, splittings		Manufactured, cut or stamped, built-up
	Quantity	Value	Quantity	Value	Quantity	Value	Value
Argentina	42	4	--	--	--	--	93
Australia	16	2	--	--	--	--	261
Brazil	--	--	--	--	--	--	612
Canada	2,502	289	32	5	--	--	1,663
Ecuador	22	8	--	--	--	--	89
France	176	13	34	5	--	--	19
Germany, Federal Republic of	396	44	84	12	--	--	37
India	--	--	--	--	--	--	45
Italy	302	39	--	--	--	--	2
Japan	850	143	50	7	142	124	158
Korea, Republic of	464	124	--	--	26	17	49
Mexico	1,204	122	1,398	199	--	--	709
Netherlands	378	82	--	--	--	--	651
Philippines	122	33	30	5	--	--	2
South Africa, Republic of	--	--	--	--	--	--	55
Spain	1,216	163	--	--	--	--	--
Sweden	--	--	--	--	--	--	54
Taiwan	184	19	--	--	--	--	98
United Kingdom	378	44	176	25	--	--	9
Venezuela	250	34	--	--	--	--	59
Other[2]	836	114	12	2	2	4	84
Total[3]	9,338	1,275	1,816	259	170	145	4,748

[1]Some shipments of ground mica are included in this category.
[2]Includes Bahamas, Barbados, Belgium, Chile, Colombia, the Dominican Republic, Guatemala, Hong Kong, Indonesia, Ireland, Israel, Kuwait, the Leeward and Windward Islands, Malaysia, the Netherlands Antilles, Panama, Peru, Saudi Arabia, Suriname, and Switzerland.
[3]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

Table 12.—U.S. imports for consumption of scrap and flake mica, by country

(Thousand pounds and thousand dollars)

Country	Waste and scrap		Ground or pulverized	
	Quantity	Value	Quantity	Value
1985	7,960	718	12,097	2,202
1986	9,945	1,225	12,017	2,324
1987:				
Canada	57	6	12,250	2,322
India	7,900	1,159	44	2
Indonesia	441	47	--	--
Italy	220	29	72	13
Other[1]	18	1	141	348
Total[2]	8,635	1,243	12,507	2,685

[1]Includes Austria, Brazil, the Federal Republic of Germany, Japan, and Switzerland.
[2]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

Table 13.—U.S. imports for consumption of unmanufactured sheet mica, by country

(Thousand pounds and thousand dollars)

Country	Block		Splittings		Not cut or stamped, not over 0.006 inch in thickness[1]	
	Quantity	Value	Quantity	Value	Quantity	Value
1985	55	112	1,624	957	5	11
1986	11	61	1,824	580	32	13
1987:						
Belgium	--	--	1	33	--	--
France	70	159	(2)	3	--	--
India	14	32	2,323	940	--	--
Indonesia	--	--	40	15	--	--
Mexico	(2)	1	--	--	--	--
United Kingdom	11	43	--	--	1	4
Total	95	235	2,364	991	1	4

[1]Including film.
[2]Less than 1/2 unit.

Source: Bureau of the Census.

Table 14.—U.S. imports for consumption of manufactured sheet mica, by country

(Thousand pounds and thousand dollars)

Country	Cut or stamped: Not over 0.006 inch in thickness		Cut or stamped: Over 0.006 inch in thickness		Plates and built-up		Articles not especially provided for	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1985	60	510	120	560	729	1,540	69	544
1986	32	348	66	291	1,677	3,329	331	891
1987:								
Belgium	--	--	--	--	1,077	2,633	278	665
France	--	--	--	--	74	143	9	23
Germany, Federal Republic of	--	--	--	--	--	--	11	61
India	42	407	54	327	5	12	53	504
Japan	--	--	7	42	3	15	15	110
Other[1]	--	--	1	23	(2)	4	15	157
Total[3]	42	407	62	392	1,159	2,807	382	1,519

[1]Includes Brazil, Canada, China, Italy, Mexico, Spain, Switzerland, Taiwan, and the United Kingdom.
[2]Less than 1/2 unit.
[3]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

Table 15.—Summation of U.S. mica trade data

(Thousand pounds and thousand dollars)

	Scrap and flake mica: Ground or pulverized		Scrap and flake mica: Waste and scrap[1]		Sheet mica: Unmanufactured block, film, splittings		Sheet mica: Manufactured, cut or stamped, built-up	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Exports:								
1983	16,430	2,112	3,986	545	70	109	NA	4,001
1984	11,500	1,506	3,806	532	348	549	NA	4,519
1985	14,460	1,962	2,918	408	82	159	NA	5,103
1986	11,686	1,758	3,206	472	98	196	NA	4,502
1987	9,338	1,275	1,816	259	170	145	NA	4,748
Imports for consumption:								
1983	10,304	1,873	3,787	316	1,899	986	735	2,583
1984	12,814	2,266	10,384	985	1,480	644	856	2,836
1985	12,097	2,202	7,960	718	1,683	1,080	978	3,154
1986	12,017	2,324	9,945	1,225	1,866	653	2,105	4,859
1987	12,507	2,685	8,635	1,243	2,460	1,230	1,645	5,125

NA Not available.
[1]Some shipments of ground mica are included in this category.

Source: Bureau of the Census.

WORLD REVIEW

World production of mica increased slightly to 655 million pounds. India continued to lead the world in production of sheet mica. The United States continued to lead in the production of scrap (flake) mica.

Canada.—Lacana Mining Corp., Canada's only mica producer, announced plans to further expand its processing facilities at Boucherville, Quebec. The expansion, scheduled for completion in late 1988, will increase annual capacity to 20,000 tons. Major markets for Lacana's mica were the United States, 50%, and Canada, 25%. The remainder was exported to Australia, Japan, and Western Europe.[3]

Another company, Industrial Mica Ltd., was studying the feasibility of developing two phlogopite deposits in the St. Maurice River area of northern Quebec.[4]

Finland.—Kemira Oy began full production of ground mica from its new plant near Siilinjarvi. The mica, separated during beneficiation of apatite ore, is wet-ground to various sizes in the 16,000-ton-per-year plant.[5]

Spain.—Caolines de Vimianzo S.A. constructed a plant to recover mica from the underflow of cyclones being used to process kaolin. The plant, at Vimianzo, La Coruna, will use flotation methods to separate the muscovite mica from quartz. Annual capacity was expected to be about 12,000 tons per year.[6]

[1]Physical scientist, Branch of Industrial Minerals.
[2]Production of high-quality sericite is included in the totals; however, figures for low-quality sericite, used principally for brick manufacturing, are not included.
[3]Industrial Minerals (London). Lacana to Expand Mica Production. No. 242, Nov. 1987, p. 9.
[4]Benbow, J. Mica—Markets Built on Dry Ground. Ind. Miner. (London), No. 245, Feb. 1988, p. 26.
[5]Work cited in footnote 4.
[6]Industrial Minerals (London). Mica Plant for Cavisa. No. 237, June 1987, p. 11.

Table 16.—Mica: World production, by country[1]

(Thousand pounds)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Argentina:					
Sheet	62	26	701	551	440
Waste, scrap, etc	628	613	611	[e]600	550
Brazil	7,926	[r]8,834	6,352	4,850	5,500
Canada[e]	23,000	23,000	25,000	26,000	26,000
France	20,472	23,929	22,231	23,885	24,000
India:[e]					
Exports:					
Block	2,400	2,400	2,600	2,600	2,600
Film and disk	440	440	550	550	550
Splittings	7,000	7,000	8,800	8,800	8,800
Scrap	15,500	15,500	24,200	24,200	24,200
Powder	9,000	9,000	10,400	10,400	10,400
Manufactured	1,100	1,100	2,200	2,200	2,200
Domestic consumption, all forms	6,600	6,600	7,700	7,700	8,800
Total	42,040	42,040	56,450	56,450	57,550
Korea, Republic of (all grades)	31,751	53,872	44,189	92,587	88,000
Madagascar (phlogopite)	1,585	1,587	1,299	3,514	3,300
Mexico (all grades)	3,439	3,695	3,188	[e]3,100	3,100
Morocco	[e]1,100	2,646	3,175	[e]3,300	3,300
Mozambique[e]	[3]681	660	660	300	300
Namibia	220	198	--	--	--
Peru[e]	1,200	1,200	1,200	[r]1,200	1,200
South Africa, Republic of:					
Sheet	--	--	179	--	--
Scrap	5,891	9,872	4,568	5,531	[3]2,877
Spain	2,866	2,183	1,603	717	550
Sri Lanka (scrap)[e]	[3]377	440	440	440	440
Sudan	22	22	[e]22	22	22
Taiwan	686	670	[e]250	1,706	1,102
Tanzania (sheet)	(4)	(4)	(4)	(4)	(4)
U.S.S.R. (all grades)[e]	108,000	108,000	110,000	110,000	110,000
United States (scrap and flake)[5]	280,000	322,000	275,100	296,300	[3]321,100
Yugoslavia[e]	[3]2,086	2,100	2,200	2,200	2,200
Zimbabwe	1,199	2,008	1,283	2,954	3,000
Grand total	535,231	[r]609,595	560,701	636,207	654,531

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through May 13, 1988.
[2]In addition to the countries listed, China, Norway, Pakistan, Romania, and Sweden are known to produce mica, but available information is inadequate to make reliable estimates of output levels.
[3]Reported figure.
[4]Less than 1/2 unit.
[5]Excludes U.S. production of low-quality sericite.

Molybdenum

By John W. Blossom[1]

Domestic and foreign molybdenum markets increased in 1987 and demand in market economy countries exceeded mine production. Domestic producer and consumer stocks increased in 1987. U.S. mine output of molybdenum decreased compared with that of 1986 and represented 40% of the world production. Reported end-use consumption of molybdenum in raw materials and apparent domestic demand increased compared with that of 1986. Exports of all forms of molybdenum from the United States decreased during 1987. Domestic producers' stocks of molybdenum increased, but confronted with stock inventories equivalent to about 1-1/3 years' consumption, domestic producers' prices were weak. World market prices were below those of U.S. producer quoted price listings for 1987.

Domestic Data Coverage.—Domestic production data for molybdenum are developed by the Bureau of Mines by means of three separate, voluntary surveys. These surveys are "Molybdenum Ore and Concentrate," "Molybdenum Concentrate and Molybdenum Products," and "Molybdenum Concentrates." Out of 18 operations to which surveys were sent, all responded, representing 100% of the total production shown in table 1.

Table 1.—Salient molybdenum statistics

(Thousand pounds of contained molybdenum and thousand dollars)

	1983	1984	1985	1986	1987
United States:					
Concentrate:					
Production	33,593	103,664	108,409	93,976	75,117
Shipments	48,805	102,405	111,936	95,006	69,868
Value	$166,612	$326,780	$347,812	$240,484	$179,286
Reported consumption	27,014	54,843	W	53,061	37,442
Imports for consumption	1,673	28	112	1,120	1,264
Stocks, Dec. 31: Mine and plant	11,637	12,450	9,322	8,715	15,082
Primary products:					
Production	37,533	79,689	87,436	41,490	34,659
Shipments	50,562	65,527	73,861	57,855	40,668
Reported consumption	27,225	34,792	33,451	31,898	32,629
Stocks, Dec. 31: Producers'	28,352	22,155	21,014	20,699	22,168
World: Mine production	r140,616	r214,275	216,364	p203,466	e186,405

eEstimated. pPreliminary. rRevised. W Withheld to avoid disclosing company proprietary data.

DOMESTIC PRODUCTION

Domestic mine production of molybdenum decreased to a total of 75 million pounds of contained molybdenum, compared with 94 million pounds in 1986. The country's two largest producers were AMAX Inc. and Cyprus Minerals Co. Domestic producers attempted to correct oversupply by reducing production.

Table 2.—Production, shipments, and stocks of molybdenum products in the United States

(Thousand pounds of contained molybdenum)

	Molybdic oxides[1] 1986	Molybdic oxides[1] 1987	Metal powder 1986	Metal powder 1987	Ammonium molybdate 1986	Ammonium molybdate 1987
Received from other producers	37,224	22,801	--	W	W	1,621
Gross production during year	25,445	W	5,382	5,925	W	W
Used to make other products listed here	19,298	18,706	1,126	1,744	1,749	1,771
Net production	6,147	W	4,256	4,181	W	W
Shipments	43,347	W	4,208	4,333	W	W
Producer stocks, Dec. 31	16,459	W	W	457	W	W

	Sodium molybdate 1986	Sodium molybdate 1987	Other[2] 1986	Other[2] 1987	Total 1986	Total 1987
Received from other producers	W	W	2,378	218	39,602	24,640
Gross production during year	W	W	10,663	28,734	41,490	34,659
Used to make other products listed here	W	W	1,363	1,181	23,536	23,402
Net production	W	W	7,550	7,076	17,953	11,257
Shipments	W	W	10,300	36,335	57,855	40,668
Producer stocks, Dec. 31	W	W	4,240	21,711	20,699	22,168

W Withheld to avoid disclosing company proprietary data; included with "Other."
[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, molybdenum hexacarbonyl, and data indicated by symbol W.

CONSUMPTION AND USES

The quantity of molybdenum in concentrate roasted domestically to produce technical-grade molybdic oxide decreased from that of 1986. The remainder of the mine production of concentrate was either exported for conversion, purified to lubrication-grade molybdenum disulfide, or added to the stocks at mines and plants. The oxide, or roasted concentrate, is the chief form of molybdenum utilized by industry, particularly steel, cast iron, and superalloy producers. However, some of the material is also converted to other molybdenum products, such as ferromolybdenum, high-purity oxide, ammonium and sodium molybdate, and metal powder.

Apparent consumption (defined as U.S. primary plus secondary production plus imports minus exports plus adjustments for Government and industry stock changes) decreased to 33 million pounds of molybdenum. The total reported end-use consumption of molybdenum in raw materials increased about 2% from that of 1986. Molybdenum consumed in oxide form (technical-grade, purified, and briquets) accounted for about 58% of total reported consumption; in ferromolybdenum, 16%; and in other forms, 26%.

Molybdenum reported as consumed in the production of steel accounted for 56% of total consumption. Approximately 15% of consumption was attributed to other metallurgical uses, such as cast irons, superalloys, and as a refractory metal. Catalyst, lubricant, pigment, and other nonmetallurgical applications composed the final 29% of total consumption.

Table 3.—U.S. reported consumption of molybdenum, by end use

(Thousand pounds of contained molybdenum)

End use	Molybdic oxides	Ferromolybdenum[1]	Ammonium and sodium molybdate	Other molybdenum materials[2]	Total[3]
1986					
Steel:					
Carbon	792	79	--	--	871
Stainless and heat resisting	4,300	531	--	121	4,952
Full alloy	6,532	813	--	69	7,414
High-strength, low-alloy	633	720	--	W	1,383
Tool	1,688	W	--	W	1,688
Cast irons	W	909	--	W	909
Superalloys	998	109	--	1,572	2,679
Alloys (excludes steels and superalloys):					
Welding and alloy hard-facing rods and materials	--	202	--	7	209
Other alloys[4]	229	114	--	133	476
Mill products made from metal powder	--	--	--	4,296	4,296
Chemicals and ceramics:					
Pigments	W	--	W	--	W
Catalysts	2,882	--	W	W	2,882
Other	9	2	--	766	777
Miscellaneous and unspecified	453	615	1,761	533	3,362
Total	18,546	4,094	1,761	7,497	31,898
1987					
Steel:					
Carbon	926	263	--	(5)	1,189
Stainless and heat resisting	5,604	504	--	148	6,257
Full alloy	6,454	1,198	--	59	7,712
High-strength, low-alloy	726	762	--	4	1,492
Tool	1,568	W	--	49	1,617
Cast irons	W	1,275	--	20	1,295
Superalloys	1,113	99	--	1,664	2,876
Alloys (excludes steels and superalloys):					
Welding and alloy hard-facing rods and materials	--	216	--	12	228
Other alloys[4]	217	120	--	120	456
Mill products made from metal powder	--	--	--	3,752	3,752
Chemicals and ceramics:					
Pigments	W	--	W	--	W
Catalysts	1,794	--	W	365	2,159
Other	8	--	1	729	737
Miscellaneous and unspecified	536	621	1,621	81	2,859
Total[3]	18,945	5,059	1,622	7,003	32,629

W Withheld to avoid disclosing company proprietary data.
[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]Data may not add to totals shown because of independent rounding.
[4]Includes magnetic and nonferrous alloys.
[5]Less than 1/2 unit.

STOCKS

Total industry stocks, which include those of producers and consumers, increased to 43 million pounds of contained molybdenum. Inventories of molybdenum in concentrate at mine locations increased from 8.7 to 15.1 million pounds. Producers' stocks of molybdenum in consumer products, such as oxide, ferromolybdenum, molybdate, metal powders, and other types, increased to 22 million in 1987. Compared with apparent consumption, yearend producers' stocks of these materials totaled about 1-1/3 years' supply. Domestic consumers held inventories of about 6 million pounds throughout most of the year, representing approximately a 2-month supply compared with average monthly reported consumption.

Table 4.—Industry stocks of molybdenum materials, December 31

(Thousand pounds of contained molybdenum)

Material	1983	1984	1985	1986	1987
Concentrate: Mine and plant	11,637	12,450	9,322	8,715	15,082
Producers:					
Molybdic oxides[1]	22,991	17,295	16,281	16,459	W
Metal powder	503	594	W	W	457
Ammonium molybdate	1,038	684	W	W	W
Sodium molybdate	79	W	W	W	W
Other[2]	3,741	3,582	4,733	4,240	21,711
Total	28,352	22,155	21,014	20,699	22,168
Consumers:					
Molybdic oxides[1]	1,467	1,552	2,020	2,168	3,653
Ferromolybdenum[3]	570	721	597	618	554
Ammonium and sodium molybdate	70	80	47	129	76
Other[4]	1,567	1,540	1,778	1,654	1,643
Total[5]	3,674	3,893	4,441	4,569	5,925
Grand total[5]	43,663	38,498	34,777	33,983	43,175

W Withheld to avoid disclosing company proprietary data.
[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.
[5]Data may not add to totals shown because of independent rounding.

PRICES

The price of "Metals Week Dealer" (MWD) molybdic oxide (per pound of contained molybdenum) decreased from $3.18 in January to $2.85 at the end of December 1987. The average MWD price of oxide was $3.01 or $0.10 less than the average MWD price in 1986.

The posted producer price for molybdic oxide was $3.45 in January. During May the price was reduced to $3.25 and remained at that level through December 1987.

Table 5.—Domestic price listings for molybdenum

(Per pound of contained metal)

	1986	1987
Merchant quotes:		
Concentrate (byproducts)	$2.50	$2.59
Ferromolydenum-export	3.52	3.58
Oxide	2.92	3.01
Producer quotes: Oxide	3.45	$3.45-3.25

Source: Metals Week.

FOREIGN TRADE

Exports.—Exports of molybdenum in concentrate and oxide decreased compared with that of 1986. Molybdenum concentrate exports were about 54% of domestic mine production. Approximately 98% of reported concentrates and oxides was shipped to Austria, Belgium-Luxembourg, Canada, the Federal Republic of Germany, Japan, the Netherlands, Sweden, and the United Kingdom. The calculated molybdenum content of all exports was 46 million pounds in 1987. Total value of exports decreased from $185 million in 1986 to $140 million in 1987.

Imports.—Approximately 13.5 million pounds of molybdenum in various forms was imported into the United States, an increase of 7.5 million pounds over that of 1986. Total value of all forms of molybdenum imported increased from $27 million in 1986 to $48 million in 1987. In terms of both value and quantity, the major forms imported were as concentrate, materials in chief value molybdenum, and molybdenum compounds. The principal originating countries for these imports were Canada and Chile.

The President withdrew the duty-free

treatment afforded under the Generalized System of Preferences (GSP) to imports of molybdenum ore, TSUS-601.33, and materials in chief value of molybdenum, TSUS-603.40, from all countries on or after December 31, 1987. In addition, the President issued Proclamation 5758 on December 24, 1987, which stated that general headnote 3 (e)(v)(A) to the TSUS is modified by striking out "Chile" from the enumeration of independent countries whose products are eligible for benefits under the GSP; and that no article that is the product of Chile and imported into the United States after the effective date of this Proclamation shall be eligible for preferential treatment under the GSP. This Proclamation was to become effective on February 29, 1988.

The countries mostly affected by these changes were Chile, Mexico, and Peru.

Table 6.—Molybdenum reported by producers as shipments for export from the United States

(Thousand pounds of contained molybdenum)

	1986	1987
Molybdenite concentrate	18,267	21,198
Molybdic oxide	21,325	12,273
All other primary products	836	966

Table 7.—U.S. exports of molybdenum ore and concentrates (including roasted concentrates), by country

(Thousand pounds of contained molybdenum and thousand dollars)

Country	1985		1986		1987	
	Quantity	Value	Quantity	Value	Quantity	Value
Austria	31	50	--	--	4,369	11,576
Belgium-Luxembourg	5,743	30,114	3,088	8,782	5,337	12,526
Brazil	153	627	222	761	114	381
Canada	780	1,979	3,662	8,149	1,507	2,348
Chile	102	377	93	130	44	109
France	--	--	--	--	228	644
Germany, Federal Republic of	3,379	7,758	2,028	4,299	5,966	13,564
Japan	7,031	26,202	5,818	16,555	2,852	8,071
Mexico	71	135	22	137	3	18
Netherlands	40,076	160,250	24,997	75,802	12,443	31,557
Sweden	949	2,896	2,792	6,047	1,275	3,062
United Kingdom	4,991	15,463	6,243	14,499	5,765	12,911
Other	552	1,840	188	845	611	1,615
Total[1]	63,859	247,690	49,153	136,006	40,514	98,381

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

Source: Bureau of the Census.

Table 8.—U.S. exports of molybdenum products, by product and country

(Thousand pounds, gross weight, and thousand dollars)

Product and country	1986		1987	
	Quantity	Value	Quantity	Value
Ferromolybdenum:[1]				
Canada	40	154	45	171
Japan	187	406	74	314
Malaysia	1	4	4	15
Mexico	101	346	27	74
Other	5	19	11	31
Total[2]	332	929	161	605
Metal and alloys in crude form and scrap:				
Belgium	1	17	1	4
Canada	34	317	22	184
France	2	34	8	36
Germany, Federal Republic of	148	790	70	418
India	2	9	1	6
Japan	220	923	227	1,406
Mexico	9	105	12	128
Netherlands	139	171	78	323
United Kingdom	344	592	16	154
Other	101	153	78	845
Total[2]	1,000	3,111	513	3,504

See footnotes at end of table.

Table 8.—U.S. exports of molybdenum products, by product and country —Continued

(Thousand pounds, gross weight, and thousand dollars)

Product and country	1986		1987	
	Quantity	Value	Quantity	Value
Wire:				
Argentina	3	76	2	41
Belgium-Luxembourg	8	349	20	257
Brazil	42	750	47	803
Canada	46	760	31	530
France	14	199	23	403
Germany, Federal Republic of	97	1,096	202	2,506
India	(3)	8	(3)	6
Italy	66	886	67	975
Japan	96	1,989	67	1,260
Mexico	19	107	9	252
Netherlands	2	23	4	32
Singapore	6	51	2	53
South Africa, Republic of	(3)	9	2	28
Spain	19	234	19	257
Sweden	22	277	25	382
United Kingdom	26	471	15	349
Other	28	386	39	907
Total[2]	494	7,671	573	9,043
Powder:				
Belgium-Luxembourg	71	485	974	2,363
Canada	14	175	289	2,576
France	64	357	92	589
Germany, Federal Republic of	16	195	77	379
Italy	5	60	2	31
Japan	210	278	7	88
Mexico	1	6	6	44
Netherlands	333	330	26	181
Sweden	7	51	13	92
Taiwan	49	437	133	944
United Kingdom	45	91	497	1,156
Other	41	356	28	423
Total[2]	854	2,821	2,145	8,866
Semifabricated forms, n.e.c.:				
Australia	11	216	8	149
Belgium-Luxembourg	3	148	--	--
Brazil	45	855	19	343
Canada	20	571	13	324
France	31	914	34	1,146
Germany, Federal Republic of	83	1,497	29	655
Japan	7	223	29	704
Mexico	(3)	14	3	76
Netherlands	34	1,145	63	2,547
Philippines	--	--	(3)	2
Singapore	(3)	2	(3)	5
South Africa, Republic of	10	385	7	291
United Kingdom	75	1,752	47	1,287
Other	167	1,398	30	638
Total[2]	486	9,119	282	8,167
Molybdenum compounds:				
Argentina	--	--	(3)	2
Australia	1	3	8	16
Belgium-Luxembourg	546	824	68	342
Brazil	11	40	5	21
Canada	138	411	274	1,160
Germany, Federal Republic of	3,234	4,219	3	31
Japan	1,880	4,027	3,152	7,240
Mexico	60	129	86	220
Netherlands	3,262	4,532	159	335
Sweden	1,879	2,450	--	--
Switzerland	(3)	2	--	--
United Kingdom	4,347	5,479	150	373
Other	1,703	2,882	791	1,407
Total[2]	17,063	24,997	2,696	11,146

[1]Ferromolybdenum contains about 60% to 65% molybdenum.
[2]Data may not add to totals shown because of independent rounding.
[3]Less than 1/2 unit.

Source: Bureau of the Census.

Table 9.—U.S. imports for consumption of molybdenum

(Thousand pounds and thousand dollars)

Item	TSUS No.	1986			1987		
		Gross weight	Contained molybdenum	Value	Gross weight	Contained molybdenum	Value
Ore and concentrate	601.33	1,740	1,120	3,057	2,195	1,264	3,109
Material in chief value molybdenum	603.40	1,786	1,102	3,284	8,664	5,248	15,497
Ferromolybdenum	606.31	1,599	1,077	3,626	3,815	2,283	8,042
Waste and scrap	628.70	NA	529	2,870	NA	646	2,545
Unwrought	628.72	NA	191	2,510	NA	174	2,308
Wrought	628.74	102	NA	2,701	158	NA	2,801
Ammonium molybdate	417.28	528	318	1,320	1,355	786	2,870
Molybdenum compounds	419.60	1,870	1,236	4,913	2,702	1,822	7,594
Potassium molybdate	420.20	40	27	134	--	--	--
Sodium molybdate	421.10	434	403	758	150	64	262
Mixtures of inorganic compounds, chief value molybdenum	423.88	127	38	212	66	46	220
Molybdenum orange	473.18	1,651	NA	1,754	2,438	NA	2,461
Total[1]		9,878	6,040	27,138	21,543	12,333	47,711

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

Source: Bureau of the Census.

Table 10.—U.S. import duties on molybdenum

Item	TSUS No.	Most favored nation (MFN) Jan. 1, 1987	Non-MFN Jan. 1, 1987
Molybdenum ore and concentrate	601.33	9 cents per pound	35 cents per pound.
Material in chief value molybdenum	603.40	6 cents per pound plus 1.9% ad valorem.	50 cents per pound plus 15% ad valorem.
Ferromolybdenum	606.31	4.5% ad valorem	31.5% ad valorem.
Molybdenum:			
Waste and scrap	628.70	6% ad valorem	50% ad valorem.
Unwrought	628.72	6.3 cents per pound plus 1.9% ad valorem.	50 cents per pound plus 15% ad valorem.
Wrought	628.74	6.6% ad valorem	60% ad valorem.
Molybdenum chemicals:			
Ammonium molybdate	417.28	4.3% ad valorem	29% ad valorem.
Calcium molybdate	418.26	Free	24.5% ad valorem.
Molybdenum compounds	419.60	3.2% ad valorem	20.5% ad valorem.
Potassium molybdate	420.22	3% ad valorem	23% ad valorem.
Sodium molybdate	421.10	3.7% ad valorem	25.5% ad valorem.
Mixtures of inorganic compounds, chief value molybdenum	423.88	2.8% ad valorem	18% ad valorem.
Molybdenum orange	473.18	3.9% ad valorem	25% ad valorem.

WORLD REVIEW

World mine production of molybdenum was 187 million pounds, a decrease of 17 million pounds from that in 1986. Canada, Chile, the U.S.S.R., and the United States accounted for more than 87% of the molybdenum produced worldwide. Although comprehensive statistics on world consumption were not available, market evidence clearly indicated that supply exceeded demand. World molybdenum consumption and stocks increased during 1987.

[1]Physical scientist, Branch of Ferrous Metals.

Table 11.—Molybdenum: World mine production, by country[1]

(Thousand pounds of contained molybdenum)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Bulgaria[e]	420	420	420	400	400
Canada (shipments)	22,474	25,479	17,311	24,804	25,530
Chile	33,651	37,172	40,541	36,555	36,800
China[e]	4,400	4,400	4,400	4,400	4,400
Japan[e]	214	324	215	--	--
Korea, Republic of	313	348	734	696	700
Mexico	12,932	8,938	8,292	7,385	8,000
Mongolia[e]	2,120	2,200	2,200	[r]2,425	2,425
Niger[e]	88	73	44	44	33
Peru	5,825	6,557	8,898	7,681	7,700
Philippines	86	--	--	--	--
U.S.S.R.[e]	24,500	24,700	24,900	25,100	25,300
United States	33,593	103,664	108,409	93,976	[3]75,117
Total	140,616	214,275	216,364	203,466	186,405

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

[1]Table includes data available through June 17, 1988.

[2]In addition to the countries listed, North Korea, Romania, Turkey, and Yugoslavia are believed to produce molybdenum, but output is not reported quantitatively, and available general information is inadequate to make reliable estimates of output levels.

[3]Reported figure.

Nickel

By William S. Kirk[1]

The international nickel market was characterized by record-high demand and price levels. Domestic reported consumption rose by 19%, the highest level of consumption since 1984. The steep price increases were a result of the inability of supply to keep pace with demand.

Domestic Data Coverage.—There was no domestic primary nickel production. Domestic consumption data for nickel are developed by the Bureau of Mines from a voluntary survey of U.S. plants. Of the 307 plants to which a survey request was sent, 295 responded, representing 82% of the apparent primary nickel consumption shown in table 4. Apparent consumption of primary nickel was derived by using imports minus exports plus adjustments for

Table 1.—Salient nickel statistics

(Short tons of contained nickel unless otherwise specified)

	1983	1984	1985	1986	1987
United States:					
Mine production:					
Nickel ore (gross weight)	--	1,674,600	868,100	603,400	--
Shipments	--	14,540	6,127	1,175	--
Plant production:					
Smelter, from domestic ores (includes byproduct nickel)	W	9,604	5,214	1,651	--
Refinery, from imported matte	33,400	35,329	31,168	--	--
Secondary recovery, from purchased scrap:[e]					
From ferrous scrap	30,076	35,760	36,690	35,320	[p]38,265
From nonferrous scrap	19,776	19,407	16,955	8,406	[p]8,392
Exports:					
Primary (unwrought)	23,359	31,638	21,745	2,812	2,413
Total (gross weight)	43,913	58,525	51,429	23,269	27,919
Imports:					
Primary	152,333	176,715	157,690	129,094	148,273
Primary (gross weight)	215,361	249,929	220,349	159,298	176,802
Total (gross weight)	225,537	264,778	236,001	172,683	191,154
Consumption:					
Reported:					
Primary	127,845	136,861	119,907	107,062	130,504
Secondary (purchased scrap)[e]	42,034	49,649	42,295	31,862	34,316
Apparent:					
Primary	150,879	155,395	157,795	137,582	155,500
Secondary (purchased scrap)[e]	49,852	55,167	53,645	43,724	46,657
Stocks, Dec. 31:					
Government	32,309	32,209	37,222	[r]37,215	37,215
Producer	38,500	37,300	17,400	10,300	6,824
Consumer:					
Primary	20,448	20,934	19,106	16,557	10,393
Secondary	10,304	6,520	6,302	4,669	4,375
Employment, Dec. 31:					
Mine	160	130	130	--	--
Smelter	230	170	170	--	--
Refinery	420	420	--	--	--
Price (cathode):[1]					
New York dealer, per pound	$2.20	$2.22	$2.26	$1.86	$2.28
World: Mine production	[r]742,123	[r]846,935	882,250	835,725	867,098

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Weighted average calculated by Metals Week.

Government and industry stock changes.

Legislation and Government Programs.—The Institute of Scrap Iron and Steel (ISIS) urged the U.S. Environmental Protection Agency (EPA) to remove nickel from EPA's Extremely Hazardous Substances (EHS) list. ISIS pointed out that nickel did not meet EPA's original listing criterion of toxicity. If nickel were allowed to stay on the list, many scrap processors and scrap consumers would become subject to emergency planning requirements because of the presence of nickel in the scrap metal, which they routinely handled. As of yearend 1987 the issue was unresolved.

The 100 most hazardous substances found in Superfund sites were listed by the EPA and ranked in four priority groups on the basis of chemical toxicity, frequency of occurrence at Superfund sites, and potential for human exposure. Nickel was included in the first group primarily because of its frequency of occurrence.

Negotiations between the United States and the U.S.S.R. aimed at permitting the U.S. importation of Soviet nickel suffered a setback. In December 1983, the U.S. Department of the Treasury placed an embargo on the importation of unfabricated nickel originating in the U.S.S.R. because of the Soviet refusal to certify that its shipments contained no Cuban nickel. Talks begun in December 1986 to resume Soviet shipments to the United States had seemed close to being successful, but no agreement was reached during the year.

The U.S. Department of the Treasury, Bureau of the Mint, purchased 1,975 tons of nickel under six solicitations at a total price of $9,615,302.

DOMESTIC PRODUCTION

On January 7, 1987, M. A. Hanna Co. announced the permanent closure of the sole U.S. nickel mine-smelter complex. The operation, at Riddle, OR, had been closed and on standby status since August 1986 because of low nickel prices. Apparently, the company had decided that little chance existed for the prices to rebound in the foreseeable future. Although the smelter could produce 12,000 short tons of nickel in ferronickel per year (about 8% of the annual U.S. primary nickel consumption), periodic temporary closures since 1982 had kept the output well below the rated capacity of the smelter. Approximately 300 employees were affected by the closure.

The production of domestic secondary nickel in the form of scrap was a major part of the supply of nickel for consumption. Since the Bureau of Mines documented only the recovery of nickel in scrap that was consumed, recovery and consumption figures were essentially the same. The nickel recovered from stainless steel scrap was calculated from the gross weight of the scrap and estimated at 5.7%, which was the weighted-average nickel content of all grades of stainless steel scrap consumed.

Table 2.—Nickel recovered from purchased scrap in the United States, by kind of scrap and form of recovery[e]

(Short tons of contained nickel)

	1985	1986	1987[p]
KIND OF SCRAP			
Aluminum-base	111	107	188
Copper-base	2,505	2,031	2,097
Ferrous-base	36,690	35,320	38,265
Nickel-base	14,339	6,266	6,107
Total	53,645	43,726	46,657
FORM OF RECOVERY			
Aluminum-base alloys	115	118	229
Chemical compounds	W	W	--
Copper-base alloys	11,512	6,364	6,594
Ferrous alloys	36,690	35,367	38,297
Nickel-base alloys	5,328	1,875	1,537
Total	53,645	43,724	46,657

[e]Estimated. [p]Preliminary. W Withheld to avoid disclosing company proprietary data; included with "Copper-base alloys."

CONSUMPTION

Driven chiefly by the stainless steel industry, nickel consumption increased. Reported domestic primary nickel consumption increased 22% and apparent consumption rose to 202,157 short tons. Consumption grew in all categories except cast irons; electric, magnet, and expansion alloys; and other nickel and nickel alloys. In nickel-bearing stainless steel, the largest end-use sector, production was up 22% over that of 1986. Although most stainless steel production was for domestic consumption, much was exported, a result of the lower value of the U.S. dollar. Imports of stainless steel fell slightly, while exports rose 73%.

Domestic demand for stainless steel was derived from the pulp and paper, food processing, and petrochemical industries.[2] Stainless steel scrap consumption increased during 1987 as a result of price increases. Nickel demand in superalloys rose sharply as the aerospace industry replaced engines. Demand in plating was essentially flat owing to the reduction in automobile production and transfer of some plating business to Canada, where the exchange rate was more favorable.

Commercially pure unwrought nickel (Class I), in the form of electrolytic cathodes, pellets, briquets, or powder, again dominated the forms of primary nickel consumed. These forms comprised most of the nickel consumed in all products except in the cast irons, stainless and heat-resistant steels, and nickel-copper alloys end-use sectors, wherein they were a major, but not dominant, nickel source. The Class II materials—ferronickel, nickel oxide, oxide sinter, and utility grade nickel—were primarily used in producing stainless and heat-resistant steels.

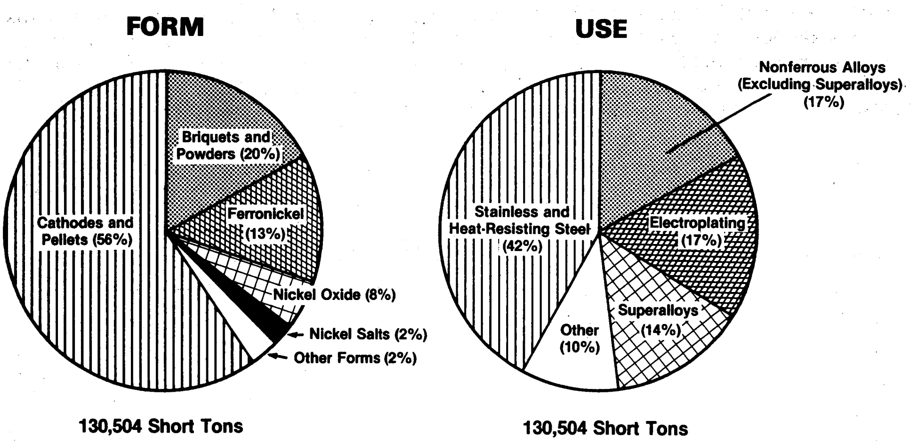

Figure 1.—U.S. nickel consumption in 1987, by form and use.

Table 3.—Reported U.S. consumption of nickel, by form

(Short tons of contained nickel)

Form	1983	1984	1985	1986	1987
Primary:					
Ferronickel	15,595	18,419	17,993	13,256	17,418
Metal	96,981	104,958	90,379	82,884	98,673
Oxide powder and oxide sinter	9,670	7,087	6,297	7,357	9,926
Salts[1]	4,402	2,962	2,770	2,416	2,435
Other	1,197	3,435	2,468	1,149	2,052
Total primary	127,845	136,861	119,907	107,062	130,504
Secondary (scrap)[2]	42,034	49,649	42,295	31,824	[p]34,316
Grand total	169,879	186,510	162,202	138,886	164,820

[p]Preliminary.
[1]Metallic nickel salts consumed by plating industry are estimated.
[2]Based on gross weight of purchased scrap consumed and estimated average nickel content.

Table 4.—U.S. consumption of nickel in 1987, by use

(Short tons of contained nickel)

Use	Commercially pure nickel	Ferronickel	Nickel oxide	Nickel salts	Other primary forms	Total primary	Secondary[e p] (scrap)	Grand total
Cast irons	590	314	40	W	239	1,183	571	1,754
Chemicals and chemical uses	1,607	--	84	95	159	1,945	--	1,945
Electric, magnet, expansion alloys	206	--	--	--	--	206	32	238
Electroplating (sales to platers)[1]	20,299	W	--	2,338	13	22,650	--	22,650
Nickel-copper and copper-nickel alloys	4,261	W	2	W	368	4,631	6,578	11,209
Other nickel and nickel alloys	17,812	61	5	W	76	17,954	1,201	19,155
Steel:								
Stainless and heat-resistant	27,843	16,677	8,894	--	761	54,175	24,966	79,141
Alloys (excludes stainless)	7,970	346	240	--	4	8,560	412	8,972
Superalloys	17,276	--	339	--	364	17,979	325	18,304
Other[2]	809	20	322	2	68	1,221	231	1,452
Total reported by companies canvassed	98,673	17,418	9,926	2,435	2,052	130,504	34,316	164,820
Total all companies, apparent	XX	XX	XX	XX	XX	[3]155,500	46,657	202,157

[e]Estimated. [p]Preliminary. W Withheld to avoid disclosing company proprietary data; included with "Other."
XX Not applicable.
[1]Based on monthly estimates.
[2]Includes batteries, ceramics, and other alloys containing nickel.
[3]U.S. production plus imports minus exports minus stock increases.

STOCKS

The combined stocks of primary nickel maintained in the United States by foreign producers with U.S. sales offices and metal-trading companies with U.S. sales offices decreased 34% during the year. At yearend, these stocks represented 12 days of domestic consumption. The drop was a reflection of very strong demand. Nickel stocks on the London Metal Exchange (LME) fell 38%. The yearend inventory was 4,584 tons. Consumer stocks declined by 50% during 1987. Stocks of nickel in ferrous scrap held by iron and steel producers were down 14% from that of 1986.

The quantity of nickel contained in the National Defense Stockpile decreased from 37,223 tons to 37,215. This change represented an inventory adjustment. The adjustment occurred when a quantity of nickel was moved from one General Services Administraton storage depot to another. In the process, it was found to weigh less than its recorded weight.

Table 5.—Nickel in consumer stocks in the United States, by form

(Short tons of contained nickel)

Form	1983	1984	1985	1986	1987
Primary:					
Ferronickel	893	692	1,930	1,028	776
Metal	17,359	17,479	13,754	11,829	8,218
Oxide and oxide sinter	1,677	2,259	3,059	3,281	995
Salts	268	229	184	175	196
Other	251	275	179	244	208
Total primary	20,448	20,934	19,106	16,557	10,393
Secondary (scrap)	10,304	6,520	6,302	4,669	[p]4,375
Grand total	30,752	27,454	25,408	21,226	14,768

[p]Preliminary.

PRICES

The world nickel price increased dramatically, particularly toward yearend. The LME cash price began the year at $1.60 per pound and rose gradually to about $2.60 in November. In December, the LME price briefly exceeded $4.00 and averaged $3.48 for the month.

There were four primary factors that accounted for the enormous price increases. The first factor was the very high demand for nickel used in stainless steel. This was unforeseen by producers and consumers. Domestic reported consumption of nickel for stainless steel rose from 29,800 tons in 1986 to 40,350 tons in 1987, a 35% increase.

The second factor was the closure of nickel production facilities. Some producers were forced to shut down their operations during the recent years of low nickel prices.

The third factor was the shortage of stainless steel scrap. Owing to improved methods of casting and cutting, there was less scrap available in 1987 than there was a few years ago.

The fourth factor was the cessation of ferronickel shipments from the Dominican Republic. In December, the Government of the Dominican Republic imposed a 25% export duty on ferronickel produced in that country by Falconbridge Dominicana C. por A. The world's second largest ferronickel producer, Falconbridge, considered the duty prohibitive and halted shipments. One of Falconbridges's main objections was that the export duty rate was pegged to the exchange rate of the peso relative to the U.S. dollar. A further decline in the value of the peso could have increased duties considerably.

There were a number of lesser factors that had an affect on nickel prices, primarily equipment failures. Many of these problems occurred because plants were being strained by operating at full capacity. Most of the minor factors would not have a significant impact on the nickel market in ordinary times.

The LME price remained the leading nickel price indicator. For 1987, this price averaged $2.19 per pound, up 25% from that of 1986. In the United States, the New York dealer price for electrolytic nickel best indicated prices paid by U.S. consumers. At a weighted average of $2.28 per pound for 1987, as calculated by Metals Week, the New York dealer price rose about the same amount from its 1986 level as did the LME price. A major North American producer reported that its average realized price for the year rose 12% to $2.18 per pound.

The price of stainless steel scrap, the largest source of secondary nickel for consumption, followed the price of primary nickel. According to the American Metal Market, the price of 18-8 stainless steel scrap in Pittsburgh rose from a range of $480 to $490 per ton at the beginning of the year to a range of $710 to $720 by yearend.

FOREIGN TRADE

The net import reliance rose to 79%, as domestic primary production fell to zero, and virtually all primary nickel consumed in the United States was imported. Canada again supplied most of the imported nickel, including most of the nickel imported from Norway, which was mined and smelted in Canada before being refined in Norway.

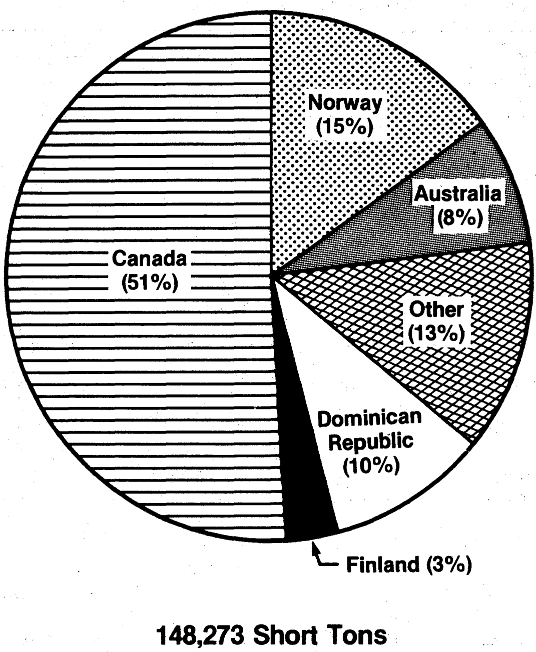

Figure 2.—Major sources of U.S. primary nickel imports in 1987.

Table 6.—U.S. exports of nickel and nickel alloy products, by class

(Gross weight unless otherwise specified)

Class	1984 Quantity (short tons)	1984 Value (thousands)	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)	1987 Quantity (short tons)	1987 Value (thousands)
Primary:								
Cathodes, pellets, briquets, and shot (unwrought)	25,997	$118,453	17,761	$86,596	1,936	$12,542	1,547	$10,581
Electroplating anodes	140	965	132	965	108	961	213	1,864
Ferronickel	7,880	NA	5,355	NA	455	NA	165	NA
Powder and flakes	1,790	12,062	1,106	8,942	584	5,913	582	6,720
Total	35,807	131,480	24,354	96,503	3,083	19,416	2,507	19,165
Nickel content[1]	31,638	XX	21,745	XX	2,812	XX	2,413	XX
Wrought:								
Bars, rods, angles, shapes, sections	3,342	34,808	4,253	45,060	2,239	29,735	2,780	31,595
Plates, sheets, strip	1,968	21,316	2,645	28,726	3,676	25,151	5,597	37,188
Tubes, pipes, blanks, fittings, hollow bar	428	7,929	303	6,356	684	6,430	294	6,916
Wire	1,119	11,166	954	9,147	844	8,520	1,216	11,896
Nickel-compound catalysts	2,718	15,156	3,523	22,811	2,243	10,631	3,984	16,940
Nickel waste and scrap	13,143	23,566	15,397	26,705	10,500	15,012	11,541	17,273
Grand total	58,525	245,421	51,429	235,308	23,269	114,895	27,919	140,973

NA Not available. XX Not applicable.

[1]Based on estimated nickel content and gross weight of primary nickel products.

Sources: Bureau of the Census and Journal of Commerce.

Table 7.—U.S. imports for consumption of nickel products, by class

(Gross weight unless otherwise specified)

Class	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)	1987 Quantity (short tons)	1987 Value (thousands)
Primary:						
Smelter products:						
Ferronickel	36,528	$60,253	37,901	$53,672	45,389	$57,481
Salts and other (including slurry)	68,210	101,101	9,170	19,281	5,241	24,754
Refined nickel:						
Cathodes, pellets, briquets, and shot (unwrought)	97,779	446,009	99,017	407,210	113,249	455,126
Flakes	242	1,151	600	2,420	937	3,622
Oxide and oxide sinter	5,079	20,722	2,868	4,372	2,278	4,277
Powder	12,511	66,566	9,742	48,631	11,040	56,784
Total	220,349	695,802	159,298	535,586	178,143	602,044
Nickel content[1]	157,690	XX	129,094	XX	148,273	XX
Wrought:						
Bars, plates, sheets, anodes	3,177	32,276	2,310	17,048	1,518	12,901
Pipes, tubes, fittings	3,744	33,984	1,487	16,616	1,539	24,633
Rods and wire	2,990	22,103	2,640	19,228	2,235	16,527
Shapes, sections, angles	189	1,297	153	1,002	152	800
Nickel waste and scrap	5,552	16,430	6,795	19,581	7,567	25,133
Grand total	236,001	801,892	172,683	609,061	191,154	682,038

XX Not applicable.
[1]Based on estimated nickel content and gross weight of primary nickel products.

Sources: Bureau of the Census and Journal of Commerce.

Table 8.—U.S. nickel imports for consumption of new nickel products in 1987, by country

(Short tons of contained nickel)

Country	Cathodes, pellets, briquets, shot (unwrought)	Powder and flakes	Oxide and oxide sinter	Ferronickel	Salts[e] and other	Total 1987	Total 1986
Australia	11,347	1,067	--	--	29	12,444	11,883
Botswana	218	--	--	--	--	218	253
Canada	62,392	9,757	683	25	2,383	75,240	60,020
Colombia	--	--	--	3,270	--	3,270	3,137
Dominican Republic	--	--	--	14,390	31	14,421	5,654
Finland	5,046	--	--	--	--	5,046	5,362
France	2,600	12	(1)	--	399	3,011	2,686
Germany, Federal Republic of	134	202	--	(1)	148	483	316
Japan	301	(1)	--	3	14	317	469
New Caledonia	--	--	--	1,254	--	1,254	3,797
Norway	21,666	--	--	--	28	21,694	16,669
South Africa, Republic of	2,282	796	--	3	--	3,081	7,159
United Kingdom	1,266	90	(1)	--	388	1,744	547
Zimbabwe	2,756	--	--	--	--	2,756	3,045
Other	3,240	54	--	--	--	3,294	8,097
Total[2]	113,249	11,977	683	18,945	3,419	148,273	129,094

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

Sources: Bureau of the Census and Journal of Commerce.

WORLD REVIEW

World demand for nickel, about 625,000 tons in 1986, was originally expected to be about the same in 1987. However, as a result of record worldwide stainless steel production, world demand increased to about 705,000 tons, according to an industry source. World supply was considerably lower at approximately 675,000 tons.

Representatives from the major nickel producing and consuming countries were scheduled to hold the inaugural meeting of the International Nickel Study Group (INSG) when at least 15 countries representing 50% or more of the world trade in nickel accepted the terms of reference for the group. The meeting, which was tentatively scheduled for June, was postponed because fewer countries had agreed to join.

Australia.—Although the Agnew Mine, owned by Seltrust Holdings Ltd. (60%) and Mount Isa Mines Ltd. (40%), remained closed throughout the year, it was kept on a care-and-maintenance status. Plans called for an underground exploration program to determine the extent of ore grades at depth. Future plans and feasibility studies were to be based on the results. Metals Exploration Ltd. permanently closed the Nepean Mine in Western Australia in May owing to the depletion of reserves. The mine had produced ore containing about 3,000 short tons of nickel per year. Western Mining Corp. began producing ore from its new Lanfranchi Mine in the Kambalda District.

Dallhold Investments Pty. Ltd., an Australian investment company, purchased a 50% share of Queensland Nickel Pty. Ltd., which operated the Greenvale Mine and Yabulu refinery in Queensland that had been held by Freeport-McMoRan Inc., New Orleans, LA. Later in the year, Dallhold purchased the other 50% of the Greenvale project from another Australian company, Metals Exploration Ltd. Dallhold reportedly planned to import nickel ore from New Caledonia to provide feedstock for its Yabulu refinery in Queensland. The ore was to supplement and eventually replace feedstock coming from the Greenvale Mine.

Brazil.—Cia. Niquel Tocantins expansion plans to double its refinery capacity by 1988 were delayed. The nickel producer reportedly announced plans to achieve that goal by 1990, raising the capacity to 11,000 short tons per year.

Canada.—The Provincial Environmental Minister of Manitoba drafted a regulation that, if passed, would require Inco Ltd.'s Thompson nickel smelter to immediately curtail sulfur dioxide emissions from 414,000 tons to 330,000 tons per year. By 1994, the company would be expected to achieve further reductions to 220,000 tons per year. A joint Federal-Provincial government research program to reduce sulfur dioxide emissions by rejecting the mineral pyrrhotite continued.

Inco, the largest nickel producer among market economy countries, increased its share of the Western World nickel market from 30% in 1986 to 34%. After several years of heavy losses or meager profits, the company posted its highest profits since 1980. Inco announced that it was launching a $20 million development project at its underground nickel mining operations in Thompson, Manitoba. Production was to begin within 1 year, with the deposit providing more than 5 million tons of nickel ore over the next 15 years.

Another Inco expansion project was the old Coleman Mine on the north rim of the Sudbury Basin. All-electric mining equipment, similar to that used in the Crean Hill Mine, was expected to be used. Inco planned for full production to be reached in 1990. In addition, the Creighton Deep ore body and the Crean Hill Mine were brought into production by Inco.

Inco reached an agreement on a new 3-year contract with mining and production workers at its Thompson plant in Manitoba. Under the new contract, workers were to receive a 50-cent-per-hour salary increase the first year and a 25-cent-per-hour increase in each of the next 2 years plus a cost-of-living increase over the life of the agreement.

Falconbridge Ltd. bought additional shares in its subsidiary, Falconbridge Dominicana a ferronickel operation in the Dominican Republic. Falconbridge purchased Armco Inc.'s 17.5% share, bringing its share to 85.2%. Separately, Falconbridge Ltd. also announced a plan to raise $13.2 million for exploration by issuing flow-through shares. In addition, Falconbridge Ltd. restructured its mining holdings by selling its 49% share in Western Platinum Ltd., Republic of South Africa, to Lonrho PLC Ltd., the majority partner.

Outokumpu Mines Ltd. Toronto, a subsidiary of Outokumpu Finland, formed a joint venture with Hudson Bay Mining & Smelting Co. Ltd., Toronto, by exercising its option to purchase 40% of the Namew Lake deposit. The deposit, in northern Manitoba, was reported to contain well over 50,000 tons of nickel. The plant was to be built under a turnkey contract by a division of Outokumpu. Nickel production was expected to begin in 1988, with the full annual production rate of about 10,000 tons of nickel, contained in concentrates, to be reached in the last quarter of the year. Negotiations were underway with Canadian producers to refine the concentrate. Two of them, Inco and Sherritt Gordon Mines Ltd., had refineries nearby.

Cuba.—The Cubans opened a processing line during the year at their Punta Gorda plant, increasing its capacity by 10,000 tons per year. All Cuban production was shipped to the U.S.S.R. or Czechoslovakia.

Dominican Republic.—In December, the Dominican Republic imposed a 25% export duty on ferronickel produced in that country by Falconbridge Dominicana, a subsidiary of Falconbridge Ltd., the world's second largest ferronickel producer. Falconbridge Dominicana was operating under a 20-year-old agreement that precluded any such action. Therefore, the company halted shipments of ferronickel rather than pay what it considered to be a prohibitive duty. At yearend, the issue had not been resolved. Falconbridge continued to produce and stockpile ferronickel. Also, Falconbridge increased its interest in its subsidiary (See "Canada" in this section.)

Finland.—Outokumpu Oy, the state-owned metals producer, closed the Kotalahti nickel mine in April to avoid operating losses. The company was depending on the Enonkoski Mine, opened in 1986, for feedstock.

Greece.—Larco S.A., the Greek state-owned ferronickel producer, was in serious financial straits owing to low nickel prices. The company planned to lay off nearly one-half of its work force and was scheduled to be auctioned in mid-1988. However, as a result of the surge in nickel prices, Larco put some of its production equipment back on-stream, and production rose from 770 short tons in October to an estimated 1,100 tons in December. Production in 1988 was expected to be 1,300 tons per month.

Table 9.—Nickel: World mine production, by country[1]

(Short tons of nickel content)

Country	1983	1984	1985	1986[p]	1987[e]
Albania (content of ore)[e]	7,900	10,100	10,600	10,700	10,900
Australia (content of concentrate)	84,465	84,793	94,531	84,590	82,100
Botswana (content of matte)	20,079	20,507	21,567	20,803	[2]18,230
Brazil (content of ore)	17,153	25,940	22,377	14,843	14,700
Burma (content of speiss)[e]	22	22	22	22	22
Canada[3]	141,220	192,017	187,361	180,381	207,000
China[e]	14,300	15,400	27,600	[r]27,600	27,600
Colombia (content of ferroalloys)	19,243	24,124	17,013	[r e]20,500	22,800
Cuba (content of oxide, sinter, sulfide)	41,487	35,087	35,458	[e]36,000	37,500
Dominican Republic	21,522	26,371	28,450	24,239	24,500
Finland (content of concentrate)	5,858	[r]7,626	9,421	13,102	[2]11,637
German Democratic Republic[e]	2,400	2,200	[r]2,200	[r]2,200	2,200
Greece (recoverable content of ore)[e]	18,500	18,400	20,600	[r]1,600	13,200
Indonesia (content of ore)[4]	54,430	52,474	44,463	58,058	64,000
New Caledonia (recoverable content of ore)	50,885	64,293	[r e]79,800	[r e]68,100	61,800
Norway (content of concentrate)	397	358	468	483	440
Philippines	15,322	14,993	31,039	14,099	[2]8,619
Poland (content of ore)[e]	2,300	2,300	2,200	2,200	2,200
South Africa, Republic of[e]	22,600	27,600	27,600	[r]35,100	37,800
U.S.S.R. (content of ore)[e]	187,000	192,000	198,000	205,000	205,000
United States (content of ore shipped)	--	14,540	6,127	1,175	--
Yugoslavia (content of ore)[e]	[r]1,760	[r]2,400	[r]3,100	[r]3,500	3,500
Zimbabwe (content of concentrate)[e]	13,250	13,390	12,253	[r]11,430	11,350
Total	[r]742,123	[r]846,935	882,250	835,725	867,098

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

[1]Insofar as possible, this table represents recoverable mine production of nickel; where data relate to some more highly processed form, the figure given has been used in lieu of unreported actual mine output to provide some indication of the magnitude of mine output, and is so noted parenthetically following the country name, or by footnote. Table includes data available through June 24, 1988.

[2]Reported figure.

[3]Refined nickel and nickel content of oxides and salts produced, plus recoverable nickel in exported mattes and speiss.

[4]Includes a small amount of cobalt not reported or recovered separately.

Table 10.—Nickel: World plant production, by country[1]

(Short tons of nickel content)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Australia[3]	46,077	42,615	44,982	46,404	[4]49,830
Brazil[5]	9,165	10,127	14,680	14,840	14,700
Canada[3]	96,100	114,600	100,300	180,381	214,400
China[e]	14,300	15,400	24,800	24,800	24,800
Colombia[5]	14,396	18,810	13,007	[e]20,500	22,800
Cuba[6]	10,298	9,311	9,759	[r e]9,600	9,800
Czechoslovakia[e]	3,300	5,000	5,000	5,000	4,400
Dominican Republic[5]	23,369	26,698	28,450	24,239	24,250
Finland	16,355	16,846	17,258	19,611	[4]16,967
France	5,401	5,751	7,738	11,023	8,200
German Democratic Republic[e]	3,300	3,300	3,300	[r]3,500	3,500
Germany, Federal Republic of[e 7]	1,320	1,100	800	--	--
Greece	14,174	17,448	17,584	11,380	[4]10,141
Indonesia[5]	5,352	5,320	5,293	4,980	2,200
Japan[8]	90,556	98,489	102,175	102,186	[4]102,817
New Caledonia[5]	23,939	32,141	39,797	36,377	[4]32,552
Norway	31,547	39,185	41,351	42,118	[4]49,124
Philippines	6,721	3,889	18,732	2,288	--
Poland[e]	2,300	2,300	2,300	2,300	2,100
South Africa, Republic of	[e]18,740	22,597	[e]22,000	[r e]28,000	30,200
U.S.S.R.[e]	204,000	211,000	[r]215,000	[r]222,000	222,000
United Kingdom	25,574	24,582	19,621	34,130	[4]32,518
United States	33,400	44,933	36,382	1,651	--
Yugoslavia[e 5]	[r]1,100	[r]2,000	[r]3,100	[r]3,500	3,500
Zimbabwe	11,184	11,300	10,340	10,725	10,800
Total	[r]711,968	[r]784,742	803,749	861,533	891,599

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

[1]Refined nickel plus nickel content of ferronickel produced from ore and/or concentrates unless otherwise specified. Table includes data available through June 24, 1988.

[2]In addition to the countries listed, North Korea is believed to have produced metallic nickel and/or ferronickel, but information is inadequate for formulation of reliable estimates of output levels. Several countries produced nickel-containing matte, but output of nickel in such materials has been excluded from this table in order to avoid double counting. Countries producing matte include the following, with output indicated in short tons of contained nickel: Australia: 1983—54,900 (estimated); 1984—56,330 (estimated); 1985—56,858; 1986—54,078; and 1987—52,728; Botswana: 1983—20,080; 1984—20,507; 1985—21,567; 1986—20,913; and 1987—18,230; Indonesia: 1983—20,159; 1984—25,149; 1985—27,498; 1986—30,999; and 1987—32,500 (estimated); and New Caledonia: 1983—5,046; 1984—6,021 (revised); 1985—9,816 (revised); 1986—10,097; and 1987—9,130.

[3]Refined nickel plus the nickel content of oxide.

[4]Reported figure.

[5]Nickel content of ferronickel only. (No refined nickel was produced.)

[6]Content of granular nickel oxide and powder only; Cuba also produces nickel oxide sinter and a processed sulfide, but these are not included in order to avoid double counting, as they may be processed to metal elsewhere. Output of sinter was as follows, in short tons: 1983—12,723; 1984—9,804; 1985—7,776; 1986—7,700 ; and 1987—7,900 (estimated). Output of processed sulfide was as follows, in short tons: 1983—18,466; 1984—15,971; 1985—17,835; 1986—18,700 (revised, estimated); and 1987—19,200 (estimated).

[7]Includes nickel content of nickel alloys.

[8]Includes nickel content of ferronickel, refined nickel, and nickel oxide.

Japan.—Oita Nickel Co. Ltd., a subsidiary of Tokyo Nickel Co. Ltd., installed a new roasting furnace that increased its nickel oxide sinter production capacity from 17,000 to 35,000 tons per year. The company processed nickel matte from Indonesia. Nippon Mining Co. Ltd. permanently closed its smelter at Saganoseki in September. The smelter had a capacity of 11,000 short tons of nickel contained in ferronickel.

Korea, Republic of.—Construction was begun on a new utility nickel production facility in Onsan. The plant was to be owned and operated by Korea Nickel Corp., which was jointly owned by Korea Zinc Co. (70%) and Inco, Canada (30%). Construction of the 13,000-ton-per-year plant was expected to be completed by yearend of 1988. Feedstock was to be nickel oxide or nickel oxide sinter supplied by Inco from Canada or Indonesia. The project was initiated owing to an expected increase in demand for nickel by the domestic stainless steel industry.

Norway.—The Norwegian firm of Leonard, Nielson & Sonner reportedly investigated the possibility of developing a nickel deposit near Ballengen in northern Norway. The deposit was said to contain 2 to 2.75 million short tons of nickel.

Philippines.—The U.S.S.R. reportedly submitted a proposal to participate technically and financially in the Nonoc Mining and Industrial Corp. nickel operation near

Surigao.

South Africa, Republic of.—Lonrho gained almost full control of Western Platinum by purchasing Falconbridge's 49% share. Western Platinum produced byproduct nickel and cobalt from its platinum-group metals operations.

U.S.S.R.—Outokumpu Oy won a contract to supply nickel-processing equipment to the Pechenga concentrator project in the Kola Peninsula. The equipment was to be used for modernizing the grinding, flotation, and chemical preparation plants. Reports indicated that production was disrupted following an accident at the Soviet nickel production facility in Norilsk. The Soviets were expanding their line of nickel products. The monchegorsk Severonikel plant, near Murmansk, was to begin production of nickel powder and pellets. New cutting mills also went into operation. The latter action was taken, not only to add value to their nickel products, but to expand the Soviets' potential end market. Formerly their uncut nickel either had to be shipped to Rotterdam for cutting or sent to the few stainless steel producers with facilities large enough to handle it.

Zimbabwe.—The Zimbabwean Government reportedly agreed to provide funds to Bindura Nickel Corp. so that the company could continue to operate.

TECHNOLOGY

Mining and Processing.—Inco used a continuous loader-crusher combination with a belt-bender conveyor system that could carry ore around corners to institute a continuous mining system.

The Enonkoski Mine, in southeastern Finland, was that country's most modern mine.[3] The mine featured the latest in Finnish high-technology mining and mineral processing equipment and systems. Outokumpu the operator, developed a computer-aided mine planning system.

Cobalt-rich manganese crusts in the Exclusive Economic Zone represented a resource of cobalt, nickel, and other metals. Three promising chemical processes for extracting metals from the crusts were investigated: sulfuric acid oxidation pressure-leaching, aqueous sulfur dioxide leaching, and acid sulfation. Each has resulted in metal extractions exceeding 95%. The advantages of each were described.[4]

Nickel Products.—An electrical wiring cable was developed that was reported to be capable of withstanding temperatures in excess of 1,093° C. The cable had a number of applications in the oil industry where critical electronic circuits must remain functional in a flash fire. The cable was sheathed in high-nickel alloy 825 with a nickel-clad copper or pure nickel conductor.[5]

Electroplated coatings of nickel alloys were developed as replacements for gold, silver, and palladium in electrical contacts.[6] These alloys were NiX, where X equals such materials as antimony, arsenic, boron, germanium, and phosphorus.

In Japan, the adoption of flexible stainless steel pipe to replace galvanized steel pipes for gas pipelines in urban areas was proposed.[7] The stainless steel type 304 pipe reduced the potential for gas leaks that could occur at the numerous fittings required by galvanized pipe.

A method of increasing the activity of nickel as a catalyst more than 100,000 times was developed.[8] Nickel normally forms a protective oxide coating when exposed to air, causing it to become resistant to chemical reactions. Giving nickel powder an ultrasonic bath by irradiating it with sound waves at 20 kilohertz agitates the particles so that they are cleaned of their oxide layer by abrasion. A clean metal surface is therefore continuously present to react as a catalyst.

A company that produces heating element wires obtained a license to use a nickel-aluminide produced by Oak Ridge National Laboratory. Early test results encouraged the company to believe that aluminides offered significant advantages as a heating element material. The successful penetration of this material into the heating element market could result in increased nickel consumption.

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[1]Physical scientist, Branch of Ferrous Metals.

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Nitrogen

By William F. Stowasser[1]

U.S. production of anhydrous ammonia containing 82.2% nitrogen increased 12% over production in 1986. The total value of ammonia sold or used was about $1.2 billion. The value of apparent consumption was about $1.4 billion. These values were based on average 1987 f.o.b. gulf coast spot prices. The market for ammonia fertilizers, particularly the export market, showed improvement over the low point in demand in 1983. Nitrogen fertilizer demand was dependent on the demand from the agricultural sector. Demand for agricultural products and nitrogen improved in the last half of 1987. Exports of farm products rose and Federal subsidies, although less than those of 1986, added about $20 billion to farm income. Global crop production declined by about 4% and it is expected that inventories will decline, export demand for U.S. farm products will increase, and demand for nitrogenous fertilizers will increase. Anhydrous ammonia imports increased to 3.9 million tons, which was substantially more than imports over the past 5 years that ranged from 1.7 to 2.3 million tons per year. Anhydrous ammonia exports increased to 1.5 million tons per year, or about three times those of 1986.

Domestic Data Coverage.—Domestic production data for anhydrous ammonia were developed by the Bureau of the Census, U.S. Department of Commerce, and published monthly under product code 28371 30 in Current Industrial Reports, Inorganic Fertilizer Materials and Related Products, M28B. The Bureau of the Census surveyed approximately 100 firms manufacturing inorganic fertilizer materials. Production data are shown in table 1.

Table 1.—Salient ammonia statistics

(Thousand short tons of contained nitrogen)

	1983	1984	1985	1986	1987[p]
United States:					
Production[1 2]	11,297	13,368	13,238	11,499	13,284
Exports	298	438	1,010	531	848
Imports for consumption	2,169	2,699	2,306	2,048	2,357
Consumption, apparent[2 3]	13,719	15,346	14,439	13,305	15,251
World: Production	[r]88,661	[r]96,930	98,939	[p]99,275	[e]102,653

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Synthetic anhydrous ammonia and coke oven ammonia.
[2]Coke oven ammonia not available for 1985-87.
[3]Includes producers' stock changes in synthetic anhydrous ammonia and coke oven ammonia.

DOMESTIC PRODUCTION

Anhydrous ammonia production was uniform throughout the year. Production, expressed in tons of contained nitrogen, was about 1.1 to 1.2 million tons per month from January through June. Production declined to about 1 million tons per month from July through September. Production increased to 1.2 million tons per month in October, November, and December, to supply a strong export demand that developed for ammonium phosphates. Uniform spot-selling prices of ammonia, f.o.b. gulf, and a stable consumption pattern contributed to the consistent production level during the year.

Chevron Chemical Co. shut down its 1,195-ton-per-day anhydrous ammonia plant at Pascagoula, MS, in January 1987. Olin Corp. decided that its 92,000-ton-per-year nitrogen-rated urea plant at Lake Charles, LA, will remain closed indefinitely. Ammonia production was not affected.

Table 2.—Fixed nitrogen production in the United States

(Thousand short tons of contained nitrogen)

	1983	1984	1985	1986	1987[p]
Ammonium compounds, coking plants:					
Ammonia liquor[1]	5	5	NA	NA	NA
Ammonium sulfate[1]	46	[r]65	NA	NA	NA
Anhydrous ammonia, synthetic plants[2]	11,246	13,309	13,238	11,499	13,284
Total	11,297	13,368	13,238	11,499	13,284

[p]Preliminary. [r]Revised. NA Not available.
[1]Quarterly Coal Report, U.S. Department of Energy, Jan.-Mar. 1985.
[2]Current Industrial Reports, M28B, Bureau of the Census.

The combining of hydrogen with atmospheric nitrogen to form ammonia is the first step in making nitrogen fertilizers. Ammonia and phosphoric acid reacted with each other to form diammonium phosphate and monoammonium phosphate. Granular ammonium phosphates have become the leading fertilizers in the world. Carbon monoxide produced in ammonia production is converted to carbon dioxide. When it reacts with ammonia at elevated temperature and pressure, urea is formed. Urea is the highest analysis solid nitrogen fertilizer. Ammonia is burned to manufacture ammonium nitrate, passed through a catalyst, and absorbed in water to produce nitric acid. Nitric acid reacting with ammonia forms an ammonium nitrate solution, which is evaporated to a melt and granulated for use as a fertilizer.

Table 3.—Major nitrogen compounds produced in the United States

(Thousand short tons, gross weight)

Compound	1985	1986	1987[p]
Acrylonitrile	1,173	1,157	1,275
Ammonium nitrate	6,907	5,569	6,416
Ammonium phosphate	12,373	10,039	12,773
Ammonium sulfate[1]	2,049	2,084	2,183
Nitric acid	7,808	6,561	7,102
Urea	6,478	6,005	7,431

[p]Preliminary.
[1]Excludes coke plant ammonium sulfate.

Sources: Bureau of the Census and International Trade Commission.

Table 4.—Domestic producers of anhydrous ammonia in 1987

(Thousand short tons per year of ammonia)

Company	Location	Capacity
Agrico Chemical Co	Blytheville, AR	407
Do	Donaldsonville, LA	468
Do	Verdigris, OK	840
Air Products and Chemicals Inc	New Orleans, LA	245
Do	Pace Junction, FL	100
Allied Chemical Corp	Hopewell, VA	390
American Cyanamid Co	Fortier, LA	340
Arcadian Corp	Geismar, LA	352
Do	La Platte, NE	172
Borden Chemical Co	Geismar, LA	400
Carbonaire Co. Inc	Palmerton, PA	35
Center Plains Industries Inc	Dumas, TX	160
C. F. Industries Inc	Donaldsonville, LA	420

Table 4.—Domestic producers of anhydrous ammonia in 1987 —Continued

(Thousand short tons per year of ammonia)

Company	Location	Capacity
Chevron Chemical Co	El Sequndo, CA	20
Do	St. Helens, OR	80
Do	Finley, WA	140
Columbia Nitrogen Corp	Augusta, GA	510
Cominco American Incorporated	Borger, TX	400
E. I. du Pont de Nemours & Co. Inc	Beaumont, TX	520
Farmland Industries Inc	Dodge City, KS	210
Do	Enid, OK	840
Do	Lawrence, KS	340
Do	Pollock, LA	420
First Mississippi Corp	Donaldsonville, LA	400
W. R. Grace & Co	Woodstock, TN	340
Green Valley Chemical Corp	Creston, IA	35
International Minerals & Chemical Corp	Sterlington, LA	1,050
Laroche Industries	Cherokee, AL	175
Mississippi Chemical Corp	Yazoo City, MS	393
Monsanto Co	Luling, LA	460
N-Ren Corp	East Dubuque, IL	238
Do	Pryor, OK	94
Occidental Chemical Co	Tacoma, WA	28
Olin Corp	Lake Charles, LA	490
Pennwalt Chemical Co	Portland, OR	8
PPG Industries Inc	Natrium, WV	50
J. R. Simplot Co	Pocatello, ID	108
Sohio Chemical Co	Lima, OH	510
Tennessee Valley Authority	Muscle Shoals, AL	71
Terra Chemicals International Inc	Port Neal, IA	230
Triad Chemical Co	Donaldsonville, LA	364
Union Chemical Co	Kenai, AK	1,100
Do	Brea, CA	280
Wycon Chemical Co	Cheyenne, WY	163
Total		14,396

Source: Economics and Marketing Research Section, Tennessee Valley Authority. World Fertilizer Capacity, Ammonia. Muscle Shoals, AL, July 4, 1987.

CONSUMPTION AND USES

The consumption of nitrogen as nitrogenous fertilizers by U.S. farms recovered in 1987 after the decline in 1986. Consumption in 1987 compared favorably with that of 1985. The lower consumption level in 1986 was due primarily to a 7% decline in planted acreage. Although planted acres declined in 1987, nitrogen application rates probably increased because farm income increased, farm debt had declined steadily since 1982, and farmland prices had improved. Demand for most crops was greater than production. Export demand for nitrogenous fertilizers improved, and thereby affected demand for domestic consumption of ammonia in fertilizer production.

Nitrogen fertilizer plays a critical role in supplying world food and fiber requirements. There is considerable confusion in the industry when political and environmental issues interact to restrain the consumption of nitrogenous fertilizers. Consumption of nitrogenous fertilizers is generally forecast to increase to meet food demands in the world. New ammonia plants are planned to replace obsolete plants and increase capacity. Current oversupplies were probably caused by miscalculating future demand, but even with excess capacity, nitrogen supplies may have to increase to meet fertilizer and food demands in the future. After decades of fertilizer application to restore the soil's original fertility and after centuries of cropping, the industry is being persuaded to limit application of nitrogen by organizations monitoring the environment. There is concern by environmental organizations that excessive application of nitrogen fertilizers to the soil will increase the probability that nitrogen will be leached into ground waters. Ground water contamination and its effect on human health may decrease nitrogen application rates. The impact of this controversy may have more effect on nitrogen consumption in the future than politically administered acreage reduction programs.

Approximately 80% of ammonia production was used as fertilizer or was used to manufacture fertilizer blends or compounds. An estimated 10% was used to manufacture fibers, plastics, and resins; 4% was used for explosives; and 6% was used in miscellaneous applications.

STOCKS

Producers' stocks at the beginning of 1987 were 1.5 million tons of contained nitrogen. Stocks gradually declined and stood at less than 1 million tons from April through November. At yearend, producers' stocks were slightly more than 1 million tons of contained nitrogen. The reduction indicated that producers' expectations for improvement in nitrogen demand were not optimistic. Acreage reduction programs and a hesitant farm economy reduced producer confidence in the market.

PRICES

Ammonia prices at the beginning of the year were $77 to $79 per ton, f.o.b. The price improved in the first quarter of the year to $116 to $120 per ton. In the second quarter, prices were stable, ranging from $116 to $119 per ton. In the third quarter, delivered prices were $93 to $95 per ton. By yearend, prices declined to $83 to $86 per ton. The price improvement in the export market was accompanied by higher freight rates for ammonia. Another factor influencing ammonia prices early in the year was the lack of agreement between Spain and the Soviet Union on prices for fourth-quarter shipments from the Soviet Union. In December, lower priced Soviet production was again available and prices declined.

Table 5.—Price quotations for major nitrogen compounds at yearend 1987

(Per short ton)

Compound	Price
Ammonium nitrate: Delivered Corn Belt	$100-$120
Ammonium sulfate: F.o.b. Corn Belt	90- 102
Anhydrous ammonia:	
Delivered Corn Belt	130- 140
F.o.b. gulf coast	203- 206
Diammonium phosphate: F.o.b. central Florida	170- 173
Urea:	
Delivered Corn Belt	125- 135
F.o.b. gulf coast, granulated	118- 122
F.o.b. gulf coast, prilled	114- 117

Source: Green Markets, Fertilizer Market Intelligence Weekly, Dec. 28, 1987.

FOREIGN TRADE

Anhydrous ammonia exports increased 60% compared with those of 1986. The increase was attributable to an improved world market. The gross weight of exported nitrogen compounds for fertilizer and industrial uses increased 27% in 1987. Diammonium phosphate exports increased 37% in 1987. Exports to China accounted for most of the incremental increase in export tonnage.

Imports of anhydrous ammonia increased 14% in 1987. Imports of urea decreased 28% in 1987. Imports of fertilizer materials declined 9% in 1987.

Of the 6.2 million tons of diammonium phosphate exported in 1987, 1.6 million tons was shipped to China, 655,000 tons was shipped to Belgium for distribution in Western Europe, and 485,000 tons was exported to Turkey.

The principal supplies of anhydrous ammonia imported into the United States were 1.4 million tons from Canada, 814,000 tons from the U.S.S.R. as part of the barter contract with Occidential Chemical Agricultural Products Inc., 398,000 tons from Trinidad and Tobago, and 525,000 tons from Mexico. All of these suppliers had low-cost natural gas feedstock to produce anhydrous ammonia for international trade. The principal supplies of imported urea were 355,000 tons from the U.S.S.R., 248,000 tons from the Netherlands, and 122,000 tons from Kuwait.

Table 6.—U.S. exports and imports for consumption of major nitrogen compounds in 1987

(Thousand short tons and thousand dollars)

Compound	Gross weight	Nitrogen content	Value
EXPORTS			
Fertilizer materials:			
Ammonium nitrate	257	90	NA
Ammonium sulfate	746	157	NA
Anhydrous ammonia	1,031	847	NA
Diammonium phosphate	6,225	1,121	NA
Monoammonium phosphate	592	65	NA
Nitrogen solutions	777	249	NA
Sodium nitrate	10	2	NA
Urea	1,125	518	NA
Mixed chemical fertilizers	7	1	NA
Other ammonium phosphates	28	3	NA
Other nitrogen fertilizers	66	13	NA
Industrial chemicals:			
Ammonia, aqua (ammonia content)	3	3	168
Ammonium nitrate	28	9	1,421
Ammonium phosphate	3	1	3,642
Ammonium sulfate	3	1	76
Total	10,901	3,080	[1]5,307
IMPORTS			
Fertilizer materials:			
Ammonium nitrate	307	107	23,325
Ammonium nitrate-limestone mixtures	1	(2)	73
Ammonium sulfate	285	60	18,317
Anhydrous ammonia	2,830	2,326	228,124
Calcium cyanamide or lime nitrogen	2	(2)	934
Calcium nitrate	152	23	13,110
Diammonium phosphate	29	5	5,035
Nitrogen solutions	515	165	27,557
Potassium nitrate	22	3	4,167
Potassium nitrate-sodium nitrate mixtures	21	3	2,309
Sodium nitrate	102	16	10,959
Urea	2,501	1,150	205,260
Mixed chemical fertilizers	35	4	4,989
Other ammonium phosphates	124	14	18,696
Other nitrogen fertilizers	62	12	10,703
Industrial chemicals:			
Ammonium nitrate	72	25	6,936
Ammonium phosphate	3	1	1,791
Ammonium sulfate	1	(2)	118
Anhydrous ammonia and chemical-grade aqua	1	1	150
Total	7,065	3,915	582,553

NA Not available.
[1]Total includes chemicals only.
[2]Less than 1/2 unit.

Source: Bureau of the Census.

WORLD REVIEW

The conflict in the Persian Gulf did not have a significant impact on fertilizer trade. There are two Saudi Arabian ammonia-urea plants, one at Al Jubail and the other at Damman. The other major producers in the region are Bahrain, Kuwait, Qatar, and the United Arab Emirates. Gas feedstock costs could be expected to increase in Western Europe and the United States if the gulf conflict escalated. The link between oil prices and gas feedstock is such that most natural gas contracts equate the price of gas to the price of heavy fuel oil in terms of heating value. Escalation of the gulf war would have an impact on nitrogen production costs and on nitrogen fertilizer trade.

Australia.—Snamprogetti Ltd. planned to construct a 1,357-ton-per-day anhydrous ammonia plant and a 4,600-ton-per-day urea plant at Port Kembla, New South Wales. The plant will use natural gas as the feedstock.

In Western Australia, CSBP and Farmers and Norsk Hydro A/S planned a 1,234-ton-per-day nitrogen-rated ammonia plant and a 598-ton-per-day nitrogen-rated urea plant to be 20 miles south of Perth.[2]

INCITEC announced a 600,000-ton-per-year nitric acid plant and an ammonium nitrate plant at its Newcastle, New South Wales, complex. Construction was scheduled for completion in late 1988.[3]

China.—M. W. Kellogg Ltd. of the United Kingdom received a contract to construct a 163,000-ton-per-year anhydrous ammonia plant at the ammonia-urea complex at Sichuan. The plant was planned to come onstream in late 1989. Shanxi Chemical Fertilizer Co. commissioned a 980,000-ton-per-year nitrophosphate plant 500 miles south of Beijing.[4]

France.—The CdF Chemie Group planned a 330,000-ton-per-day nitric acid plant and a 500,000-ton-per-year ammonium nitrate plant at Rouen.[5]

Table 7.—Ammonia: World production, by country[1]

(Thousand short tons of contained nitrogen)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Afghanistan[e]	9	[3]45	50	[r]44	44
Albania[e]	84	88	88	88	88
Algeria	145	161	[e]165	[e]165	165
Argentina	63	[r]54	72	[e]55	75
Australia	424	414	446	375	[3]456
Austria[e]	546	550	550	500	441
Bahrain	--	--	--	--	441
Bangladesh	197	389	395	430	469
Belgium	495	498	426	386	296
Brazil	814	963	1,042	1,102	1,049
Bulgaria	1,238	1,254	1,254	[e]1,257	1,260
Burma[e]	59	63	139	[r]147	[3]175
Canada	3,183	3,851	3,991	[r e]3,902	3,022
China[e]	15,200	15,400	16,500	17,000	16,000
Colombia	112	103	110	[e]110	98
Cuba	95	189	[e]210	[r e]176	220
Czechoslovakia	651	635	580	677	660
Denmark	13	(4)	(4)	(4)	--
Egypt	713	756	754	750	869
Finland	75	76	72	[r e]72	77
France	[e]2,200	[e]2,600	2,217	2,229	[3]2,236
German Democratic Republic	1,329	1,326	1,329	1,315	1,380
Germany, Federal Republic of	1,877	2,164	2,103	1,731	2,130
Greece[e]	[3]250	250	250	250	280
Hungary	[e]896	897	872	894	867
Iceland	[e]8	[e]8	8	9	9
India[5]	3,930	4,382	4,766	5,963	5,842
Indonesia	1,268	1,828	2,268	2,534	2,606
Iran	[e]32	[e]24	299	73	75
Iraq[e]	88	88	66	66	66
Ireland	324	409	372	391	440
Israel	59	63	63	[e]63	68
Italy	1,169	1,334	1,609	1,664	[3]1,579
Japan	1,703	1,839	1,794	1,627	1,715
Korea, North[e]	500	500	500	500	500
Korea, Republic of	474	512	487	470	526
Kuwait	345	319	356	497	637
Libya	491	545	453	388	NA
Malaysia	32	43	59	[r e]330	354
Mexico	2,134	1,954	2,049	1,766	2,000
Netherlands	1,922	2,549	2,630	2,373	3,117
New Zealand	48	64	66	[e]66	80
Nigeria	--	--	--	--	110
Norway	565	702	505	330	[3]383
Pakistan	1,211	1,243	1,220	1,272	1,300
Peru[e]	94	94	94	66	100
Philippines	22	18	[e]19	[e]19	--
Poland	1,571	1,647	[e]1,382	[e]1,380	2,018
Portugal	122	176	170	[r e]165	170
Qatar	531	572	580	600	618
Romania	3,006	3,154	3,175	[e]3,200	3,090
Saudi Arabia	323	[r]458	481	514	702
South Africa, Republic of	634	639	[e]639	[e]639	603
Spain	[r]558	738	664	512	495
Sri Lanka	69	[e]77	[e]33	--	--
Sweden	54	54	20	51	50
Switzerland[e]	36	33	33	33	43
Syria	125	[r]124	146	151	102
Taiwan	342	296	228	292	262
Trinidad and Tobago	1,095	1,190	1,197	[e]1,200	1,242
Turkey	307	320	239	209	200
U.S.S.R	18,629	19,510	20,062	21,605	22,050
United Arab Emirates	--	249	311	320	333

See footnotes at end of table.

Table 7.—Ammonia: World production, by country[1] —Continued

(Thousand short tons of contained nitrogen)

Country[2]	1983	1984	1985	1986[p]	1987[e]
United Kingdom	1,896	2,024	1,948	1,530	[3]1,560
United States[6]	11,297	13,368	13,238	11,499	[3]13,284
Venezuela[e]	[3]418	510	[r]540	[r]720	577
Yugoslavia[e]	[3]452	440	460	440	847
Zambia	31	31	19	27	[3]30
Zimbabwe	78	76	76	66	[3]72
Total	[r]88,661	[r]96,930	98,939	99,275	102,653

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.
[1]Table includes data available through May 20, 1988.
[2]In addition to the countries listed, Vietnam has a nitrogen (N content of ammonia) production capacity of about 60,000 short tons per year; it is not known at what output level the plant is operating.
[3]Reported figure.
[4]Revised to zero.
[5]Data are for years beginning Apr. 1 of that stated.
[6]Synthetic anhydrous ammonia and coke oven ammonia. Coke oven ammonia data not available for 1985 and 1986.

TECHNOLOGY

An increase in nitrogenous fertilizer consumption probably will be required in future years, particularly to support food production in developing countries where the demand will occur. A compromise may become necessary between using nitrogenous fertilizers to maintain and increase food production and the need to minimize nitrates in drinking water. To alleviate high levels of nitrates in drinking water, a number of solutions have been proposed: (1) blending with water that has a low nitrate concentration, (2) storing of water in reservoirs to permit natural denitrification mechanisms time to take effect, and (3) replacing the high nitrate water source with one with acceptable nitrate levels. In the event that these options are not viable, water treatment plants may be the only economically acceptable option for controlling nitrate levels. According to the British Sulphur Corp.,[6] two processes show promise for nitrate removal: single bed, strong-base anion exchange and continuous fluidized-bed biological denitrification. Commercial strong-base ion exchange resins, normally in the chloride form, are used to remove nitrates. Spent resin is regenerated with a sodium chloride solution and rinsed with water, prior to returning to the system. Both fixed-bed and continuous-loop ion exchange plants have been used in the United Kingdom for removing nitrates. In the absence of dissolved oxygen, biological denitrification reduces nitrates. A biodegradable carbon substrate that may be methanol, ethanol, or acetic acid must be added to sustain bacterial growth and a supply of phosphate is also necessary for good biological activity. Fixed bed and bacterial floc blankets have been successfully used; however, the fluidized bed system is preferred.

In the United States, minimum tillage is practiced to minimize contaminating ground water. Deep plowing increases percolation of chemical residues into ground water sources. Conservation (minimum) tillage ties up surface-applied nitrogen. The efficiency of the minimum-till practice is effective in stopping the downward movement of nitrogen. The risk of ammonia volatilization into the air when soil conditions are dry can be reduced by injecting liquid nitrogen into the soil.

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[1]Physical scientist, Branch of Industrial Minerals.
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[6]———. No. 168. July-Aug. 1987, pp. 38-41.

Peat

By James P. Searls[1]

Peat production in the United States increased slightly in 1987. In decreasing order of quantity, Florida, Michigan, Illinois, Iowa, and Indiana were the major peat-producing States. Reed-sedge peat was the most common kind produced, followed by humus, sphagnum moss, and hypnum moss. Peat sold in both bulk and packaged forms by domestic producers decreased 8% in quantity and increased 9% in value. Apparent consumption was essentially unchanged. Imports for consumption, primarily from Canada, decreased 7% but represented about one-third of apparent consumption. The predominant end use of peat was for agricultural and horticultural purposes. One peatland owner started construction of a 23-megawatt-electric powerplant, and another owner was in the permitting phase to establish a 200-megawatt-electric powerplant.

Domestic Data Coverage.—Domestic production data for peat are developed by the Bureau of Mines from a voluntary survey of U.S. peat operations. Of the 114 operations to which a survey request was sent, 8 reported that they were out of business. Of the remaining 106 mines, 97 responded, representing 92% of the total production shown in table 1. Production for the nine nonrespondents was estimated using prior year production levels adjusted for regional production trends and inflation.

Table 1.—Salient peat statistics

	1983	1984	1985	1986	1987
United States:					
Number of active operations	94	101	99	92	92
Production ____ thousand short tons	704	800	839	r912	955
Sales by producers ____ do	725	814	882	r1,038	958
Bulk ____ do	223	373	396	r522	499
Packaged ____ do	503	441	486	516	459
Value of sales ____ thousands	$18,667	$19,907	$21,892	r$23,988	$26,170
Average per short ton	$25.73	$24.47	$24.81	r$23.11	$27.31
Average per short ton, bulk	$18.34	$20.47	$20.29	r$16.44	$18.32
Average per short ton, packaged or baled	$29.00	$27.85	$28.49	$29.86	$37.07
Imports for consumption ____ thousand short tons	419	485	477	553	515
Consumption, apparent[1] ____ do	1,042	1,146	1,255	r1,548	1,544
Stocks, Dec. 31: Producers' ____ do	438	577	638	r555	481
World: Production ____ do	r244,459	r235,915	229,226	p236,505	e252,465

eEstimated. pPreliminary. rRevised.

[1]Apparent consumption equals U.S. primary production plus imports minus exports plus adjustments for industry stock changes.

DOMESTIC PRODUCTION

Peat was produced by 92 active domestic operations with a wide variation in production levels. Ten operations produced more than 25,000 short tons per year. There were five reed-sedge operations and one humus operation in Florida, two reed-sedge operations and one humus operation in Michigan, and one reed-sedge operation in Illinois. These 10 operations accounted for 50% of the total production. Irrespective of the size of the operation, reed-sedge production accounted for 60% of total output in 1987, humus was 30%, sphagnum moss was 5%, and hypnum moss was 5%.

Table 2.—Relative size of peat operations in the United States

Size in short tons per year	Active operations		Production (thousand short tons)	
	1986	1987	1986	1987
25,000 and over	r11	10	r482	475
15,000 to 24,999	8	13	155	250
10,000 to 14,999	10	7	122	83
5,000 to 9,999	13	9	85	67
2,000 to 4,999	r15	19	r46	60
1,000 to 1,999	11	9	14	13
Under 1,000	24	25	7	8
Total[1]	92	92	r912	955

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

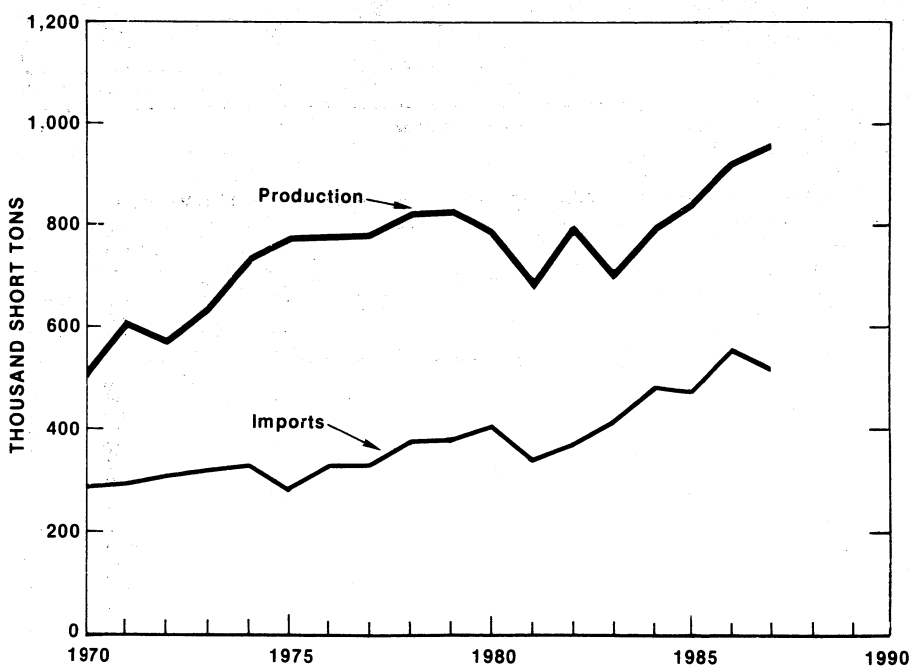

Figure 1.—Production and imports of peat in the United States.

CONSUMPTION AND USES

U.S. peat producers' domestic sales decreased 8% by weight. The sales distribution pattern was of 66% reed-sedge, 28% humus, 3% hypnum moss, 2% sphagnum moss, and 1% other. Sales of unclassified peat were entirely from stocks. The largest end use was for general soil improvement, which accounted for 64% of total sales. Approximately 71% of that was sold in packages, and the rest was sold in bulk form. Large percentages of each of the four types of peat were sold into this end use. The sales of reed-sedge and humus in bulk form to potting soil manufacturers and nurseries accounted for an additional 27% of total sales. Sales increased for peat that was used as an earthworm culture medium, for golf courses, mixed fertilizers, potting soils, and unclassified end uses. Peat sales decreased for general soil improvement, mushroom beds, nurseries, as root packing for flowers, trees, and shrubs, as seed inoculant, and for vegetable growing.

Table 3.—U.S. peat sales by producers in 1987, by use

Use	In bulk		In packages		Total[1]	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Earthworm culture medium	3,439	$64	263	$7	3,702	$70
General soil improvement	176,905	2,908	439,138	11,006	616,043	13,915
Golf courses	29,825	783	259	13	30,084	797
Ingredient for potting soils	144,992	2,785	13,682	896	158,674	3,681
Mixed fertilizers	9,744	130	--	--	9,744	130
Mushroom beds	1,248	46	13	1	1,261	47
Nurseries	115,655	1,816	665	69	116,320	1,884
Packing flowers, plants, shrubs, etc	717	10	--	--	717	10
Seed inoculant	942	335	5,238	5,036	6,180	5,371
Vegetable growing	1,194	26	125	3	1,319	29
Other	14,128	236	--	--	14,128	236
Total	498,789	9,139	459,383	17,031	958,172	26,170

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

Table 4.—U.S. peat production and sales by producers in 1987, by State

State	Active operations	Production	Sales		
		Quantity (thousand short tons)	Quantity (thousand short tons)	Value[1] (thousands)	Percent packaged
California	2	W	W	W	28
Colorado	3	W	W	W	7
Florida	13	353	363	$6,068	15
Georgia	2	W	W	W	99
Illinois	5	W	W	W	96
Indiana	5	45	44	W	68
Iowa	3	W	24	W	59
Maine	2	W	--	--	--
Maryland	1	W	W	W	22
Massachusetts	1	W	W	W	100
Michigan	15	240	281	5,290	73
Minnesota	5	35	30	W	87
Montana	2	W	W	W	1
New Jersey	5	W	32	614	87
New York	4	1	1	34	--
North Carolina	2	W	W	W	62
North Dakota	1	--	W	W	7
Ohio	3	W	W	W	--
Pennsylvania	8	20	18	513	23
South Carolina	1	W	W	W	50
Washington	4	8	7	191	--
West Virginia	1	W	W	W	--
Wisconsin	4	17	9	W	33
Total[2] or average	92	955	958	26,170	48

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1]Values are f.o.b. producing plant.
[2]Data may not add to totals shown because of independent rounding.

Table 5.—U.S. peat sales by producers in 1987, by use

Use	Sphagnum moss: Quantity: Weight (short tons)	Sphagnum moss: Quantity: Volume[1] (cubic yards)	Sphagnum moss: Value (thousands)	Hypnum moss: Quantity: Weight (short tons)	Hypnum moss: Quantity: Volume (cubic yards)	Hypnum moss: Value (thousands)	Reed-sedge: Quantity: Weight (short tons)	Reed-sedge: Quantity: Volume (cubic yards)	Reed-sedge: Value (thousands)
Earthworm culture medium	413	1,387	$13	450	1,000	$12	2,139	3,990	$38
General soil improvement	15,523	83,585	852	20,106	50,801	647	452,350	947,622	10,058
Golf courses	744	2,480	20	5,450	12,000	198	15,222	31,290	306
Ingredient for potting soils	166	1,016	12	650	1,500	15	132,758	267,314	3,258
Mixed fertilizers	--	--	--	--	--	--	--	--	--
Mushroom beds	13	106	1	1,200	3,000	45	48	96	1
Nurseries	27	100	2	700	1,600	16	23,993	53,254	587
Packing flowers, plants, shrubs, etc	27	100	2	--	--	--	300	500	4
Seed inoculant	--	--	--	400	1,000	10	5,780	11,716	5,361
Vegetable growing	--	--	--	445	1,200	11	484	968	12
Other	5,400	18,000	126	400	1,000	15	152	420	3
Total[2]	22,313	106,774	1,027	29,801	73,101	969	633,226	1,317,170	19,628

Use	Humus: Quantity: Weight (short tons)	Humus: Quantity: Volume (cubic yards)	Humus: Value (thousands)	Other: Quantity: Weight (short tons)	Other: Quantity: Volume (cubic yards)	Other: Value (thousands)	Total[2]: Quantity: Weight (short tons)	Total[2]: Quantity: Volume (cubic yards)	Total[2]: Value (thousands)
Earthworm culture medium	700	1,200	$8	--	--	--	3,702	7,577	$70
General soil improvement	128,064	201,955	2,357	--	--	--	616,043	1,283,963	13,915
Golf courses	8,668	16,496	273	--	--	--	30,084	62,266	797
Ingredient for potting soils	25,100	42,973	396	--	--	--	158,674	312,803	3,681
Mixed fertilizers	9,744	16,240	130	--	--	--	9,744	16,240	130
Mushroom beds	--	--	--	--	--	--	1,261	3,202	47
Nurseries	91,600	152,900	1,280	--	--	--	116,320	207,854	1,884
Packing flowers, plants, shrubs, etc	390	680	4	--	--	--	717	1,280	10
Seed inoculant	--	--	--	--	--	--	6,180	12,716	5,371
Vegetable growing	390	779	6	--	--	--	1,319	2,947	29
Other	25	50	([3])	8,151	40,755	$92	14,128	60,225	236
Total[2]	264,681	433,273	4,455	8,151	40,755	92	958,172	1,971,073	26,170

[1]Volume of nearly all sphagnum moss was measured after compaction and packaging.
[2]Data may not add to totals shown because of independent rounding.
[3]Less than 1/2 unit.

Table 6.—U.S. peat production and producers' yearend stocks in 1987, by kind

Kind	Active operations	Production (short tons)	Percent of production	Yearend stocks (short tons)
Sphagnum moss	13	50,441	5.3	40,471
Hypnum moss	8	41,703	4.4	22,027
Reed-sedge	45	574,349	60.1	322,137
Humus	30	288,272	30.2	94,180
Other	1	--	--	2,500
Total	[1]92	954,765	100.0	481,315

[1]Data do not add to total shown because some plants produce multiple kinds of peat.

PRICES AND SPECIFICATIONS

The average reported price per ton for all types of peat, f.o.b. plant, increased 18% in 1987 compared with that of 1986. The unit price for bulk peat increased 11% over that of 1986, and the unit price for packaged peat increased 24% over that of 1986. The price per ton of imported peat increased nearly 10% over that of 1986.

Table 7.—Prices[1] for peat in 1987

(Dollars per unit)

	Sphagnum moss	Hypnum moss	Reed-sedge	Humus	Other	Average
Domestic:						
Bulk:						
Per short ton	22.18	32.29	21.76	13.68	11.24	18.32
Per cubic yard	7.96	13.90	10.67	8.51	2.25	9.52
Packaged or baled:						
Per short ton	75.03	32.63	37.08	30.91	--	37.07
Per cubic yard	10.39	12.92	17.60	17.43	--	16.84
Average:						
Per short ton	46.01	32.51	31.00	16.83	11.24	27.31
Per cubic yard	9.62	13.25	14.90	10.28	2.25	13.28
Imported, total, per short ton[2]	137.93	XX	XX	XX	XX	137.93

XX Not applicable.
[1]Prices are f.o.b. plant.
[2]Average customs value.

Table 8.—Average density of domestic peat sold in 1987

(Pounds per cubic yard)

	Sphagnum moss	Hypnum moss	Reed-sedge	Humus	Other
Bulk	718	861	981	1,245	400
Packaged	277	792	949	1,128	--
Bulk and packaged	418	815	961	1,222	400

FOREIGN TRADE

Peat imports for domestic consumption decreased 7% in quantity but increased nearly 2% in value compared with those of 1986. More than 99% of imported products was sphagnum moss peat from Canada. Sphagnum moss peat was in demand for its special qualities, consumer loyalty to a brand name, and inadequate domestic production. Domestic sphagnum moss peat production was insufficient to satisfy domestic demand. Almost 41% of the imported peat entered the United States through two customs districts in the State of New York. Large quantities also entered through customs districts in Maine, Michigan, Montana, and North Dakota.

Table 9.—U.S. imports for consumption of peat moss in 1987, by country

Country	Poultry- and stable-grade		Fertilizer-grade		Total	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Canada	13,928	$1,822	499,915	$69,034	513,843	$70,856
Mexico	178	21	--	--	178	21
Netherlands	17	6	74	11	91	17
New Zealand	160	24	12	3	172	27
Philippines	34	4	--	--	34	4
Other[1]	56	12	141	29	197	41
Total[2]	14,373	1,890	500,142	69,076	514,515	70,966

[1]Includes Belgium, Cameroon, China, Denmark, the Federal Republic of Germany, Guatemala, Ireland, Japan, Morocco, Sweden, and the United Kingdom.
[2]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

Table 10.—U.S. imports for consumption of peat moss in 1987, by customs district

Customs district	Poultry- and stable-grade		Fertilizer-grade		Total[1]	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Boston, MA	37	$5	--	--	37	$5
Buffalo, NY[2]	5,305	825	53,244	$6,873	58,549	7,698
Detroit, MI[2]	7,302	706	43,442	6,025	50,744	6,731
Duluth, MN[2]	--	--	3,436	561	3,436	561
Great Falls, MT[2]	--	--	85,137	14,822	85,137	14,822
Honolulu, HI	--	--	12	3	12	3
Laredo, TX	178	21	--	--	178	21
Los Angeles, CA	77	16	--	--	77	16
Miami, FL	129	16	--	--	129	16
New York, NY	--	--	96	18	96	18
Norfolk, VA[2]	388	126	--	--	388	126
Ogdensburg, NY[2]	25	7	151,129	17,921	151,154	17,928
Pembina, ND[2]	--	--	70,273	11,084	70,273	11,084
Portland, ME[2]	376	41	55,961	5,704	56,337	5,745
St. Albans, VT[2]	29	4	20,663	2,867	20,692	2,871
San Francisco, CA	--	--	35	5	35	5
San Juan, PR[2]	525	117	60	15	585	132
Savannah, GA	1	4	--	--	1	4
Seattle, WA[2]	--	--	16,654	3,179	16,654	3,179
Tampa, FL	1	1	--	--	1	1
Total[1]	14,373	1,890	500,142	69,076	514,515	70,966

[1]Data may not add to totals shown because of independent rounding.
[2]Predominantly of Canadian origin.

Source: Bureau of the Census.

WORLD REVIEW

There were moderate increases in the level of peat used for fuel in Ireland and the U.S.S.R. This caused a 7% rise in estimated world peat production. Reinterpretation of data changed the level of the U.S.S.R. fuel peat consumption and a decrease in world peat production.

Table 11.—Peat: World production, by country[1]

(Thousand short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Argentina: Agricultural use	4	3	4	3	4
Australia[3]	11	15	17	6	15
Burundi	15	15	11	14	14
Canada: Agricultural use	583	[e]550	709	r [e]810	800
Denmark: Agricultural use[4]	[e]37	35	43	53	55
Finland:					
Agricultural use	303	248	378	r [e]385	385
Fuel	3,698	2,991	3,461	r [e]3,500	3,500
France: Agricultural use[e]	121	250	220	240	230
Germany, Federal Republic of:					
Agricultural use	2,059	1,575	1,671	2,223	2,400
Fuel	285	305	313	271	270
Hungary: Agricultural use[e]	77	77	77	77	77
Ireland:					
Agricultural use	[e]105	106	106	106	[5]89
Fuel	[e]7,330	8,746	2,897	5,566	[5]6,331
Israel: Agricultural use[e]	22	22	22	22	22
Netherlands[e]	441	496	500	440	440
Norway:[e]					
Agricultural use	33	33	33	33	33
Fuel	1	1	1	1	1
Poland: Fuel and agricultural use[e]	220	220	220	220	220
Spain	44	61	60	[e]57	58
Sweden: Agricultural use[e]	66	66	44	66	66
U.S.S.R.:					
Agricultural use[e]	200,000	200,000	200,000	[r]200,000	210,000
Fuel	28,300	19,300	17,600	21,500	26,500
United States:					
Agricultural use	703	789	828	912	[5]955
Fuel	1	11	11	--	--
Total	[r]244,459	[r]235,915	229,226	236,505	252,465
Fuel peat included in total	[r]39,835	[r]31,574	24,503	31,058	36,822

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through June 10, 1988.
[2]In addition to the countries listed, Austria, Iceland, and Italy produce negligible quantities of fuel peat, and the German Democratic Republic and Venezuela are major producers, but output is not officially reported, and available information is inadequate for formulation of reliable estimates of output levels.
[3]Excludes data from some States.
[4]Sales.
[5]Reported figure.

TECHNOLOGY

Construction was started at midyear on a commercial peat-fired electric powerplant. A Belgium engineering firm, a Texas venture capital firm, and a Maine peat producer, Peat Products of America Inc., combined resources to construct and operate the 22.8-megawatt-electric Down East Peat powerplant near Deblois, ME.[2] The output will be purchased by a local power company. A North Carolina peatlands owner, First Colony Farms Inc., applied for environmental permits and regulatory approvals for a 200-megawatt-electric powerplant on the Albemarle-Pamlico Peninsula.

[1]Physical scientist, Branch of Industrial Minerals.
[2]Peat Products of America Inc. (Bangor, ME). DEP Breaks Ground on Electric Power Plant. Press Release, July 11, 1987, 1 p.

Perlite

By Arthur C. Meisinger[1]

U.S. production of processed perlite increased 5% in quantity and value. Expanded perlite sales, however, decreased slightly in quantity with average value per short ton about the same as that of 1986. The quantity of processed perlite imported from Greece continued to slowly increase, primarily for use in expanding plants along the eastern seaboard. Construction-related uses for expanded perlite declined 10% but continued to account for most of the domestic perlite market with 66% of total sales.

Domestic Data Coverage.—Domestic production data for perlite are developed by the Bureau of Mines from two separate voluntary surveys, one for domestic mine operations and the other for plant operations. Of the 14 mining operations to which a request was sent, all responded; 13 were active, representing 100% of the total processed ore sold and used shown in table 1. Of the 66 expanding plants canvassed, 62 were active; of these, 39 plants, or 63%, responded, representing 50% of the total expanded perlite sold and used shown in table 1. Plant data for the 23 nonrespondents were estimated using reported prior-year production levels adjusted by trends in employment and other guidelines.

Table 1.—Perlite mined, processed, expanded, and sold and used by producers in the United States

(Thousand short tons and thousand dollars)

Year	Perlite mined[1]	Processed perlite: Sold to expanders: Quantity	Processed perlite: Sold to expanders: Value	Processed perlite: Used at own plant to make expanded material: Quantity	Processed perlite: Used at own plant to make expanded material: Value	Processed perlite: Total quantity sold and used	Expanded perlite: Quantity produced	Expanded perlite: Sold and used: Quantity	Expanded perlite: Sold and used: Value
1983	608	293	9,942	181	5,722	474	387	385	63,500
1984	653	310	10,395	188	6,243	498	440	439	74,000
1985	678	309	10,714	209	6,821	518	461	459	81,000
1986	735	303	9,536	204	6,110	507	480	479	83,700
1987	778	333	10,471	200	6,023	533	464	466	81,800

[1]Crude ore mined and stockpiled for processing.

DOMESTIC PRODUCTION

Processed Perlite.—Perlite mined for processing from 13 operations by 12 companies in 6 Western States totaled 778,000 tons. New Mexico, with five mine operations, accounted for 86%. The remaining 14% came from Arizona, California, Colorado, Idaho, and Nevada.

Production of processed perlite sold and used increased 5% in quantity and value compared with that of 1986. New Mexico operations accounted for 82% of the U.S. total.

Ore producers were Guzman Construction Co.; Harborlite Corp.; Nord Perlite Co., a subsidiary of Nord Resources Corp., and Perlite Co., a subsidiary of Wonder Industries, in Arizona; American Perlite Co. in California; Persolite Products Inc. in Colorado; National Perlite Co. in Idaho; Delamar Perlite Co. in Nevada; and Grefco Inc., Manville Products Corp., Silbrico Corp., and USG Corp. in New Mexico.

Expanded Perlite.—The quantity of expanded perlite produced by 62 plants in 32 States decreased slightly compared with that of 1986. Expanded perlite sales also decreased slightly in quantity. Leading States in descending order of sales were Mississippi, Pennsylvania, California, Georgia, Illinois, Florida, Kentucky, Virginia, Minnesota, Indiana, Alabama, and Texas. California and Texas each had seven active expanding plants.

Table 2.—Expanded perlite produced and sold and used by producers in the United States, by State

State	1986				1987			
	Quantity produced (short tons)	Sold and used			Quantity produced (short tons)	Sold and used		
		Quantity (short tons)	Value (thousands)	Average value per ton[1]		Quantity (short tons)	Value (thousands)	Average value per ton[1]
California	40,100	41,500	$7,696	$186	41,900	42,900	$7,922	$185
Florida	27,600	27,500	5,171	188	26,600	26,700	4,638	174
Indiana	19,800	19,200	4,932	256	21,000	21,400	5,186	243
Kansas	1,100	1,100	301	274	1,100	1,100	290	274
Massachusetts	2,000	2,000	644	329	2,200	2,000	714	361
Pennsylvania	W	W	W	W	47,800	47,800	8,801	184
Texas	22,500	21,900	5,033	230	18,300	19,100	4,582	240
Utah	1,300	1,300	350	260	1,900	1,900	575	306
Wisconsin	1,000	1,000	270	270	1,200	1,200	301	242
Other[2]	364,000	363,600	59,228	163	302,100	302,100	48,772	161
Total[3]	480,000	479,000	83,700	175	464,000	466,000	81,800	176

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Average value based on unrounded data and rounded to nearest dollar.
[2]Includes Alabama, Arizona, Arkansas, Colorado, Georgia, Idaho, Illinois, Iowa, Kentucky, Louisiana, Maine, Michigan, Minnesota, Mississippi, Missouri, Nevada, New Jersey, New York, North Carolina, Oregon, Tennessee, Virginia, Wyoming, and data indicated by symbol W.
[3]Data may not add to totals shown because of independent rounding.

CONSUMPTION AND USES

Apparent domestic consumption of processed perlite increased nearly 5% to 563,000 tons compared with 537,000 tons in 1986. Domestic consumption of expanded perlite was slightly lower than that of 1986, primarily because of a decline in the roof-insulation board market. Construction-related uses for perlite decreased 10% to 306,200 tons. Expanded perlite used as fillers, filter aid, and for horticultural aggregate increased significantly and totaled 137,000 tons compared with 114,600 tons in 1986.

Table 3.—Expanded perlite sold and used by producers in the United States, by use

(Short tons)

Use	1986	1987
Concrete aggregate	7,700	7,600
Fillers	18,800	28,900
Filter aid	58,000	66,000
Formed products[1]	309,300	277,200
Horticultural aggregate[2]	37,800	42,100
Low-temperature insulation	2,500	3,500
Masonry and cavity-fill insulation	12,800	13,300
Plaster aggregate	8,700	8,100
Other[3]	23,800	19,300
Total	[4]479,000	466,000

[1]Includes acoustic ceiling tile, pipe insulation, roof insulation board, and unspecified formed products.
[2]Includes fertilizer carriers.
[3]Includes fines, high-temperature insulation, paint texturizer, refractories, and various nonspecified industrial uses.
[4]Data do not add to total shown because of independent rounding.

PRICES

The average price of processed perlite sold to expanders and used by captive expanders were $31.44 and $29.97 per ton, respectively. The average value of all processed perlite sold and used was $30.95 per ton compared with $30.86 per ton in 1986. The value of expanded perlite sold and used averaged $176 per ton compared with $175 per ton in 1986.

FOREIGN TRADE

Perlite exports, primarily to Canada, were estimated to be 35,000 tons compared with 30,000 tons in 1986. Imports of perlite ore from Greece were estimated to be 65,000 tons compared with 60,000 tons in 1986.

[1]Industry economist, Branch of Industrial Minerals.

Table 4.—Perlite: World production, by country[1]

(Thousand short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Australia[3]	3	4	[e]3	[e]3	4
Czechoslovakia[e]	[4]49	49	49	50	49
Greece	167	196	178	[e]190	190
Hungary[3]	103	[r]104	104	121	120
Italy[e]	83	88	88	80	80
Japan[e]	83	83	83	83	83
Mexico[3]	46	35	41	[e]40	40
New Zealand[3]	1	--	--	--	--
Philippines	2	17	4	[e]4	4
Turkey	32	67	[e]66	[e]66	66
U.S.S.R.[e]	660	660	660	660	660
United States (processed ore sold and used by producers)	474	498	518	507	[4]533
Total	1,703	[r]1,801	1,794	1,804	1,829

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Unless otherwise specified, figures represent processed ore output. Table includes data available through June 3, 1988.
[2]In addition to the countries listed, Algeria, Bulgaria, China, Iceland, Mozambique, the Republic of South Africa, and Yugoslavia are believed to have produced perlite, but output data are not reported, and available information is inadequate for formulation of reliable estimates of output levels.
[3]Crude ore.
[4]Reported figure.

Phosphate Rock

By William F. Stowasser[1]

The precipitous decline in phosphate rock production in 1986 from 50.8 million tons[2] to 40.3 million tons appears to have stabilized in 1987 when 41.0 million tons was produced. The result of the slight increase in production in 1987 was a further decline in both domestic and export selling prices in an intensely competitive international market. Exports of phosphoric acid, ammonium phosphates, and superphosphate were the principal markets for the phosphate industry, but selling prices at times throughout the year did not cover production costs.

Phosphate rock consumption increased about 4%, a reflection of the depressed domestic and international markets for agricultural products and phosphate fertilizers. In the United States, acreage reduction programs remained in place, and Government subsidies supported the agricultural sector at a level equivalent to that of 1986.

Table 1.—Salient phosphate rock statistics[1]

(Thousand metric tons and thousand dollars unless otherwise specified)

	1983	1984	1985	1986[r]	1987
United States:					
Mine production (crude ore)	125,691	163,012	175,227	135,683	148,426
Marketable production	42,573	49,197	50,835	40,320	40,954
P_2O_5 content	13,088	14,889	[r]15,634	12,248	12,470
Value	$1,021,095	$1,182,244	[2]$1,235,800	[2]$897,131	[2]$793,280
Average per metric ton	[3]$23.98	[3]$24.03	[4]$24.31	[4]$22.25	[4]$19.37
Sold or used by producers[5]	46,839	53,277	46,634	41,776	43,673
P_2O_5 content	14,336	16,244	14,363	12,750	13,286
Value	$1,122,966	$1,278,356	[2]$1,133,675	[2]$929,621	[2]$845,812
Average per metric ton[4 6]	$23.97	$23.99	$24.31	$22.25	$19.37
Exports[7]	12,010	11,528	9,136	7,848	8,454
P_2O_5 content	3,839	3,646	2,931	2,521	2,737
Value	$327,345	$324,784	[2]$263,631	$211,701	[2]$194,691
Average per metric ton[4]	$27.26	$28.17	$28.86	$26.97	$23.03
Imports for consumption	9	[8]9	[8]34	528	464
C.i.f. value	$376	$274	$1,747	$25,435	$22,134
Average per metric ton	$42.69	$31.71	[9]$51.54	[9]$48.18	$47.70
Consumption[10]	34,838	41,758	37,532	34,456	35,683
Stocks, Dec. 31: Producers'	14,500	11,897	15,534	13,277	10,884
World: Production	[r]140,889	[r]151,568	148,606	[p]138,740	[e]145,148

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Data for the same items appearing in this and other tables may not reconcile because of computer rounding.
[2]The total value is based on a weighted value.
[3]Arithmetic average of sold or used values.
[4]Computer-calculated average value based on the weighted sold or used value.
[5]Includes domestic sales and exports.
[6]Weighted average of sold or used values.
[7]Exports reported to the Bureau of Mines by companies.
[8]Bureau of the Census data, excluding reported Canadian and Israeli imports.
[9]Average unit value obtained from unrounded data.
[10]Measured by sold or used plus imports minus exports.

Phosphate rock inventories declined throughout the year from about 13 million tons to 11 million tons at yearend. Employment in the phosphate rock mining industry was about 5,000. A number of phosphate rock mines in Florida and Idaho were closed for all or part of the year. It is estimated that the phosphate rock industry operated at about 63% of its capacity of 63.2 million tons per year.

Domestic Data Coverage.—Domestic production data for phosphate rock are developed by the Bureau of Mines from two separate voluntary surveys of U.S. operations. Typical of these surveys is the semiannual "Phosphate Rock Survey." Of the 25 operations to which a survey request was sent, all responded, representing 100% of the U.S. production data shown in table 1.

Legislation and Government Programs.—The Corps of Engineers, U.S. Army, completed the Federal improvement to Tampa Harbor, FL, in December 1985 at a cost of $170 million. The main channel from the Gulf of Mexico to East Bay was enlarged to 12.8 meters deep and 152.4 meters wide, with appropriate overdepths and overwidths in the entrance for wave allowance. Branch channels 12.2 meters deep in Port Tampa, Hillsborough Bay Cut D, and Sparkman Channels and 11.6 meters deep in Ybor Channel were being dredged in 1987. Federal maintenance of the Port Sutton terminal channel is scheduled following its enlargement to 12.8 meters deep and 61 meter wide at local cost.

The work was accomplished with the expectation that future exports of phosphate rock from Tampa Bay would follow the pattern developing in 1975. It was forecast that larger tonnages would be hauled by large carriers and lesser amounts in smaller ships. With adequate channel depths, the cargoes would be carried in 40,000- to 85,000-deadweight-ton ships, but a substantial tonnage would still be carried in 20,000- to 40,000-deadweight-ton vessels.

The 1987 session of the Florida Legislature granted the Florida phosphate industry a significant two-phase reduction of the severance tax beginning July 1, 1987. The severance tax in 1986 was $2.51 per ton. The rate was reduced slightly to $2.46 per ton for the January 1, 1987, through June 30, 1987, period. From July 1, 1987, through December 31, 1987, the rate was $1.97 per ton. The rate in 1988 was scheduled to be $1.49 per ton. The severance tax reduction had the effect of reducing phosphate rock production costs in Florida.

An integral part of the budget reconciliation legislation passed by the U.S. Congress in late December was major changes in farm programs. Target prices established by the U.S. Department of Agriculture were reduced from 1987 levels. Paid land diversion for feed grains was reduced from 15% with a payment of $2 per bushel to 10% and a payment of $1.75 per bushel. Caps were placed on paid land diversion programs.

Target prices were established at $4.23 per bushel for wheat, $2.93 per bushel for corn, 75.9 cents per pound for cotton, and $11.50 per hundredweight for rice. To achieve the 2-year budget savings mandated by the Gramm-Rudman-Hollings Deficit Reduction Act, target prices will drop in 1989. The wheat target will drop to $4.10, corn to $2.84, cotton to 73.4 cents, and rice to $10.80.

The U.S. Court of Appeals for the District of Columbia dismissed suits seeking to compel the Secretary of the Interior to issue to the appellants leases to mine phosphate rock in the Osceola National Forest. The judgment of the district court was vacated, and the suits were dismissed as moot. After the appellants filed suit in the district court in 1983, Congress enacted the Florida Wilderness Act in 1984, prohibiting the U.S. Department of the Interior from issuing phosphate leases to mine phosphate rock in the Osceola Forest. On cross-motions the district court held that to demonstrate the discovery of "valuable deposits" of phosphates, the appellants were required to show the economic and technical feasibility of reclaiming lands covered by the lease applications. The court of appeals concluded that the restoration technologies did not exist in 1984 or at any earlier time. The court did not discuss the effect of the Florida Wilderness Act on the litigation or even refer to that statute. The effect of the statute was to make the cause a moot one. The appellants argued that the committee reports on the Florida Wilderness Act were not intended to prejudice or affect any pending legislation. Government agencies assured Congress that the legislation would not prejudice the rights of the lease applicants in any way, and they should be permitted to bring an action in the U.S. Claims Court for compensation for value of the leases.

DOMESTIC PRODUCTION

Production of marketable phosphate rock from Florida and North Carolina increased 6% compared with that of 1986, and production in Tennessee and the Western States decreased 22%. One mining operation was closed in Tennessee, and several mines in Montana and Idaho were closed for part of the year. A number of mines remained closed in Florida.

Florida and North Carolina.—Phosphate rock was produced in central Florida by Agrico Chemical Co., CF Industries Inc., Estech Inc., Gardinier Inc., W. R. Grace & Co., International Minerals & Chemical Corp. (IMC), Mobil Mining and Minerals Co., and USS Agri-Chemicals Inc. In Hamilton County, northern Florida, Occidental Chemical Agricultural Products, Inc., produced phosphate rock.

Manko Co., Howard Phosphate Co., and Loncala Phosphate Co. recovered soft phosphate rock from hard-rock phosphate mine tailing ponds in north-central Florida. The soft rock was sold as an animal feed supplement.

Texasgulf Chemical Co., a subsidiary of Société Nationale Elf Aquitaine, operated the Lee Creek Mine on the Pamlico River in eastern North Carolina. The only organization producing phosphate rock in North Carolina, Texasgulf announced a joint venture with Albright and Wilson Americas to construct a phosphoric acid purification plant at Lee Creek. Texasgulf will supply wet-process phosphoric acid and operate the facility. Albright and Wilson will use the industrial-grade phosphoric acid to produce sodium phosphates in plants in South Carolina and Ohio.

Agrico, a subsidiary of Williams Co. of Tulsa, OK, was sold to Freeport-McMoran Resource Partners Ltd. In Florida, Agrico closed the Saddle Creek Mine in December and reopened the Payne Creek Mine. The Fort Green Mine's operating schedule was changed to balance production.

CF Industries produced phosphate rock from its Hardee Complex Mine. The matrix was mined from the North Pasture deposit. Low domestic demand for phosphate fertilizers restricted operation of the Hardee Complex Mine to one shift per day throughout the year.

Estech operated the Watson Mine, which is two-thirds owned by Zen Noh Phosphate Corp. The Silver City Mine was reopened in late 1986 and was scheduled to produce from the remaining reserve for another 4 years. The Watson Mine will also be depleted in 1991.

The Four Corners Mine, co-owned by W. R. Grace and IMC, had closed in March 1986 and remained closed in 1987. The decision not to reopen the mine in 1988 was confirmed at yearend. W. R. Grace operated the Hookers Prairie Mine in Polk County, FL. In March, W. R. Grace announced that its agricultural chemical business was for sale.

IMC operated the Clear Springs, Kingsford, Noralyn-Phosphoria, and Haynsworth Mines in central Florida. IMC planned to reconstruct the Lonesome Mine and reopen it in the early 1990's or when demand improves to justify additional production.

Mobil purchased the idle Big Four Mine from FCS Energy Inc., in February 1987, only a few days after FCS Energy purchased the mine from AMAX Inc. The Fort Meade Mine operated throughout the year.

Occidental Chemical Co. operated the Suwannee River and Swift Creek Mines north of Lake City, FL. All of the phosphate rock production except for phosphate rock exports was converted into superphosphoric acid at the chemical plants at the respective mines. Occidental has a contract to export up to 700,000 tons per year P_2O_5 as superphosphoric acid to the U.S.S.R.

USS Agri-Chemicals, a division of U.S. Diversified Group, USX Corp., operated the Rockland Mine in a 50-50 partnership with Freeport Chemical Co. The Fort Meade Chemical Products plant, adjacent to the Rockland Mine, is a 50-50 partnership with W. R. Grace. The Bartow Chemical plant, Bartow, FL, is another partnership with W. R. Grace. All of USS Agri-Chemical's assets were for sale.

Tennessee.—Occidental and Stauffer Chemical Co. mined phosphate rock in Giles, Hickman, Maury, and Williamson Counties in south-central Tennessee. The phosphate rock was smelted in electric furnaces to produce elemental phosphorus. Occidental purchased 2,300 acres of Giles County farmland from the Tennessee Valley Authority for their phosphate rock deposits.

Imperial Chemical Industries purchased Stauffer Chemical Co. in June and within several months sold the chemical division of Stauffer to Rhône-Poulenc Inc.

Western States.—Phosphate rock was mined in Idaho, Montana, and Utah. Phosphate rock from Montana was used to manufacture phosphate fertilizer in Canada. Phosphate rock from Idaho was used to produce fertilizer and elemental phosphorus.

Cominco American Incorporated reactivated the Warm Springs Mine in Montana. The underground mine had been closed since November 1985. A washing, crushing, and drying plant will be moved from Kimberly, British Columbia, Canada, to the Warm Springs Mine. The company, which had previously shipped mine-run ore, planned to upgrade the ore by removing clay in the washer and to ship a sized dry product to Cominco's fertilizer plant at Trail, British Columbia. Full-scale production was scheduled for 1989.

The Conda Partnership was a 50-50 partnership of Beker Phosphate Corp. and Western Cooperative Fertilizers Ltd., Calgary, Alberta, Canada. Nu-West Industries purchased the assets of Beker's phosphate fertilizer plant at Conda, ID, and Beker's 50% interest in the Conda Partnership. The mines and Conda beneficiation plant were closed in May 1986 and reactivated in September 1987.

Chevron Resources Co. mined phosphate rock from the Vernal, UT, mine. After beneficiation, the concentrated slurry was pumped to Rock Springs, WY. Sulfur was supplied to the Rock Springs plant from a large gasfield with high concentration of hydrogen sulfide at Carter Creek, WY. Ammonia was shipped to Rock Springs. The Rock Springs plant was designed to produce 320,000 tons per year of dry fertilizer and 27,000 tons per year of superphosphoric acid.

J. R. Simplot Co. operated the Gay Mine on the Fort Hall Indian Reservation and the Smoky Canyon Mine in the Caribou National Forest. About 80% of the ore from the Gay Mine, a 24% to 26% P_2O_5 shale, was shipped to FMC Corp.'s electric-furnace plant west of Pocatello, ID. The balance of main-bed ore was used by Simplot in its fertilizer plant. Slurried ore from the Smoky Canyon Mine was pumped to Conda, ID. After concentration the product was calcined and shipped by rail to the Pocatello fertilizer plant.

Table 2.—Production of phosphate rock in the United States, by region[1]

(Thousand metric tons and thousand dollars)

Region	Mine production		Marketable production							Ending stocks
			Used directly		Beneficiated		Total[2]			
	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content	Value[3]	
1986[r]	135,683	17,807	3,285	860	37,035	11,388	40,320	12,248	897,131	13,277
1987:										
January-June:										
Florida and North Carolina	68,657	8,163	--	--	17,610	5,387	17,610	5,387	352,825	10,379
Idaho, Montana, Tennessee, and Utah	2,922	702	1,005	265	795	236	1,800	502	28,026	1,450
Total[2]	71,579	8,865	1,005	265	18,406	5,624	19,410	5,889	[4]379,863	11,829
July-December:										
Florida and North Carolina	72,728	9,138	--	--	18,596	5,750	18,596	5,750	363,176	9,337
Idaho, Montana, Tennessee, and Utah	4,119	1,420	1,778	476	1,170	354	2,948	830	49,258	1,547
Total[2]	76,847	10,558	1,778	476	19,766	6,104	21,544	6,580	[4]413,206	10,884
Grand total[2]	148,426	19,423	2,783	741	38,172	11,728	40,954	12,469	[4]793,069	XX

[r]Revised. XX Not applicable.
[1]Data for the same items appearing in this and other tables may not reconcile because of computer rounding.
[2]Data may not add to totals shown because of independent rounding.
[3]Computer-calculated value based on the weighted sold or used value.
[4]The total value is based on a weighted value. The total value does not equal the sum of the regional or 1/2-year totals because weighted regional or overall 1/2-year unit values were used in the calculations. The regional and 1/2-year values are approximate.

CONSUMPTION AND USES

Phosphate rock is the raw material used to manufacture phosphate fertilizers, animal feed phosphates, and elemental phosphorus. Phosphate rock was exported to countries with production facilities for fertilizer, animal feeds, and phosphorus. Phosphate rock was converted into merchant-grade and superphosphoric acid, ammonium phosphates, and superphosphates that were sold domestically or exported. The principal feed phosphate producers, Occidental, Texasgulf, Consolidated Minerals Inc., and IMC, produced for the domestic market. Elemental phosphorus produced in Tennessee, Idaho, and Montana by Occidental, Stauffer, and Monsanto supplied domestic plants that produce a large number of phosphorus chemicals.

Phosphate rock consumption improved 4% in 1987. The increase occurred because of increases in phosphate rock and phosphate fertilizer exports. Domestic demand was restricted by acreage reduction programs and weak export demand for agricultural products. Phosphate rock mined in Florida and North Carolina was consumed in manufacturing fertilizer or animal feeds. The Utah and Montana production was used to produce fertilizer. Phosphate rock produced in Idaho was used to produce fertilizer and elemental phosphorus. All Tennessee phosphate rock was consumed in electric furnaces.

Table 3.—U.S. phosphate rock sold or used grade distribution pattern

Grade (percent BPL[1] content)	Distribution (percent)				
	1983	1984	1985[2]	1986[r]	1987
74 or more	3.0	4.7	2.9	4.5	3.4
72 to less than 74	5.5	2.0	4.2	4.0	5.4
70 to less than 72	8.3	10.1	12.0	7.8	7.1
66 to less than 70	60.6	63.0	62.9	57.5	61.6
60 to less than 66	14.6	8.1	13.1	20.3	17.5
Less than 60	8.0	12.1	4.8	5.9	5.0

[r]Revised.
[1]1.0% BPL (bone phosphate of lime or tricalcium phosphate)=0.458% P_2O_5.
[2]Data do not add to 100% because of independent rounding.

Table 4.—Florida and North Carolina phosphate rock sold or used grade distribution pattern

Grade (percent BPL[1] content)	Distribution (percent)				
	1983	1984	1985[2]	1986	1987
74 or more	3.5	5.4	3.4	5.1	3.8
72 to less than 74	6.4	2.4	4.8	4.6	6.0
70 to less than 72	9.6	9.9	12.6	9.0	7.6
66 to less than 70	64.2	67.5	65.9	60.7	65.3
60 to less than 66	13.0	7.0	12.8	20.6	17.3
Less than 60	3.3	7.8	.6	--	([3])

[1]1.0% BPL (bone phosphate of lime or tricalcium phosphate)=0.458% P_2O_5.
[2]Data do not add to 100% because of independent rounding.
[3]Less than 0.1 of 1%.

Table 5.—Tennessee and Western States phosphate rock sold or used grade distribution pattern

Grade (percent BPL[1] content)	Distribution (percent)				
	1983[2]	1984[2]	1985[2]	1986[r]	1987
70 to less than 72	NA	NA	NA	--	3.5
66 to less than 70	NA	NA	NA	36.1	33.9
60 to less than 66	NA	NA	NA	18.5	19.3
Less than 60	NA	NA	NA	45.4	43.3

[r]Revised. NA Not available.
[1]1.0% BPL (bone phosphate of lime or tricalcium phosphate)=0.458% P_2O_5.
[2]Data for Tennessee and Western States (Idaho, Montana, and Utah) were reported separately in the 1985 and 1986 Minerals Yearbook chapter.

Table 6.—Phosphate rock sold or used by producers in the United States, by grade and region[1]

(Thousand metric tons and thousand dollars)

Grade (percent BPL[2] content)	Florida and North Carolina			Tennessee and Western States[3]			Total		
	Rock	P_2O_5 content	Value[4 5]	Rock	P_2O_5 content	Value[4 5]	Rock	P_2O_5 content	Value[4 5]
January-June 1986[r]	17,665	5,466	398,067	2,776	780	68,006	20,441	6,246	466,073
July-December 1986[r]	18,668	5,769	412,362	2,669	735	51,187	21,337	6,504	463,549
January-June 1987:									
74 or more	410	142	11,850	--	--	--	410	142	11,850
72 to less than 74	1,719	579	39,269	--	--	--	1,719	579	39,269
70 to less than 72	1,216	394	27,933	--	--	--	1,216	394	27,933
66 to less than 70	11,912	3,679	228,190	828	257	19,331	12,740	3,937	247,521
60 to less than 66	3,753	1,053	73,474	470	129	4,664	4,224	1,182	78,138
Below 60	17	4	372	888	226	10,049	905	231	10,421
Total[6]	19,027	5,851	381,088	2,186	613	34,044	21,214	6,465	415,132
July-December 1987:									
74 or more	1,071	368	25,244	--	--	--	1,071	368	25,244
72 to lss than 74	624	208	13,428	--	--	--	624	208	13,428
70 to less than 72	1,707	554	42,848	173	57	6,095	1,880	611	48,943
66 to less than 70	13,337	4,107	248,167	859	266	20,271	14,196	4,373	268,438
60 to less than 66	2,925	801	54,285	493	137	5,639	3,418	938	59,924
Below 60	--	--	--	1,270	323	14,703	1,270	323	14,703
Total[6]	19,664	6,039	383,972	2,795	783	46,708	22,459	6,821	430,680

[r]Revised.
[1]Data for the same items appearing in this and other tables may not reconcile because of computer rounding.
[2]1.0% BPL (bone phosphate of lime or tricalcium phosphate)=0.458% P_2O_5.
[3]Includes Idaho, Montana, and Utah.
[4]F.o.b. mine.
[5]The total value is based on a weighted value. The total value does not equal the sum of the regional totals because weighted regional unit values were used in the calculations. The regional values are approximate.
[6]Data may not add to totals shown because of independent rounding.

Table 7.—Phosphate rock sold or used by producers in the United States, by use[1]

(Thousand metric tons)

Use	1986 total		1987 January-June		1987 July-December		1987 Total[2]	
	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content
Domestic:[3]								
Wet-process phosphoric acid	27,979	8,512	15,017	4,538	15,852	4,791	30,868	9,329
Normal superphosphate	210	66	36	12	15	5	50	16
Triple superphosphate	1,292	436	422	141	505	162	927	303
Defluorinated rock	78	27	111	38	75	26	186	65
Direct applications	1,032	325	--	--	9	3	9	3
Elemental phosphorus	r3,177	r822	1,317	347	1,696	444	3,013	791
Ferrophosphorus	r162	r40	75	19	91	23	166	42
Total[2]	r33,930	r10,228	16,978	5,095	18,242	5,454	35,219	10,549
Exports[4]	7,848	2,521	4,237	1,369	4,217	1,368	8,454	2,737
Grand total[2]	r41,778	r12,751	21,214	6,464	22,458	6,821	43,673	13,286

rRevised.
[1]Data for the same items appearing in this and other tables may not reconcile because of computer rounding.
[2]Data may not add to totals shown because of independent rounding.
[3]Includes rock converted to products and exported.
[4]Exports reported to the Bureau of Mines by companies.

Table 8.—Phosphate rock sold or used by producers in the United States, by use and region[1]

(Thousand metric tons)

Use	Florida and North Carolina		Tennessee and Western States[2]		Total[3]	
	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content
1986r	36,333	11,236	5,443	1,515	41,776	12,750
1987:						
January-June:						
Domestic:[4]						
Agricultural	14,854	4,503	731	227	15,586	4,730
Industrial	34	10	1,358	356	1,392	366
Total	14,888	4,513	2,089	583	16,978	5,096
Exports[5]	4,140	1,339	97	30	4,237	1,369
Total[3]	19,028	5,852	2,186	613	21,215	6,465
July-December:						
Domestic:[4]						
Agricultural	15,487	4,685	968	302	16,455	4,987
Industrial	24	7	1,763	460	1,787	467
Total	15,511	4,692	2,731	762	18,242	5,454
Exports[5]	4,153	1,348	64	20	4,217	1,368
Total[3]	19,664	6,040	2,795	782	22,459	6,822
Grand total[3]	38,692	11,892	4,981	1,395	43,674	13,287

rRevised.
[1]Data for the same items appearing in this and other tables may not reconcile because of computer rounding.
[2]Includes Idaho, Montana, and Utah.
[3]Data may not add to totals shown because of independent rounding.
[4]Includes rock converted to products and exported.
[5]Exports reported to the Bureau of Mines by companies.

Table 9.—Florida and North Carolina phosphate rock sold or used by producers[1]

Year	Rock (thousand metric tons)	P_2O_5 content (thousand metric tons)	Value: Total[2] (thousands)	Value: Average per ton f.o.b. mine
1983	40,223	12,456	$944,509	$23.48
1984	46,411	14,309	1,089,647	23.48
1985	40,857	12,702	972,748	23.81
1986	36,333	11,236	810,429	22.31
1987	38,692	11,891	765,061	19.77

[1]Data for the same items appearing in this and other tables may not reconcile because of computer rounding.
[2]The total value is based on a weighted value.

Table 10.—Tennessee and Western States[1] phosphate rock sold or used by producers[2]

Year	Rock (thousand metric tons)	P_2O_5 content (thousand metric tons)	Value: Total[3] (thousands)	Value: Average per ton f.o.b. mine
1983[4]	NA	NA	NA	NA
1984[4]	NA	NA	NA	NA
1985[4]	NA	NA	NA	NA
1986[r]	5,443	1,515	$119,192	$21.90
1987	4,981	1,395	80,751	16.21

[r]Revised. NA Not available.
[1]Includes Idaho, Montana, and Utah.
[2]Data for the same items appearing in this and other tables may not reconcile because of computer rounding.
[3]The total value is based on a weighted value.
[4]Data for Tennessee and Western States were reported separately in the 1985 and 1986 Minerals Yearbook chapter.

Table 11.—Marketable phosphate rock yearend stocks

(Million metric tons)

Year	Quantity
1978	15.7
1979	14.5
1980	13.7
1981	19.6
1982	18.3
1983	14.5
1984	11.9
1985	15.5
1986	[r]13.3
1987	10.9

[r]Revised.

PRICES

Phosphate rock was sold under contracts negotiated between buyers and sellers. Although list selling prices were occasionally published by producing organizations, actual negotiated prices were not published.

Phosphate rock export prices from Tampa and Jacksonville, FL, included freight, loading, and weighing costs of $6.17 and $9.30, respectively. The severance tax, included in the export price, was $2.46 per ton for the first half of the year and $1.97 per ton in the second half.

The weighted averaged prices or values, f.o.b. mine, for each grade of phosphate rock and for each producing region were calculated and published by the Bureau of Mines from the semiannual survey of producers.

Table 12.—Phosphate rock estimated export prices[1] per metric ton, unground, f.o.b. vessel Tampa Range or Jacksonville, FL, by grade

Grade (percent BPL[2] content)	1984[3]	1985[4]	1986[5]	1987[6]
75	$35.00	$34,00	$33.00	$32.00
72	30.50	30.50	31.00	29.00
70	27.50	28.00	27.00	27.50
68	26.50	26.00	25.50	24.00

[1]Prices include severance taxes, rail freight costs from mine to port, and port loading and weighing charges.
[2]1.0% BPL (bone phosphate of lime or tricalcium phosphate)=0.458% P_2O_5.
[3]Estimated selling price including $2.39 severance tax.
[4]Estimated selling price including $2.52 severance tax.
[5]Estimated selling price including $2.51 severance tax.
[6]Estimated selling price including $2.46 severance tax.

Table 13.—Moroccan phosphate rock export prices, U.S. dollars per metric ton, f.a.s. Safi or Casablanca,[e] by grade

Grade (percent BPL[1] content)	1984	1985	1986	1987
Khouribga:				
76 to 77	47.00	47.00	45.00	42.00
70 to 71	36.00	36.00	36.00	34.00
Youssoufia:				
74 to 75	43.00	43.00	40.50	39.50
68 to 69	30.00	30.00	30.50	30.00

[e]Estimated.
[1]1.0% BPL (bone phosphate of lime or tricalcium phosphate)=0.458% P_2O_5.

Table 14.—Price or value of Florida and North Carolina phosphate rock, by grade

(Dollars per metric ton, f.o.b. mine)

Grade (percent BPL[1] content)	1986			1987		
	Domestic	Export	Average	Domestic	Export	Average
74 or more	28.87	35.05	31.32	26.73	24.48	25.05
72 to less than 74	18.93	24.67	22.43	19.90	23.68	22.49
70 to less than 72	18.80	25.18	24.38	23.64	24.26	24.21
66 to less than 70	20.32	22.15	20.50	18.62	21.06	18.87
60 to less than 66	24.63	21.53	24.47	19.26	17.10	19.13
Less than 60	--	--	--	21.66	--	21.66
Average	21.64	25.02	22.31	18.93	22.87	19.77

[1]1.0% BPL (bone phosphate of lime or tricalcium phosphate)=0.458% P_2O_5.

Table 15.—Price or value of Tennessee and Western States[1] phosphate rock, by grade

(Dollars per metric ton, f.o.b. mine)

Grade (percent BPL[2] content)	1986			1987		
	Domestic	Export	Average	Domestic	Export	Average
70 to less than 72	--	--	--	35.27	--	35.27
66 to less than 70	[r]28.36	47.87	[r]33.61	22.62	31.50	23.47
60 to less than 66	10.04	41.69	16.11	10.70	--	10.70
Less than 60	[r]14.93	--	[r]14.93	11.47	--	11.47
Average	[r]18.18	46.21	[r]21.90	15.70	31.50	16.21

[r]Revised.
[1]Includes Idaho, Montana, and Utah.
[2]1.0% BPL (bone phosphate of lime or tricalcium phosphate)=0.458% P_2O_5.

Table 16.—Price or value of U.S. phosphate rock, by grade

(Dollars per metric ton, f.o.b. mine)

Grade (percent BPL[1] content)	1986			1987		
	Domestic	Export	Average	Domestic	Export	Average
74 or more	28.87	35.05	31.32	26.73	24.48	25.05
72 to less than 74	18.93	24.67	22.43	19.90	23.68	22.49
70 to less than 72	18.80	25.18	24.38	28.32	24.26	24.83
66 to less than 70	[r]20.86	27.26	[r]21.57	18.88	21.69	19.15
60 to less than 66	23.13	28.23	23.48	18.12	17.10	18.07
Less than 60	[r]14.93	--	[r]14.93	11.55	--	11.55
Average	[r]21.16	26.97	[r]22.25	18.49	23.03	19.37

[r]Revised.
[1]1.0% BPL (bone phosphate of lime or tricalcium phosphate)=0.458% P_2O_5.

FOREIGN TRADE

Export tonnage of phosphate rock was 8% higher than that of 1986, although it did not exceed the average of the past 7 years. The increase in export sales was due primarily to competitive prices offered by U.S. exporters. Phosphate rock was again in oversupply in 1987, causing downward pressure on prices.

Phosphate rock imports for consumption decreased in 1987. The principal countries exporting to the United States were Togo and Morocco. Lesser tonnages were imported from the Federal Republic of Germany, the Netherlands Antilles, the United Kingdom, and miscellaneous sources.

Table 17.—U.S. exports of phosphate rock, by country

(Thousand metric tons and thousand dollars)

(Schedule B No. 480.4500)

Country	1986 Quantity[1]	1986 Value	1987 Quantity[1]	1987 Value
Australia	112	NA	52	NA
Austria	45	NA	34	NA
Belgium-Luxembourg	449	NA	317	NA
Brazil	43	NA	9	NA
Canada	2,351	NA	1,384	NA
Finland	91	NA	64	NA
France	787	NA	699	NA
Germany, Federal Republic of	535	NA	592	NA
India	278	NA	344	NA
Italy	95	NA	394	NA
Japan	966	NA	1,036	NA
Korea, Republic of	1,374	NA	1,344	NA
Mexico	278	NA	412	NA
Netherlands	51	NA	668	NA
New Zealand	67	NA	162	NA
Philippines	32	NA	--	NA
Poland	521	NA	604	NA
Romania	91	NA	150	NA
Sweden	82	NA	98	NA
United Kingdom	1	NA	--	NA
Other	927	NA	322	NA
Total[2]	9,176	211,701	8,685	194,691

NA Not available.

[1]Individual country exports furnished by Bureau of the Census will not add to totals.

[2]Total quantity and value reported to the Bureau of Mines, f.o.b. mine.

Table 18.—U.S. exports of superphosphates, more than 40% P_2O_5, by country

(Thousand metric tons and thousand dollars)

(Schedule B No. 480.7050)

Country	1986 Quantity	1986 Value[1]	1987 Quantity	1987 Value[1]
Argentina	10	NA	11	NA
Australia	60	NA	79	NA
Belgium-Luxembourg	43	NA	30	NA
Brazil	207	NA	172	NA
Bulgaria	46	NA	23	NA
Burma	16	NA	15	NA
Canada	277	NA	434	NA
Chile	129	NA	170	NA
Colombia	12	NA	21	NA
Costa Rica	10	NA	6	NA
Czechoslovakia	118	NA	26	NA
Dominican Republic	13	NA	11	NA
France	--	NA	3	NA
Germany, Federal Republic of	10	NA	--	NA
Ireland	30	NA	--	NA
Japan	38	NA	60	NA
Mexico	122	NA	24	NA
Peru	28	NA	15	NA
Spain	18	NA	--	NA

See footnotes at end of table.

Table 18.—U.S. exports of superphosphates, more than 40% P_2O_5, by country —Continued

(Schedule B No. 480.7050)

Country	1986 Quantity	1986 Value[1]	1987 Quantity	1987 Value[1]
Uruguay	15	NA	14	NA
Other	31		46	
Total	1,233	155,774	1,160	192,308

NA Not available.
[1]All values f.a.s. (free alongside ship).

Source: Bureau of the Census.

Table 19.—U.S. exports of superphosphates, less than 40% P_2O_5, by country

(Schedule B No. 480.7030)

Country	1986 Quantity (metric tons)	1986 Value[1] (thousands)	1987 Quantity (metric tons)	1987 Value[1] (thousands)
Canada	3,990	$87	2,404	NA
Other	--	--	376	NA
Total	3,990	87	2,780	$94

NA Not available.
[1]All values f.a.s. (free alongside ship).

Source: Bureau of the Census.

Table 20.—U.S. exports of diammonium phosphates, by country

(Thousand metric tons and thousand dollars)

(Schedule B No. 480.8005)

Country	1986 Quantity	1986 Value[1]	1987 Quantity	1987 Value[1]
Argentina	106	NA	72	NA
Australia	190		181	
Belgium-Luxembourg	353		594	
Brazil	173		101	
Canada	117		162	
Chile	67		71	
China	542		1,441	
Colombia	91		133	
Costa Rica	17		22	
Dominican Republic	25		43	
Ecuador	28		30	
France	26		146	
Germany, Federal Republic of	17		137	
Guatemala	25		13	
India	441		--	
Iran	--		116	
Ireland	17		54	
Italy	196		326	
Japan	162		343	
Kenya	--		80	
Mexico	83		39	
New Zealand	24		34	
Pakistan	607		32	
Peru	--		48	
Spain	--		163	
Thailand	9		32	
Turkey	286		44	
Uruguay	32		37	
Venezuela	--		224	
Yugoslavia	24		55	
Other	462		874	
Total	4,120	641,385	5,647	890,801

NA Not available.
[1]All values f.a.s. (free alongside ship).

Source: Bureau of the Census.

Table 21.—U.S. exports of phosphoric acid, less than 65% P_2O_5, by country

(Thousand metric tons and thousand dollars)

(Schedule B No. 480.7015)

Country	1986 Quantity	1986 Value[1]	1987 Quantity	1987 Value[1]
Australia	--	NA	61	NA
Canada	2	NA	2	NA
Colombia	9	NA	3	NA
India	273	NA	179	NA
Indonesia	46	NA	65	NA
Japan	--	NA	58	NA
Venezuela	106	NA	79	NA
Other	264	NA	53	NA
Total	700	110,010	500	85,912

NA Not available.
[1]All values f.a.s. (free alongside ship).

Source: Bureau of the Census.

Table 22.—U.S. exports of elemental phosphorus, by country

(Schedule B No. 415.3500)

Country	1986 Quantity (metric tons)	1986 Value[1] (thousands)	1987 Quantity (metric tons)	1987 Value[1] (thousands)
Brazil	6,537	NA	5,621	$10,368
Canada	487	NA	133	210
Japan	8,436	NA	6,170	9,339
Korea, Republic of	402	NA	1,277	1,715
Mexico	2,832	NA	6,481	8,424
Taiwan	1,424	NA	84	103
Other	148	NA	536	637
Total	20,266	$33,310	20,302	30,796

NA Not available.
[1]All values f.a.s. (free alongside ship).

Source: Bureau of the Census.

Table 23.—U.S. imports for consumption of phosphate rock and phosphatic materials

(Thousand metric tons and thousand dollars)

Fertilizer	TSUS No.[1]	1986 Quantity	1986 Value[2]	1987 Quantity	1987 Value[2]
Phosphates, crude and apatite[3]	480.4500	528	22,265	464	18,816
Phosphatic fertilizers and fertilizer materials	480.7070-480.8095	69	8,351	55	7,820
Dicalcium phosphate	418.2800	1,420	1,209	1,960	2,086
Phosphorus	415.3500	1,510	3,548	4,463	6,609
Phosphoric acid, technical-grade	480.7010	([4])	157	1	1,667
Normal superphosphate	480.7030	1	204	3	585
Triple superphosphate	480.7050	1	112	49	6,262

[1]Tariff Schedules of the United States.
[2]Declared customs valuation.
[3]Excludes reported imports from Canada and Israel.
[4]Less than 1/2 unit.

Source: Bureau of the Census.

WORLD REVIEW

Phosphate rock production exceeded world demand. Oversupply of phosphate rock in world markets sharpened competition; prices declined, and profit margins disappeared. Numerous phosphate rock mines were closed or operating schedules were reduced to balance demand and prevent inventories from rising.

Demand for phosphate fertilizers declined substantially as food supplies increased throughout the world. The oversupply of agricultural commodities drastically reduced demand for phosphate fertilizers. Acreage reduction programs in the United States, designed to reduce farm commodity surpluses, and similar programs in Western Europe and Japan were extended through 1987 in an attempt to manage agricultural production, reduce inventories, and improve the farm economy.

Plans to develop new phosphate rock mines or expand existing mines were deferred or canceled by governments and companies. It is probable that the phosphate rock industry will, under pressure from lower prices, have to wait until supply and demand are in balance before new projects and ventures are implemented.

The phosphate rock tabulation in table 24 was developed with the assistance of the International Fertilizer Industry Association Ltd., Paris, France.

Australia.—In Western Australia, Union Oil sold its 60% interest in the Mount Weld phosphate deposit, near Laverton, to CSBP & Farmers. The Broken Hill Pty. Ltd. (BHP) retained its 40% interest. About 7,500 tons of phosphate rock was mined. It was unsuitable for the manufacture of superphosphates but was used in organic horticultural fertilizer products. Queensland Phosphate Pty. Ltd. produced 26,813 tons from the Duchess Mine in a campaign operation. The mine was in a care and maintenance condition for the balance of the year.[3]

China.—The State Statistical Bureau, Beijing, reported that phosphate fertilizer production peaked at 2,666,000 tons in 1983 and declined in successive years to 1,760,000 tons in 1985.

Christmas Island.—The Australian Government closed the phosphate rock mines on Christmas Island after production declined in 1986, and the rate of production continued downward in 1987.[4]

Egypt.—A new beneficiation plant for the El Nasrab phosphate rock mine was scheduled to start operating in early 1988. Prior to construction of the new plant, the phosphate rock was hand-sorted and crushed. The new plant will process up to 1.2 million tons per year using two production lines.[5]

Iraq.—The Government of Iraq announced the discovery of 3,500 million tons of phosphate rock reserves at the Akashat Mine.[6]

Jordan.—Jordan Phosphate Mines Co. planned to produce 800,000 tons of phosphate rock from the Eshidiya Mine in 1988. The Rusaifa Mine, closed in 1985, remained inactive. Production in 1987 was restricted to the El Abiad and El Hassa Mines.

Mexico.—The fertilizer project at Lazaro Cardenas on the Pacific coast was commissioned. The first-phase 50-LAC project and part of the second-phase 93-LAC project were completed in 1986; however, the triple superphosphate plant of 93-LAC was not completed until 1987.[7]

Morocco.—The Moroccan Office Cherifien des Phosphates announced plans to increase the phosphoric acid capacity at Jorf Lasfar by adding to Maroc Phosphore. The new plants will double the capacity of Jorf Lasfar. A new mine on the Oulad Abdoun Plateau, part of the Khouribga District, will gradually replace the Sidi Daoui Mine as it is depleted. The new mine, Sidi Chennane, is scheduled to start producing in 1990 and will supply dried phosphate rock to Jorf Lasfar.

Senegal.—Industries Chemiques du Senegal (ICS) is a chemical complex adjacent to the Taiba phosphate mines at Darow-Khoudoss, 90 kilometers northeast of Dakar. The plant has gradually increased production since its inception. The sulfuric acid plant has a capacity of 560,000 tons per year, and the phosphoric acid plant was rated at 220,000 tons per year. Triple superphosphates and diammonium phosphates are produced in the Dakar suburbs for the export market.[8]

Syria.—Gecopham, a Government-owned company, produced phosphate rock from two mines in the Kneifiss and the eastern areas of the Ghardiral Hamal region of the Palmrides. Gecopham added mining machinery in the phosphate mines and expanded the export facilities at Tartous from 1.3 million tons per year to 2.4 million tons per year to be able to supply additional phosphate rock if sales improve.[9]

Tunisia.—The Government authorized the development of the Kef Eddour phosphate mine near Gafsa to produce phosphate rock for a new phosphoric acid plant at La Skirrah, which was due on-stream in 1987. The phosphoric acid plant will use phosphate rock from the Gafsa District until the 1.4-million-ton-per-year Kef Eddour Mine is completed.[10]

U.S.S.R.—The Soviet Union awarded a contract to Outokumpu Oy, Finland's state-owned mining company, to construct a new flotation plant on the Kola Peninsula. The beneficiation plant's first stage was completed in 1985 with a capacity of 1.3 million tons per year.[11]

Table 24.—Phosphate rock, basic slag, and guano: World production, by country[1]

(Thousand metric tons)

Commodity and country[2]	Gross weight 1983	Gross weight 1984	Gross weight 1985	Gross weight 1986[p]	Gross weight 1987[e]	P_2O_5 content 1983	P_2O_5 content 1984	P_2O_5 content 1985	P_2O_5 content 1986[p]	P_2O_5 content 1987[e]
Phosphate rock:										
Algeria	893	[e]1,000	1,207	1,203	1,073	276	309	[e]381	[e]380	336
Australia	5	15	33	34	10	1	4	7	7	2
Brazil	3,208	3,855	4,214	4,509	4,777	1,119	1,345	1,475	1,620	1,694
Chile	1	5	7	7	7	(3)	(3)	1	1	1
China[e]	12,500	11,800	6,970	6,700	9,000	3,375	3,186	1,882	[r]1,810	2,700
Christmas Island (Indian Ocean)	1,094	1,259	1,187	880	[4]842	385	443	418	310	295
Colombia	17	11	24	27	34	3	2	5	[e]6	8
Egypt	647	1,043	[e]1,074	1,271	1,083	205	253	270	315	312
Finland	381	477	512	527	553	141	176	189	195	195
India	688	892	929	659	750	212	294	307	219	234
Indonesia	6	2	1	1	3	2	1	1	1	1
Iraq[e]	1,199	1,000	1,000	1,000	1,500	261	218	218	218	380
Israel	2,969	3,312	4,076	3,673	[4]3,798	892	995	1,210	1,110	1,214
Jordan	4,749	6,263	6,067	6,249	6,801	1,548	2,042	2,010	2,072	2,254
Korea, North[e]	500	500	500	500	500	160	160	160	160	160
Mexico[5]	389	375	550	600	640	117	113	166	[e]180	197
Morocco[6]	20,106	21,245	20,737	21,178	20,955	[e]6,400	[e]6,762	[e]6,574	[e]6,714	6,650
Nauru	1,684	1,358	1,508	1,494	[4]1,376	648	523	[e]581	[e]575	530
Pakistan	--	--	--	50	[4]32	--	--	--	16	[4]10
Peru	3	13	12	30	90	1	4	[e]4	[r] [e]9	27
Philippines	4	7	6	[e]6	8	1	2	2	[e]2	2
Senegal	1,521	1,912	1,814	1,850	1,880	534	583	[e]617	[e]641	680
South Africa, Republic of	2,887	2,585	2,433	2,920	2,623	[e]996	[e]939	[e]883	[e]1,060	950
Sri Lanka	16	14	14	15	21	6	5	5	5	7
Sweden	107	133	187	192	221	41	51	74	72	82
Syria	1,229	1,514	[e]1,270	[e]1,606	1,986	375	461	380	485	606
Tanzania	20	15	[e]15	[e]10	18	6	4	[e]4	[e]3	4
Thailand	5	3	4	5	4	1	1	1	1	1
Togo	2,081	2,696	2,452	2,314	[4]2,644	755	979	890	840	960
Tunisia	5,924	5,346	4,530	5,951	6,390	1,700	1,554	[e]1,303	[e]1,712	1,836
Turkey	50	96	[e]37	3	19	15	29	[e]12	[e]1	6
U.S.S.R.[e]	[r]33,100	[r]33,300	[r]33,750	[r]33,900	34,100	[r]10,350	[r]10,550	[r]10,650	[r]10,700	10,750
United States	42,573	49,197	50,835	38,710	[4]40,954	13,088	14,889	15,674	11,857	12,491
Vietnam[e]	200	200	[r]516	[r]530	300	66	66	[r]170	[r]175	105
Zimbabwe	133	125	135	136	156	47	44	48	48	55
Total	[r]140,889	[r]151,568	148,606	138,740	145,148	[r]43,728	[r]46,987	46,558	43,509	45,735

Basic (Thomas converter) slag:										
Argentina	1	1	[e]1	[e]1	1	([3])	([3])	([3])	([3])	([3])
Belgium	250	254	143	[r] [e]150	175	45	46	26	[r] [e]27	32
Egypt[e]	[4]10	[4]10	10	8	8	2	2	2	2	2
France	1,124	1,194	1,165	855	1,000	202	215	210	154	180
Germany, Federal Republic of	409	446	491	374	370	93	62	67	55	50
Luxembourg	586	728	701	[e]650	700	105	131	126	[e]117	126
United Kingdom	4	4	[e]4	--	--	1	1	[e]1	--	--
Total	2,384	2,637	2,515	2,038	2,254	448	[r]457	432	355	390
Guano:										
Chile	([3])	3	3	8	7	([3])	([3])	([3])	1	1
Kenya	([3])	([3])	([3])	([3])	([3])	([3])	([3])	([3])	([3])	([3])
Philippines	1	1	1	[e]1	1	([3])	([3])	([3])	[e]([3])	([3])
Seychelles Islands (exports)[e]	5	5	5	5	5	[4]2	[4]2	2	2	2
Total	6	[r]9	9	14	13	2	2	2	3	3

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

[1]Table includes data available through May 13, 1988. Data for major phosphate-rock-producing countries derived in part from the International Fertilizer Industry Association; other figures are from official country sources where available.

[2]In addition to the countries listed, Belgium and Uganda may have produced small quantities of phosphate rock, and Namibia may have produced small quantities of guano, but output is not officially reported, and available information is inadequate for formulation of reliable estimates of output levels.

[3]Less than 1/2 unit.

[4]Reported figure.

[5]Includes only output used to manufacture fertilizers.

[6]Production from Western Sahara area included with Morocco.

TECHNOLOGY

The declining quality of phosphate rock reserves has promoted the development of processes to reduce the levels of impurities in marketable phosphate rock. Impurities collected in phosphoric acid cause problems in processing the acid and with the quality of downstream products. In some instances it is possible to beneficiate the phosphate ore or matrix by physically separating a size fraction that contains the impurity. If the impurity is part of the chemical structure of the mineral and cannot be liberated by size reduction, the ore will not respond to the treatment. In addition to classification, it is usually necessary to employ flotation if the mixture of ore and gangue is of a similar size. A flotation circuit is commonly used to separate phosphate minerals from a silicate gangue and reduce carbonate to an acceptable level. The flotation feed is treated with reagents to cause the surfaces of different minerals to be attracted to air or water, permitting one or more to be floated or depressed in the mixture of water and air bubbles.

Société Industrielle d'Acide Phosphorique et d'Engrais (SIAPE) installed a 13,000-ton-per-year P_2O_5 demonstration plant to reduce magnesium oxide in phosphoric acid. The plant, which used a folded-bed chemical separation process, was constructed and commissioned in Sfax, Tunisia, in 1986. An ion-exchange section removes magnesium, and the resin is regenerated with sulfuric acid. Magnesium oxide was reduced from 0.55% to 0.65% to 0.04% to 0.1% levels.[12]

Negev Phosphates Ltd., developed a proprietary flotation reagent that can separate phosphate-bearing minerals from calcium carbonate. This process replaces a washing and classification flowsheet that separates a middle-size-fraction from phosphate-poor coarse and fine fractions. The flotation process improved grade and recovery. The flotation process was used at the Tamar facility, recovering phosphate rock from a fine waste tailing.[13]

Highly reactive, finely ground phosphate rock can be used as a fertilizer where the soils, particularly soils in the tropics, are deficient in phosphorus. If the indigenous phosphate rock is unsuitable for dried application, a partially acidulated phosphate rock may perform well, and the crop response may be similar to that of soil treated with conventional single or triple superphosphate. A partially acidulated phosphate rock (PAPR) is one that is acidulated with less than the stoichiometric quantity of sulfuric or phosphoric acid to achieve complete solubility. The amount of water-soluble phosphate in a PAPR will vary with the degree of acidulation.

Run-of-pile PAPR is produced by continuously mixing ground phosphate rock and sulfuric acid in a pugmill or similar mill. The mixed product may be transferred to storage.

The single-step acidulation-granulation process mixes phosphate rock, acid, and water plus recycled material in a rotary drum granulator. The product is dried, screened, and crushed if necessary to obtain a sized product.[14]

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[1]Physical scientist, Branch of Industrial Minerals.
[2]All quantitiess are in metric tons unless otherwise specified.
[3]U.S. Embassy, Canberra, Australia. State Dep. Airgram, Apr. 8, 1987, 1 p.
[4]Fertilizer Week. No. 35, Jan. 11, 1988, p. 4.
[5]Fertilizer International. No. 236, Oct. 9, 1986, p. 6.
[6]Mining Annual Review. June 1987, pp. 454-455.
[7]Fertilizer International. No. 237, Oct. 23, 1986.
[8]Page 427 of work cited in footnote 6.
[9]Pages 449-450 of work cited in footnote 6.
[10]U.S. Embassy, Tunis, Tunisia. State Dep. Airgram 01579, Feb. 19, 1988, 2 pp.
[11]Engineering and Mining Journal. No. 147, Jan. 1987, p. 14.
[12]Phosphorus & Potassium. No. 148, Mar.-Apr. 1987, pp. 35-40.
[13]———. No. 147, Jan.-Feb. 1987, p. 37.
[14]———. No. 150, July-Aug. 1987, pp. 48-53.

Platinum-Group Metals

By J. Roger Loebenstein[1]

The Stillwater Mining Co. (SMC) opened a new platinum-palladium mine in Montana and shipped its first concentrate to Belgium for refining. This was the first time since 1976 that the United States mined platinum-group metals (PGM) as a primary product from a domestic deposit. The Republic of South Africa remained the leading producer of platinum. The U.S.S.R. remained the leading producer of palladium.

Table 1.—Salient platinum-group metals[1] statistics

(Thousand troy ounces unless otherwise specified)

	1983	1984	1985	1986	1987
United States:					
Mine production[2]	6	15	W	W	W
Value[3] thousand dollars	$1,118	$2,456	W	W	W
Refinery production:					
Primary refined	9	24	7	r4	6
Secondary:					
Nontoll-refined	303	340	259	r354	165
Toll-refined	995	1,157	1,038	r1,155	1,444
Total refined metal	1,307	1,521	1,304	r1,513	1,615
Stocks, yearend:					
Industry (refined)	943	1,319	1,129	r1,292	1,235
National Defense Stockpile:					
Platinum	453	453	453	453	453
Palladium[4]	1,255	1,262	1,265	1,265	1,265
Iridium[5]	28	30	30	30	30
Exports:					
Refined[6]	446	599	526	382	432
Total	1,229	1,162	889	751	708
Imports for consumption:					
Refined[6]	2,790	3,928	3,438	3,727	3,179
Total	3,218	4,474	3,990	4,477	3,807
Imports, general	3,218	4,485	3,990	4,399	3,807
Consumption (reported sales to industry)	1,914	2,200	2,271	r2,080	1,944
Consumption, apparent[7]	2,813	3,299	3,358	r3,536	2,969
Net import reliance[8] as a percent of apparent consumption	89	89	92	r90	94
Price, dealer, average, per ounce:					
Platinum	$424	$357	$291	$461	$553
Palladium	$136	$148	$107	$116	$130
World: Mine production[9]	6,525	r7,653	7,941	p8,314	e8,671

eEstimated. pPreliminary. rRevised. W Withheld to avoid disclosing company proprietary data.
[1]The platinum group comprises six metals: platinum, palladium, iridium, osmium, rhodium, and ruthenium.
[2]Byproduct of copper refining.
[3]Value based on dealer prices.
[4]Includes 7,200 ounces purchased in 1984 and 2,400 ounces purchased in 1985, but not added to inventory in those years.
[5]Includes 2,400 ounces purchased in 1983 and another 2,400 ounces purchased in 1984, but not added to inventory in those years.
[6]Includes both unwrought and semimanufactured.
[7]1983-84 includes mine production plus nontoll-refined production plus refined imports for consumption minus refined exports plus or minus changes in Government and industry stocks. 1985-87 mine production excluded to avoid disclosing company proprietary data.
[8]Refined imports for consumption minus refined exports plus or minus changes in Government and industry stocks.
[9]1985-87 totals exclude U.S. mine production to avoid disclosing company proprietary data.

PGM were used for a number of advanced material applications. For example, platinum-iridium alloys were used in crucibles for growing crystals used in computer memory devices and lasers. Platinum was used as a catalyst in the electrodes of phosphoric acid fuel cells, used for generating electricity.

Domestic Data Coverage.—Domestic production data for PGM are developed by the Bureau of Mines from a voluntary survey of U.S. refiners. Of the 24 refiners to which a survey request was sent, all responded. These represent 100% of the total refined metal production shown in tables 1 and 2.

Legislation and Government Programs.—An advisory panel composed of industry and Government representatives recommended that the Government should add rhodium and ruthenium to the National Defense Stockpile. Currently, the only PGM in the stockpile are platinum, palladium, and iridium.

DOMESTIC PRODUCTION

Exploration for PGM at the Stillwater Complex in Montana was first initiated in 1967 by Manville Corp. In March, SMC, a joint venture of Lac Minerals Ltd., Chevron Corp., and Manville Corp., shipped its first load of PGM concentrate to Métallurgie Hoboken-Overpelt S.A. (MHO) in Belgium. MHO processed the concentrate, which contained about 40 troy ounces of platinum and palladium per short ton. It returned the metal sponge to the partners, who then sold the metals in the spot market. Gold, rhodium, and silver also were recovered by MHO. In 1987, production of platinum was estimated to be 25,000 ounces. Production of palladium was estimated to be 75,000 ounces. By 1990, production of platinum and palladium is projected to double.[2]

The U.S. Geological Survey reportedly discovered substantial quantities of platinum in gold ore from the Tolovana and Rampart mining districts near Fairbanks, AK.[3] ASARCO Incorporated produced refined platinum and palladium as byproducts of copper refining from their Amarillo, TX, refinery.

Secondary metal was refined by about 24 firms. Most PGM scrap was refined on a toll basis. The largest scrap processor in the United States was Johnson Matthey Inc.

A new company, Catalyst Collectors Corp. (CCC), based in Union, NJ, was formed to collect and process catalytic converter scrap. CCC planned to have its scrap refined through Nippon Engelhard Ltd. in Tokyo, Japan.

The Industrial Products Div. of Heraeus Inc., based in Newark, NJ, announced plans to expand its precious metals recycling program. Heraeus recovers PGM, gold, and silver from scrap generated by the chemical, pharmaceutical, and electronics industries.

Table 2.—Platinum-group metals refined in the United States

(Troy ounces)

	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total
PRIMARY METAL							
Nontoll-refined:							
1983	879	5,005	--	--	--	--	5,884
1984	1,430	13,003	--	--	--	--	14,433
1985	524	3,463	--	--	--	--	3,987
1986	613	3,742	--	--	--	--	4,355
1987	1,032	5,095	--	--	--	--	6,127
Toll-refined:							
1983	1,150	2,026	--	--	--	--	3,176
1984	1,153	4,895	1,000	250	--	2,000	9,298
1985	1,100	--	--	--	--	2,200	3,300
1986	(1)	(1)	--	(1)	--	(1)	(1)
1987	--	--	--	--	--	--	--

See footnote at end of table.

Table 2.—Platinum-group metals refined in the United States —Continued

(Troy ounces)

	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total
SECONDARY METAL							
Nontoll-refined:							
1983	118,579	177,816	2,357	--	3,663	750	303,165
1984	89,702	243,347	735	27	3,668	2,047	339,526
1985	52,383	201,362	252	--	3,126	1,474	258,597
1986[r]	70,867	277,366	297	--	4,316	1,313	354,159
1987	37,939	120,351	115	604	3,944	1,597	164,520
Toll-refined:							
1983	433,700	456,732	5,820	925	41,624	55,788	994,589
1984	524,158	568,489	7,826	49	37,584	19,288	1,157,394
1985	490,595	490,948	7,007	3	36,336	13,356	1,038,245
1986[r]	674,412	398,270	3,584	1,415	57,618	19,701	1,155,000
1987	725,961	616,311	3,269	796	60,930	37,430	1,444,697
1986 TOTALS[r]							
Total primary	613	3,742	--	(1)	--	(1)	4,355
Total secondary	745,279	675,636	3,881	1,415	61,934	21,014	1,509,159
Total refined metal	745,892	679,378	3,881	1,415	61,934	21,014	1,513,514
1987 TOTALS							
Total primary	1,032	5,095	--	--	--	--	6,127
Total secondary	763,900	736,662	3,384	1,400	64,874	38,997	1,609,217
Total refined metal	764,932	741,757	3,384	1,400	64,874	38,997	1,615,344

[r]Revised.
[1]Revised to zero.

CONSUMPTION AND USES

Domestic industrial consumption of PGM remained essentially the same as that of 1986. PGM were used principally in catalysts for the control of automobile and industrial plant emissions; in reforming catalysts used to upgrade the octane rating of gasolines; and in catalysts used to produce acids, organic chemicals, and pharmaceuticals. They were also used in bushings for making glass fibers used in fiber-reinforced-plastic and other advanced materials, in electrical contacts, in capacitors, in conductive and resistive films used in electronic circuits, and in dental alloys used for making crowns and bridges.

Platinum, palladium, and rhodium were used in emission catalysts for light trucks (weighing 14,000 pounds or less, gross weight) and for automobiles. A typical emission catalyst in 1987 contained 0.057 ounce of platinum, 0.015 ounce of palladium, and 0.006 ounce of rhodium. Historically, quantities of the metals contained in each catalyst have varied. Variation depends on the year the vehicle was manufactured, the vehicle's engine size, the normal operating temperature of the vehicle's engine, and the manufacturer of the catalyst. In 1987, domestic vehicle production was 10.6 million vehicles outfitted with catalytic converters. One-third was light trucks and the rest were automobiles. For comparison, in 1983 domestic production was 9 million vehicles, with one-quarter of total vehicles being light trucks. Thus, it appears that light trucks are growing in importance in the total vehicle market using catalytic converters.

In electronic applications, ruthenium was the principal PGM used in thick film resistors. Palladium was the principal PGM used in thick-film conductors, multilayer ceramic capacitors, and connectors.

For glass applications, most of the PGM, specifically platinum, rhodium, and palladium, were used in bushings for the extrusion of textile or continuous-filament glass fiber.

In other applications, platinum and iridium crucibles were used for growing oxide single crystals, such as gadolinium gallium garnet (GGG) and yttrium aluminium garnet (YAG). GGG and YAG are used for computer memory devices and solid-state lasers. Platinum with titanium and columbium was used for cathodic protection of steel reinforcing bars in bridge and highway concrete. It prevents their corrosion by deicing salts used on roadways.

The Bureau of Mines does not collect data on domestic investor demand for platinum. According to Johnson Matthey PLC, the mid-range estimate for platinum investment demand in North America decreased to about 100,000 ounces, somewhat less than half of the 1986 level.[4]

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
1983	796,716	921,829	5,023	1,389	44,225	144,777	1,913,959
1984	876,227	1,150,500	7,117	1,072	76,253	88,619	2,199,788
1985	1,025,765	1,060,319	10,664	885	88,252	85,574	2,271,459
1986:							
Automotive[2]	625,000	165,000	r93	--	67,000	r500	r857,593
Chemical	77,696	44,485	929	17	5,083	24,910	153,120
Dental and medical	r20,752	r267,138	372	672	611	98	r289,643
Electrical	103,506	r286,390	1,630	--	6,813	61,489	r459,828
Glass	r15,945	--	93	--	2,952	20	r19,010
Jewelry and decorative[r]	11,330	4,795	1,033	--	3,195	745	21,098
Petroleum	30,566	60,959	--	--	--	--	91,525
Miscellaneous	r96,209	61,182	8,132	--	7,775	15,202	r188,500
Total[r]	981,004	889,949	12,282	689	93,429	102,964	2,080,317
1987:							
Automotive[2]	605,000	160,000	55	--	63,000	--	828,055
Chemical	61,719	34,682	884	--	3,446	2,242	102,973
Dental and medical	15,387	333,601	3,252	919	334	341	353,834
Electrical	58,545	318,301	882	--	5,775	24,857	408,360
Glass	9,157	--	55	--	1,772	24	11,008
Jewelry and decorative	5,706	7,099	626	--	7,391	259	21,081
Petroleum	23,773	41,344	--	--	--	--	65,117
Miscellaneous	45,962	100,239	2,330	--	4,823	630	153,984
Total	825,249	995,266	8,084	919	86,541	28,353	1,944,412

[r]Revised.
[1]Comprises primary and nontoll-refined secondary metals.
[2]1984-87 platinum, palladium, and rhodium sales to the automotive industry are estimated based on U.S. light truck sales and U.S. automobile production.

STOCKS

In addition to the stocks reported and held by refiners, importers, and dealers, end users of PGM held sizable quantities of PGM that were not reported to the Bureau of Mines.

Table 4.—Refiner, importer, and dealer stocks of refined platinum-group metals[1] in the United States, December 31

(Troy ounces)

Year	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total
1983	433,457	412,178	16,944	489	51,107	28,973	943,148
1984	648,130	524,924	19,600	1,302	53,120	71,571	1,318,647
1985	571,725	454,999	16,930	274	47,133	37,618	1,128,679
1986[r]	656,718	545,206	19,649	381	47,417	22,664	1,292,035
1987	611,000	558,005	16,275	36	32,018	17,653	1,234,987

[r]Revised.
[1]Includes metal in depositories of the New York Mercantile Exchange (NYMEX); on Dec. 28, 1987, this comprised 291,000 troy ounces of platinum and 61,800 troy ounces of palladium.

PRICES

World platinum supply exceeded industrial demand plus investment demand in 1987 by about 280,000 ounces (table 10). As a result, average monthly dealer prices were more often under $600 per ounce than over $600 per ounce. Less fluctuation was felt in average monthly dealer prices in 1987 than in 1986, possibly because of fear in 1986 that the U.S. Congress would impose economic sanctions on purchases of PGM from the Republic of South Africa. Trading volume for platinum and palladium on the New York Mercantile Exchange declined in 1987.

Table 5.—Average producer and dealer prices[1] of platinum-group metals

(Dollars per troy ounce)

	Platinum		Palladium		Rhodium		Iridium		Ruthenium		Osmium	
	Producer	Dealer	Producer	Dealer	Producer	Dealer	Producer	Dealer	Producer	Dealer	Producer	Dealer
1983	475	424	130	136	600	312	600	309	45	28	110	132
1984	475	357	147	148	625	607	600	424	(2)	103	(3)	455
1985	475	291	127	107	915	929	600	438	(2)	101	(3)	915
1986:												
January	475	365	120	102	1,150	1,149	600	422	(2)	70	(3)	874
February	475	373	120	101	1,150	1,104	600	425	(2)	71	(3)	854
March	475	413	120	110	1,150	1,140	600	440	(2)	75	(3)	850
April	475	417	120	107	1,150	1,132	600	427	(2)	72	(3)	687
May	475	411	120	108	1,150	1,144	600	407	(2)	69	(3)	633
June	475	432	120	110	1,150	1,156	600	399	(2)	70	(3)	650
July	475	439	120	111	1,150	1,163	600	396	(2)	69	(3)	650
August	505	537	127	128	1,169	1,202	600	406	(2)	70	(3)	650
September	600	595	150	140	1,300	1,317	600	414	(2)	70	(3)	650
October	600	571	150	135	1,364	1,205	600	414	(2)	79	(3)	650
November	600	510	150	122	1,267	1,101	600	408	(2)	78	(3)	650
December	600	474	150	117	1,200	1,075	600	407	(2)	77	(3)	650
Average	519	461	131	116	1,196	1,157	600	414	(2)	73	(3)	704
1987:												
January	600	515	150	123	1,200	1,124	600	397	(2)	74	(3)	650
February	600	515	150	120	1,200	1,180	600	394	(2)	71	(3)	650
March	600	525	150	123	1,200	1,157	600	384	(2)	71	(3)	650
April	600	585	150	136	1,200	1,201	600	375	(2)	72	(3)	626
May	600	605	150	145	1,200	1,245	600	384	(2)	72	(3)	625
June	600	565	150	137	1,220	1,225	600	379	(2)	72	(3)	625
July	600	568	150	140	1,275	1,230	507	345	(2)	67	(3)	632
August	600	608	150	140	1,275	1,273	600	350	(2)	68	(3)	650
September	600	586	150	137	1,275	1,272	420	354	(2)	68	(3)	650
October	600	564	150	129	1,275	1,270	420	332	(2)	68	(3)	650
November	600	494	150	111	1,275	1,246	420	330	(2)	67	(3)	600
December	600	500	150	121	1,275	1,243	420	335	(2)	67	(3)	590
Average	600	553	150	130	1,239	1,222	532	363	(2)	70	(3)	633

[1]Average prices calculated at the low end of the range and rounded to the nearest dollar.
[2]Producer price suspended on June 7, 1984.
[3]Producer price suspended on Jan. 13, 1984.

Source: Metals Week.

Table 6.—NYMEX trading volume for future contracts, yearend

(Number of contracts)

	1984	1985	1986	1987
Platinum[1]	571,127	693,256	1,624,635	1,361,546
Palladium[2]	159,019	133,223	145,562	160,284

[1]50 troy ounces per contract.
[2]100 troy ounces per contract.

The European Options Exchange in Amsterdam, in conjunction with stock exchanges in Montreal, Sydney, and Vancouver, opened the world's first platinum options contract. An options contract allows one to buy metal at a specified price for a specified period. Before it expires, an option can either be sold to another investor or exercised. If exercised, the investor must invest additional funds to purchase metal, according to the terms of the option.

In the United Kingdom, Samuel Montagu Ltd., Aryton Metals Ltd., Sharps Pixley Ltd., Mase Westpac Ltd., Johnson Matthey, and Engelhard Corp., joined to create the London Platinum and Palladium Market, a wholesale professional market. Member firms are exempt from paying value-added taxes on wholesale platinum and palladium transactions. Creation of the London market is expected to increase trading significantly in the next few years. Membership is open to other platinum-palladium traders besides the original six founding members.

Table 7.—U.S. exports of platinum-group metals, by year and country

Year and country	Ores and concentrates (troy ounces)	Waste, scrap, and sweepings (troy ounces)	Metal not rolled (troy ounces)			Metal rolled (troy ounces)		Total	
			Platinum	Palladium	Other platinum group	Platinum	Other platinum group	Troy ounces	Value (thousands)
1983	31,827	751,140	138,928	155,607	71,289	45,671	34,292	1,228,754	$309,917
1984	40,920	522,425	177,401	182,692	167,635	43,484	27,475	1,162,032	274,775
1985	3,967	358,417	182,487	215,626	87,727	4,526	35,901	888,651	187,161
1986	29,375	339,373	93,112	175,605	86,474	11,043	15,693	750,675	201,807
1987:									
Australia	--	--	--	2,893	--	--	--	2,893	165
Belgium-Luxembourg	--	17,346	--	2,386	5,664	--	--	25,396	10,046
Brazil	--	593	--	474	1,971	--	44	3,082	1,229
Canada	2,092	15,230	25,158	19,144	26,857	2,028	11,028	101,537	38,369
China	724	--	6,813	2,276	7,772	--	--	17,585	5,392
France	--	3,992	--	424	986	205	904	6,511	1,397
Germany, Federal Republic of	--	4,592	41	8,676	10,391	474	2,027	26,201	6,884
Israel	--	--	15	55	1,513	--	--	1,583	387
Italy	--	46,482	374	--	2,259	238	200	49,553	12,137
Japan	170	16,087	42,747	52,716	20,907	4,147	231	137,005	47,755
Korea, Republic of	1,244	--	12	861	109	110	3	2,339	296
Mexico	--	115	166	121	1,863	198	344	2,807	1,379
Netherlands	--	--	23	22,096	497	17	1,084	23,717	3,851
Norway	--	--	--	684	661	--	--	1,345	497
Singapore	--	--	350	3,576	513	--	--	4,439	1,170
South Africa, Republic of	--	--	--	--	3,422	--	--	3,422	1,223
Sweden	--	13,544	--	141	5,245	--	--	18,930	4,383
Switzerland	1,000	9,574	98	6,238	13,616	--	--	30,526	9,388
Taiwan	--	--	183	5,021	82	--	--	5,286	1,155
United Kingdom	--	143,642	6,209	55,295	31,333	370	1,293	238,142	75,803
Other	300	--	160	920	4,448	72	98	5,998	2,063
Total	5,530	271,197	82,349	183,997	140,109	7,859	17,256	708,297	224,969

Source: Bureau of the Census.

Table 8.—U.S. imports for consumption of platinum-group metals, by year and country

Year and country	Unwrought (troy ounces)										
	Platinum grains and nuggets	Platinum sponge	Palladium	Iridium	Osmium	Osmiridium	Rhodium	Ruthenium	Unspecified combinations	Platinum-group metals from precious metal ores	Sweepings, waste, and scrap
1983	8,513	1,005,208	1,223,951	23,266	1,747	848	119,958	163,623	18,143	2,137	417,431
1984	19,786	1,527,841	1,795,939	18,225	1,630	150	155,671	198,257	8,822	--	526,738
1985	20,827	1,464,645	1,396,810	20,972	5,153	--	201,028	162,887	10,330	218	530,724
1986	10,465	1,713,971	1,387,131	30,368	5,776	4,500	179,068	176,580	19,864	1,870	737,813
1987:											
Argentina	87	--	--	--	--	--	--	--	--	--	3,468
Australia	203	195	5,786	--	--	--	--	--	34	--	109,225
Belgium-Luxembourg	12	30,894	120,947	--	--	--	1,254	--	--	--	2,027
Botswana	--	--	2,000	--	--	--	--	3,000	--	--	--
Canada	396	4,075	48,099	--	--	--	76	2,000	50	1,165	130,111
China	81	1,043	977	--	--	--	255	--	280	--	310
Colombia	28	--	--	--	--	--	--	--	--	--	--
Denmark	--	--	2,344	--	--	--	--	--	--	--	--
El Salvador	--	--	--	--	--	--	--	--	--	--	2,129
Finland	--	--	2,253	--	--	--	--	--	664	--	88
France	--	2,160	14	106	--	--	--	--	300	--	--
Germany, Federal Republic of	--	9,173	44,114	2,309	449	--	273	1,140	--	--	12,404
Hong Kong	--	611	24,436	224	--	--	690	--	--	--	182,755
Italy	--	22,544	20,448	--	--	--	462	--	--	--	--
Japan	--	696	9,635	--	--	--	--	138	--	--	69
Mexico	--	--	10	--	--	--	--	--	--	139	57,440
Netherlands	--	1,883	126,985	--	--	5,800	25,487	--	2,101	--	--
Norway	--	500	--	--	--	--	--	--	--	--	22,789
South Africa, Republic of	--	882,433	696,182	8,339	1,530	--	108,856	55,611	1,475	--	--
Sweden	--	--	--	--	--	--	--	--	--	--	15,703
Taiwan	--	--	15,103	--	--	--	--	--	--	--	20,436
U.S.S.R.	--	13,957	224,427	317	--	--	42,529	822	--	--	--
United Kingdom	11	145,201	185,401	519	69	--	30,769	21,688	432	--	62,342
Venezuela	3	--	--	--	--	--	--	--	2,647	--	77
Other	--	8,653	--	--	--	--	815	--	--	485	3,543
Total	821	1,124,018	1,529,161	11,814	2,048	5,800	211,466	84,399	7,983	1,789	624.916

Table 8.—U.S. imports for consumption of platinum-group metals, by year and country—Continued

Year and country	Semimanufactured (troy ounces)					Platinum-group metals in materials not elsewhere specified (troy ounces)	Total	
	Platinum	Palladium	Iridium	Rhodium	Unspecified combinations		Troy ounces	Value (thousands)
1983	109,376	108,247	213	11,245	--	4,116	3,218,022	$752,756
1984	60,140	158,012	164	2,389	10	332	4,474,106	1,118,088
1985	78,206	84,492	3,700	145	1,480	7,977	3,989,594	1,025,692
1986	94,655	114,596	4	1	2	513	4,477,177	1,346,715
1987:								
Argentina	--	--	--	--	--	--	3,555	2,001
Australia	--	--	--	--	--	--	115,443	2,734
Belgium-Luxembourg	--	--	--	--	--	--	155,134	35,330
Botswana	--	--	--	--	--	--	5,000	498
Canada	1,857	11	--	--	--	49	187,889	35,568
China	--	--	--	--	--	--	2,946	1,715
Colombia	1,960	--	--	--	--	208	2,196	1,083
Denmark	--	--	--	--	--	--	2,344	399
El Salvador	--	--	--	--	--	--	2,129	320
Finland	--	--	--	--	--	--	6,880	1,536
France	--	--	--	--	3,875	--	2,580	1,613
Germany, Federal Republic of	--	1,992	--	--	--	--	71,854	17,770
Hong Kong	289	659	--	--	--	--	209,664	13,357
Italy	--	--	--	--	--	--	43,454	14,976
Japan	490	1	--	--	--	--	11,029	2,368
Mexico	--	--	--	--	--	--	57,589	1,414
Netherlands	--	52	--	--	--	--	162,308	49,756
Norway	--	--	--	--	--	--	23,289	445
South Africa, Republic of	--	5,000	--	--	--	--	1,759,426	727,085
Sweden	--	--	--	--	--	--	15,703	10,181
Taiwan	--	2,244	--	--	--	--	37,783	4,743
U.S.S.R.	7,978	90,620	--	160	--	--	380,810	101,456
United Kingdom	32,583	50,680	65	669	--	--	530,429	205,064
Venezuela	--	--	--	--	--	--	2,727	905
Other	647	240	--	--	3	--	14,386	7,763
Total	45,804	151,499	65	829	3,878	257	3,806,547	1,240,080

Source: Bureau of the Census.

Table 9.—Estimated U.S. imports of platinum, palladium, and rhodium, by country[1]

(Thousand troy ounces)

Country	Platinum		Palladium		Rhodium	
	1986	1987	1986	1987	1986	1987
South Africa, Republic of	1,178	883	531	702	98	109
U.S.S.R	45	22	247	315	25	43
United Kingdom	366	209	337	267	38	31
Other	483	376	857	716	33	29
Total[2]	2,073	1,490	1,972	2,000	195	212

[1]This table is based on the figures shown in table 8. Estimates are based on the explicit categories of platinum, palladium, and rhodium plus estimates of the metal content in the following categories: unspecified combinations, ores, and scrap, and materials not elsewhere specified.

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

WORLD REVIEW

Three companies in the Republic of South Africa produced PGM from platinum ores. The U.S.S.R. and two companies in Canada produced PGM from nickel-copper ores. The South African companies were Rustenburg Platinum Mines Ltd., Impala Platinum Holdings (Pty.) Ltd., and Western Platinum Ltd.; the Canadian companies were Inco Ltd. and Falconbridge Nickel Mines Ltd. World production of platinum was 3.8 million ounces and world production of palladium was 4.0 million ounces, of which the U.S.S.R. produced an estimated 980,000 ounces of platinum and 2.6 million ounces of palladium.

World platinum supply exceeded industrial demand plus investment demand by about 280,000 ounces in market economy countries (table 10). Palladium and rhodium supply and demand were fairly balanced. According to Johnson Matthey, investment demand in 1987 was only half of its 1986 level, possibly because of uncertain world economic and political conditions in 1986.

Nineteen eighty-seven marked a year of intense exploration for PGM. The Republic of South Africa, Canada, Australia, and New Zealand reported the most activity.

Australia.—Australia planned to produce legal tender platinum bullion coins, in 1-ounce, 1/2-ounce, 1/4-ounce, and 1/10-ounce weights.

Table 10.—Supply and demand for platinum, palladium, and rhodium in 1987

(Thousand troy ounces)

	Platinum	Palladium	Rhodium
SUPPLY			
Mine production (market economy countries):			
South Africa, Republic of[e]	2,600	1,100	130
Canada	186	195	17
Other	39	68	--
Total	2,825	1,363	147
Secondary from old scrap:			
Japan	45	200	7
United States	37	117	4
Other	10	150	2
Total	92	467	13
Soviet sales to market economy countries	459	1,609	54
Total	3,376	3,439	214

See footnote at end of table.

Table 10.—Supply and demand for platinum, palladium, and rhodium in 1987 —Continued

(Thousand troy ounces)

	Platinum	Palladium	Rhodium
DEMAND			
Industrial:			
Japan	1,352	1,644	100
United States	825	995	87
Western Europe	500	560	20
Other	200	200	5
Total	[1]2,877	3,399	212

[e]Estimated.
[1]Excludes approximately 220,000 ounces of investment demand.

Sources: Johnson Matthey PLC, CPM Group Ltd., and Bureau of Mines estimates.

Belgium-Luxembourg.—Johnson Matthey announced plans to build a new automobile catalyst manufacturing plant in Evere to complement the company's existing facility in Royston, United Kingdom. The plant will have a capacity of 4.5 million exhaust catalysts per year, making it one of the largest plants in Europe. The new plant is expected to produce catalysts by the end of 1988. It will help meet a European Economic Community directive requiring all new car models with engines larger than 2 liters to be fitted with converters after October 1988.

Canada.—Madeleine Mines Ltd. of Toronto said that it would develop its Lac des Iles platinum-palladium deposit. The company plans to build a smelter at Thunder Bay and a refinery in Calgary to process the output of its 3,000-short-ton-per-day open pit mine. The mine could be producing 15,000 ounces of platinum and 120,000 ounces of palladium by 1988.[5]

International Platinum Corp. owns interests in over 20 PGM properties. It explored for PGM in Canada and the United States. Among its most promising Canadian properties were Big Trout Lake, Ontario; Lac des Iles, Ontario; Delta Sill, Quebec; and Red Lake, Ontario. Degussa AG of the Federal Republic of Germany, a major world refiner and fabricator of precious metals, entered into a joint venture agreement with International Platinum. Degussa was to acquire a 50% interest in properties owned by International Platinum, but International Platinum would remain as operator of the joint venture. Degussa was to provide some of the $4.5 million budgeted for exploration of the properties over the next 3 years.[6]

France.—The French Government issued its first commemorative platinum and palladium coins in celebration of the bicentennial of the French Revolution. The platinum coins weigh 20 grams and the palladium coins weigh 17 grams. Manfra, Tordella & Brookes Inc. of New York was the exclusive distributor in North America.

Korea, Republic of.—In a joint venture, Hankuk Engelhard Corp. and Hyundai Motor Co. planned to build an automotive exhaust catalyst manufacturing plant in Ahnsahn city. Hankuk Engelhard is owned by Engelhard Corp. and Hi-Seong Metal Industries Co. Ltd. Startup of the plant was expected in the fourth quarter of 1987.

South Africa, Republic of.—All three of the PGM producers in the Republic of South Africa—Rustenburg Platinum Mines Ltd., Impala Platinum Holdings (Pty.) Ltd., and Western Platinum—announced major expansion plans in 1987.

Rustenburg decided to expand production of PGM at its Atok Mine and possibly develop a mine at its deposit at Maandagshoek, both in the black homeland of Lebowa. Together, the two deposits were to be known as Lebowa Platinum Mines Ltd. and would be listed on the Johannesburg Stock Exchange. Lebowa could produce as much as 300,000 ounces of PGM per year by 1991.[7]

Impala planned to build a new mine near Marikana that would produce 100,000 ounces per year of platinum by 1991. Eventually it would increase to 300,000 ounces per year. The new mine, called Karee, was expected to replace declining production from Impala's existing mines.[8]

Western Platinum planned to double its output of PGM to 500,000 ounces per year by 1992 or 1993. The additional production was expected to be mined from the UG-2 reef.[9]

Between 1989 and 1993, five new PGM companies presumably will begin mining the Merensky and UG-2 reefs of the Bushveld Complex in the Republic of South Africa. It was projected that South Africa production of platinum could grow from an estimated 2.5 million ounces in 1987 to 3.5 million ounces by the early 1990's. Some of the new production was no doubt spurred by the need to supply the growing demand for PGM in the autocatalyst market.

Northam Platinum Ltd., a subsidiary of Gold Fields of South Africa Ltd., continued to develop its deep mine near Rustenburg's Amandelbult section. Mining at depths of over 6,600 feet, the project was expected to require elaborate refrigeration facilities. Initial production of 250,000 ounces per year of PGM was slated to begin by 1991. By 1994, Northam could produce 350,000 ounces per year of PGM. Up to 200,000 ounces of this total would be platinum.

Golden Dumps Ltd. announced plans to develop a new PGM mine to exploit the UG-2 reef, to be called Lefkochrysos, near the town of Brits. Production was expected to be 170,000 ounces per year of PGM by 1989, mined from deposits only 65 feet below the surface. Other deposits, over 3,000 feet deep, could eventually be producing about 650,000 ounces per year of PGM, of which 350,000 ounces per year would be platinum.[10]

Rand Mines Ltd. and Vansa Vanadium S.A. Ltd. agreed to develop a new PGM mine, near Lydenburg. It would initially produce about 435,000 ounces per year of PGM (140,000 ounces per year of platinum) beginning about 1992. The new mine, called Rhodium Reefs, was to mine the UG-2 reef exclusively.[11]

In Lebowa, another company, Messina Ltd., announced that it would begin trial mining and metallurgical testing of PGM from a mine being developed at Zebediela, east of Rustenburg's Atok Mine. When developed, the mine is expected to produce 150,000 ounces of platinum by 1993.[12] Also in Lebowa, Severin Mining and Development Inc. planned to open a new, very deep platinum mine by 1990.[13]

Zimbabwe.—Two Australian companies, Delta Gold and Mumbil Mines, announced the formation of a joint venture to consider development of a portion of the Great Dyke in Zimbabwe in an area called the Hartley project, which was previously explored by Union Carbide Corp. between 1968 and 1972. Delta and Mumbil hoped to develop the Hartley project into an operation with an annual output of 100,000 ounces of platinum, 80,000 ounces of palladium, and 30,000 ounces of gold.[14]

Table 11.—Platinum-group metals: World production, by country[1]

(Troy ounces)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Australia, metal content, from domestic nickel ore:[3]					
Palladium	[e]12,000	16,815	15,304	13,760	15,800
Platinum	[e]1,900	2,122	3,054	3,697	4,200
Canada: Platinum-group metals from nickel ore	223,925	348,216	337,088	391,917	[4]433,681
Colombia: Placer platinum	10,303	10,106	11,650	14,368	15,000
Ethiopia: Placer platinum[e]	125	125	[r]150	[r]150	150
Finland:					
Palladium	2,283	1,093	1,125	3,086	3,000
Platinum	2,186	1,061	1,125	3,858	4,000
Japan, metal recovered from nickel-copper ores:[5]					
Palladium	37,122	33,802	43,703	46,699	[4]45,558
Platinum	21,460	19,523	22,216	21,312	[4]24,209
South Africa, Republic of: Platinum-group metals from platinum ore[e 6]	2,600,000	3,500,000	3,700,000	[r]3,960,000	4,220,000
U.S.S.R.: Placer platinum and platinum-group metals recovered from nickel-copper ores[e]	3,600,000	3,700,000	3,800,000	3,850,000	3,900,000

See footnotes at end of table.

Table 11.—Platinum-group metals: World production, by country[1] —Continued

(Troy ounces)

Country[2]	1983	1984	1985	1986[p]	1987[e]
United States: Placer platinum and platinum-group metals from gold-copper ores	6,257	14,635	W	W	W
Yugoslavia:[e]					
Palladium	[4]2,926	3,100	3,300	[r]3,100	3,100
Platinum	[4]193	200	250	[r]250	250
Zimbabwe:					
Palladium	2,395	1,222	965	1,125	1,150
Platinum	1,695	772	611	836	850
Total	6,524,770	[r]7,652,792	7,940,541	8,314,158	8,670,948

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

[1]Table includes data available through May 6, 1988. Platinum-group metal production by the Federal Republic of Germany, Norway, and the United Kingdom is not included in this table because the production is derived wholly from imported metallurgical products and to include it would result in double counting.

[2]In addition to the countries listed, China, Indonesia, Papua New Guinea, and the Philippines are believed to produce platinum-group metals, and several other countries may also do so, but output is not reported quantitatively, and there is no reliable basis for the formulation of estimates of output levels. However, a part of this output not specifically reported by country is presumably included in this table credited to Japan. (See footnote 5.)

[3]Partial figure; excludes platinum-group metals recovered in other countries from nickel ore of Australian origin; however, a part of this output may be credited to Japan. (See footnote 5.)

[4]Reported figure.

[5]Japanese figures do not refer to Japanese mine production, but rather represent Japanese smelter-refinery recovery from ores originating in a number of countries; this output cannot be credited to the country of origin because of a lack of data. Countries producing and exporting such ores to Japan include (but are not necessarily limited to) Australia, Canada, Indonesia, Papua New Guinea, and the Philippines. Output from ores of Australian, Indonesian, Papua New Guinean, and Philippine origin are not duplicative, but output from Canadian material might duplicate a part of reported Canadian production.

[6]Includes osmiridium produced in gold mines.

TECHNOLOGY

The Davison Div. of W. R. Grace & Co. developed a new metal substrate catalytic converter for controlling pollution emissions from car exhausts and power stations. The substrate is made of thin metal foil, formed into corrugations, stacked and retained by rings on both edges. The new metal substrates reportedly have improved thermal durability over conventional ceramic substrates.[15]

Mitsui & Co. of Cleveland, OH, marketed a system for recovering precious metals from scrapped automobile catalytic converters. System capacities ranged from 1 short ton per day to more than 20 tons per day of crushed catalyst material. The metals are dissolved in hydrochloric acid and deposited electrolytically on carbon particles, filtered, and redissolved in hydrochloric acid. The pure metals can then be selectively precipitated.[16]

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[1]Physical scientist, Branch of Nonferrous Metals.

[2]American Metal Market, Platinum-Group Metals Supplement. Production Flows Faster Than Stillwater Projections. V. 95, No. 240, Dec. 11, 1987, p. 8A.

[3]American Metal Market. Platinum Found in Alaska Gold. V. 95, No. 187, Sept. 25, 1987, pp. 1, 8.

[4]Robson, G. G. Platinum, 1987 Interim Review, Johnson Matthey PLC. P. 11.

[5]London Mining Journal. Lac des Iles Decision. V. 309, No. 7930, Aug. 14, 1987, p. 125.

[6]Metal Bulletin Monthly. Platinum Price Drives PGM Bandwagon. No. 204, Dec. 1987, pp. 14-16.

[7]Metals Week. Rustenburg To Double Atok's Output. V. 58, No. 42, Oct. 19, 1987, p. 8.

[8]Metals Week. Impala To Establish New Platinum Mine. V. 58, No. 43, Oct. 26, 1987, p. 7.

[9]Metal Bulletin. Westplat To Double Output. No. 7168, Mar. 13, 1987, p. 13.

[10]London Mining Journal. A Proliferation of Platinum Projects. V. 309, No. 7932, Aug. 28, 1987, pp. 166-167.

[11]Salak, J. American Metal Market. Huge S. African Platinum Mine May Open in '92. V. 95, No. 155, Aug. 11, 1987, pp. 1, 6.

[12]Metal Bulletin. Messina Platinum Mine Gets Go-Ahead. No. 7208, Aug. 6, 1987, p. 9.

[13]Metals Week. A New Platinum Mine Is Being Planned. V. 58, No. 41, Oct. 12, 1987, p. 8.

[14]Mining Journal. Great Dyke Attracts Australians. V. 309, No. 7939, Oct. 16, 1987, p. 305.

[15]Materials Edge. Grace Moves Into U.S. Metal Catalytic Converters. No. 1, Sept.-Oct. 1987, p. 9.

[16]International Precious Metals Institute. Precious Metals Recovery From Catalytic Converters. V. 11, No. 9, Sept. 1987, p. 4.

Potash

By James P. Searls[1]

U.S. potash production in terms of potassium oxide (K_2O) equivalent rose 5% relative to that of 1986. Apparent consumption rose 5% on the same basis. Spring production was 47% of the annual total. Sales by U.S. producers rose 29% for the year, and average prices rose 5% on the basis of K_2O equivalent. Yearend stocks decreased 59%. The United States continued to be a net importer. Net import reliance as a percentage of apparent consumption was 75%. Canada provided an amount equal to 73% of the domestic apparent consumption. U.S. exports decreased, with exports to India falling to zero, exports to Brazil and Mexico decreasing, and exports to Japan increasing slightly.

Domestic Data Coverage.—Domestic production data for potash are developed by the Bureau of Mines from a voluntary semiannual survey of U.S. operations. Of the nine operations to which a survey request was sent, all responded, representing 100% of the total production shown in table 1.

Table 1.—Salient potash[1] statistics

(Thousand metric tons and thousand dollars unless otherwise specified)

	1983	1984	1985	1986	1987
United States:					
Production	2,770	3,039	2,569	2,381	2,464
K_2O equivalent	1,429	1,564	1,296	1,202	1,262
Sales by producers	2,950	3,184	2,505	2,291	2,904
K_2O equivalent	1,513	1,639	1,266	1,147	1,485
Value[2]	$220,800	$241,800	$178,400	r$144,900	e$195,700
Average value per ton of product dollars	$74.85	$75.95	$71.22	r$63.24	$67.38
Average value per ton of K_2O equivalent do.	$145.97	$147.55	$140.89	r$126.28	$131.73
Exports[3]	564	836	973	1,025	926
K_2O equivalent	300	446	513	547	470
Value[4]	$55,760	$85,660	NA	NA	NA
Imports for consumption[3] [5]	7,322	7,948	7,571	6,934	6,706
K_2O equivalent	4,440	4,829	4,593	4,212	4,073
Customs value	$600,600	$658,100	$499,100	$385,100	$432,700
Consumption, apparent[6]	9,708	10,296	9,103	8,200	8,683
K_2O equivalent	5,653	6,022	5,346	4,843	5,088
Yearend producers' stocks, K_2O equivalent	[7]391	[8]312	[9]336	[10]378	155
World: Production, marketable K_2O equivalent	27,418	29,334	29,151	p28,758	e29,812

eEstimated. pPreliminary. rRevised. NA Not available.
[1]Includes muriate and sulfate of potash, potassium magnesium sulfate, glaserite, 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]Includes nitrate of potash.
[6]Calculated from production plus imports minus exports plus/minus industry and Government stock changes.
[7]Inventory adjustment of minus 46,000 tons.
[8]Inventory adjustment of minus 4,000 tons.
[9]Inventory adjustment of minus 6,000 tons.
[10]Inventory adjustment of minus 12,900 tons.

DOMESTIC PRODUCTION

Domestic K_2O production rose 5% in 1987 compared with that of 1986. Of the total production for the year, 79% was standard, coarse, and granular muriate of potash, also known as potassium chloride, and 8% was sulfate of potash, also known as potassium sulfate. The remaining production comprised manure salts, soluble and chemical grades of muriate of potash, and sulfate of potash-magnesia, also known as potassium magnesium sulfate. The terms "standard," "coarse," and "granular," refer to the particle sizes of the finished product. "Standard," "coarse," and "granular" are the "three muriates," a term that ignores manure salts and soluble and chemical grades of muriate of potash. "Sulfates" is a term for the combination of sulfate of potash and sulfate of potash-magnesia.

The New Mexico producers accounted for 90% of the total marketable potash salts production. Production of crude salts in New Mexico was 11.4 million tons[2] with an average K_2O content of 14.6%. The producers were AMAX Potash Corp. of AMAX Inc.; International Minerals & Chemical Corp. (IMC); Lundberg Industries Ltd.; New Mexico Potash Corp., which is owned by Cedar Chemical Inc., a subsidiary of Fermenta AB of Sweden; and Western Ag-Minerals Co., which is controlled by Rayrock Resources Ltd. of Canada. Lundberg Industries filed for protection from its creditors under chapter 11 of the Federal Bankruptcy Code in June. A trustee for the court took control of mine and plant operations in September. All of the producers, except Western Ag-Minerals, mined sylvinite ore and beneficiated the ore into muriate of potash. Western Ag-Minerals and IMC mined langbeinite ore and beneficiated the ore to sulfate of potash-magnesia. IMC mined both types of ore and reacted fractions of each potash product to produce sulfate of potash.

Sulfate of potash was also manufactured at two plants in Texas and one in Utah. The plant in Dumas, TX, was operated by Lundberg Industries until November. Plant ownership then reverted to Ideal Basic Industries Inc., its former owner, and was operated as Potash Resources Inc. The plant was then leased to AMAX Potash and operated by AMAX Potash through yearend. Its production is reported in Bureau of Mines statistics. The Permian Chemical Corp. plant in Odessa, TX, filed for protection from its creditors under chapter 11 of the Federal Bankruptcy Code and shut down on August 31. The Permian plant and the Climax Chemical Co. plant in Utah together produced about 22,000 tons. These companies are not included in Bureau of Mines statistics because they are not mining firms.

Greensand, also known as glauconite, a natural silicate of potassium, aluminum, iron, and magnesium, was produced by Inversand Co., a subsidiary of Hungerford and Terry Inc., near Clayton, NJ, and by Contractors Sand & Gravel Co. near Middletown, DE. Production and sales information is withheld to avoid disclosing company proprietary data. Processed greensand continued to be sold as a filter media for the removal of manganese and iron from drinking water supply systems. Classified raw greensand was resold by Zook and Ranck Inc. as a soil conditioner and as a source of slowly released potash, with a K_2O content between 5% and 10%, to the organic farmers in North America.

In Utah, Texasgulf Chemicals Co. of Texasgulf Inc., which is owned by Elf Aquitaine Inc. of the Paris-based Société Nationale Elf Aquitaine, produced muriate of potash from underground bedded deposits by solution mining and solar evaporation. The salts from the solar ponds were beneficiated by flotation to separate the sylvite from the halite. This company changed its name to Moab Salt Inc. at yearend. Kaiser Chemicals of Kaiser Aluminum & Chemical Corp. produced muriate of potash from near-surface brines at the west end of the Bonneville Salt Flats by solar evaporation and flotation. Magnesium chloride was a byproduct. Great Salt Lake Minerals & Chemicals Corp., a subsidiary of Gulf Resources & Chemical Corp., remained closed throughout the year while repairing flood damage.

In California, Kerr-McGee Chemical Corp. continued to produce both muriate and sulfate of potash along with other products from underground brines at Searles Lake.

Table 2.—Production, sales, and inventory of U.S. produced potash, by type and grade

(Thousand metric tons and thousand dollars)

Type and grade	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	
	1986	1987	1986	1987	1986	1987	1986	1987	1986	1987	1986	1987	1986	1987
January-June:														
Muriate of potash, 60% K_2O minimum:														
Standard	342	240	209	147	373	344	228	210	19,500	[e]17,700	199	118	121	72
Coarse	75	107	46	66	101	122	62	75	[r]5,800	[e]6,400	21	19	13	12
Granular	263	403	159	245	274	522	166	316	14,100	[e]24,100	83	120	50	73
Chemical	1	6	(2)	4	8	11	5	7	W	W	3	1	2	1
Potassium sulfate	89	95	45	48	90	107	46	55	15,200	[e]16,200	65	36	33	18
Other potassium salts[3]	334	326	79	80	368	392	89	96	W	W	197	153	47	35
Total[4]	1,104	1,177	539	590	1,214	1,498	595	759	83,000	[e]94,000	568	446	267	210
July-December:														
Muriate of potash, 60% K_2O minimum:														
Standard	392	298	239	182	345	338	211	206	16,100	21,300	246	78	150	47
Coarse	86	113	53	69	74	124	45	76	[r]6,800	8,700	33	7	20	5
Granular	417	471	253	285	284	493	172	299	[r]10,300	31,700	215	97	130	59
Chemical	16	9	10	6	12	8	8	5	W	W	7	2	4	1
Potassium sulfate	84	101	43	52	101	106	52	54	15,300	16,800	48	31	25	16
Other potassium salts[3]	282	295	65	77	261	336	64	86	W	W	219	112	49	25
Total[4]	1,277	1,287	663	671	1,077	1,405	552	726	[r]61,900	101,700	768	328	378	155
Grand total[4]	2,381	2,464	1,202	1,262	2,291	2,904	1,147	1,485	[r]144,900	[e]195,700	XX	XX	XX	XX

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data; included in "Total." XX Not applicable.
[1]F.o.b. mine.
[2]Less than 1/2 unit.
[3]Includes soluble muriate, glaserite, manure salts, and potassium magnesium sulfate.
[4]Data may not add to totals shown because of independent rounding.

Table 3.—Production and sales of potash in New Mexico

(Thousand metric 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]
1986:							
January-June	4,397	636	971	463	1,085	522	73,500
July-December	5,382	777	1,147	588	927	465	59,400
Total[3]	9,779	1,413	2,118	1,051	2,013	987	132,900
1987:							
January-June	5,615	820	1,088	539	1,345	669	[e]83,500
July-December	5,786	841	1,161	598	1,283	654	90,700
Total[3]	11,400	1,661	2,249	1,136	2,627	1,323	174,200

[e]Estimated.
[1]Sylvinite and langbeinite.
[2]F.o.b. mine.
[3]Data may not add to totals shown because of independent rounding.

Table 4.—Salient U.S. sulfate of potash[1] statistics

(Thousand metric tons of K_2O equivalent and thousand dollars)

	1984	1985	1986	1987
Production	109	106	88	100
Sales by producers	126	103	97	109
Value[2]	$47,197	$36,465	$19,858	$33,059
Exports[3]	34	46	[4]79	[4]118
Value[5]	$13,940	NA	NA	NA
Imports[3]	29	25	27	26
Value[6]	$12,600	$10,400	$9,900	$10,500
Consumption, apparent[7]	121	82	[4]45	[4]16
Yearend producers' stocks	31	34	25	16

NA Not available.
[1]Excludes potassium magnesium sulfate.
[2]F.o.b. mine.
[3]Bureau of the Census.
[4]Preliminary export data pending verification by the Bureau of the Census.
[5]F.a.s. U.S. port.
[6]C.i.f. to U.S. port.
[7]Calculated from production plus imports minus exports plus/minus industry stock changes.

CONSUMPTION AND USES

Apparent domestic consumption of all forms of potash rose 5% compared with that of 1986. Prices rose near yearend as anti-dumping duties were assessed on potash imported from Canada. Demand for grains and, therefore, demand for potash remained strong as farmers expected the marginal cost increases for potash to be passed on to the consumer. This was made possible by the drop in the relative value of the dollar in the world marketplace, thereby reducing the cost of U.S.-produced grains relative to that of other nations' grains.

Table 5.—Sales of North American potash, by State of destination

(Metric tons of K_2O equivalent)

State	Agricultural potash 1986	Agricultural potash 1987	Nonagricultural potash 1986	Nonagricultural potash 1987
Alabama	52,968	62,341	87,005	95,097
Alaska	825	1,625	7,592	57
Arizona	943	2,382	79	1,104
Arkansas	45,055	64,576	188	588
California	51,786	68,967	8,392	10,863
Colorado	7,035	7,181	3,454	3,183
Connecticut	4,238	3,752	91	148
Delaware	23,125	15,673	37,215	34,205
Florida	134,077	142,998	2,131	650
Georgia	103,479	109,765	580	1,369
Hawaii	12,219	14,670	44	--
Idaho	24,525	22,750	22	566
Illinois	621,147	680,434	1,457	2,373
Indiana	335,011	370,977	220	344
Iowa	408,702	492,891	641	432
Kansas	28,613	44,020	1,177	2,174
Kentucky	116,581	93,328	166	248
Louisiana	64,416	120,990	946	1,445
Maine	7,284	8,725	630	1,051
Maryland	33,456	27,639	112	192
Massachusetts	5,270	3,762	461	1,029
Michigan	185,381	210,073	1,060	3,582
Minnesota	316,132	360,272	352	1,371
Mississippi	23,342	35,421	35,895	39,325
Missouri	222,751	287,563	2,967	4,341
Montana	10,869	11,316	14	432
Nebraska	30,148	30,378	132	648
Nevada	363	13	209	243
New Hampshire	461	1,024	25	58
New Jersey	7,819	5,946	864	2,504
New Mexico	7,786	9,642	16,273	17,218
New York	61,211	58,901	6,739	14,720
North Carolina	88,380	70,853	201	431
North Dakota	23,599	23,444	61	279
Ohio	398,569	420,919	64,833	57,382
Oklahoma	18,508	23,106	6,544	5,541
Oregon	25,596	29,844	1,350	1,191
Pennsylvania	53,717	57,387	2,278	2,726
Rhode Island	1,126	1,588	29	13
South Carolina	99,854	53,942	106	13
South Dakota	12,719	13,590	--	12
Tennessee	108,475	128,035	585	269
Texas	119,236	146,036	19,634	26,008
Utah	5,615	7,755	10,639	14,918
Vermont	3,070	2,850	295	--
Virginia	120,248	76,226	56	151
Washington	36,408	38,211	2,169	632
West Virginia	2,855	2,887	480	995
Wisconsin	277,501	284,227	611	8,588
Wyoming	1,497	1,879	260	410
Total	4,343,991	4,752,774	327,264	361,119

Source: Potash & Phosphate Institute.

Table 6.—Sales of North American muriate of potash to U.S. customers, by grade

(Thousand metric tons of K_2O equivalent)

Grade	1984	1985	1986	1987
Agricultural:				
Standard	446	346	319	328
Coarse	2,219	2,065	1,882	2,078
Granular	1,511	1,666	1,683	1,866
Soluble	471	392	336	360
Total	4,647	4,469	4,220	4,632
Nonagricultural:				
Soluble	120	138	98	88
Other	227	227	225	269
Total	347	365	323	357
Grand total	4,994	4,834	4,543	4,989

Source: Potash & Phosphate Institute.

According to the Potash & Phosphate Institute, the major consumers of agricultural potash from Canadian and U.S. potash producers, in decreasing order, were Illinois, Iowa, Ohio, Indiana, Minnesota, Missouri, and Wisconsin. These seven States consumed 61% of the total from Canadian and U.S. producers. Domestic producers provided 8% of Illinois' potash consumption, 5% of Iowa's consumption, 2% of Ohio's consumption, 3% of Indiana's consumption, 1% of Minnesota's consumption, 46% of Missouri's consumption, and 1% of Wisconsin's consumption. The major agricultural consumers of domestically produced potash, in decreasing order, were Texas, Missouri, California, Illinois, Kansas, and Florida. These six States accounted for 62% of the total. The major consumers of domestically produced sulfates of potash, in decreasing order, were Florida, Georgia, California, Texas, and North Carolina. These five States accounted for 58% of the total.

STOCKS

Yearend producers' stocks of potash declined 59% from that of 1986. Yearend stocks represented 12% of annual production, or 6.4 weeks of average production.

PRICES

Prices of potash were relatively low through midyear. With the application of dumping margins by the U.S. Department of Commerce on Canadian potash, prices rose after August 20 to more profitable levels for the domestic producers. The average annual price, f.o.b. mine, of U.S. potash sales of all types and grades rose 4% from that of 1986 to $131.73 per ton. The average price was $123.78 in the first half of the year and $140.04 in the second half. The average annual price for the three grades of muriate rose to $92.92 per ton. Standard-grade muriate of potash averaged $93.68 per ton, coarse-grade muriate averaged $99.80 per ton, and granular-grade averaged $90.72 per ton. The average annual price for sulfate of potash fell to $303.43 per ton.

Table 7.—Prices[1] of U.S. potash, by type and grade

(Dollars per metric ton of K_2O equivalent)

Type and grade	1985		1986		1987	
	January-June	July-December	January-June	July-December	January-June	July-December
Muriate, 60% K_2O minimum:						
Standard	101.99	97.37	85.17	76.46	84.28	103.28
Coarse	102.42	87.35	92.63	81.16	86.35	113.05
Granular	101.30	78.85	84.75	77.73	76.11	106.21
All muriate[2]	101.73	88.71	87.85	80.11	80.24	106.06
Sulfate, 50% K_2O minimum	367.24	339.98	332.24	295.58	331.06	295.65

[1]Average prices, f.o.b. mine, based on sales.
[2]Excluding soluble and chemical muriates.

FOREIGN TRADE

Total U.S. potash exports reported by the Bureau of the Census decreased 14%, by ton product. The major destinations of potash exports in Latin America, which received 60% of the total, were, in decreasing order, Brazil, Peru, Colombia, the Dominican Republic, Mexico, and Costa Rica. These countries represented 86% of the exports to Latin America. Exports to India fell to zero. Exports to Japan rose 8%, and exports to Canada rose 83%. Japan, Canada, Hong Kong, Ireland, and China, in decreasing order, represented 81% of exports to non-Latin American countries.

A 3% decrease in total U.S. imports for consumption of potash was represented primarily by reduced imports of muriate of potash from Canada. Canada supplied 92% of all muriate imports and 91%, by K_2O equivalent, of all potash imports. Israel was the second largest source of imports, with 4% of muriate of potash imports and 8%, by K_2O equivalent, of total potash imports. Imports from the U.S.S.R. increased by 510% from those of 1986.

Table 8.—U.S. exports of potash

	Approximate average K_2O content (percent)	Quantity (metric tons)		Value[1] (thousands)
		Product	K_2O equivalent	
1986:				
Potassium chloride, all grades	61	708,357	432,098	NA
Potassium sulfate	51	155,608	79,360	NA
Potassium magnesium sulfate	22	161,065	35,434	NA
Total	XX	1,025,030	546,892	NA
1987:				
Potassium chloride, all grades	61	511,590	312,022	NA
Potassium sulfate	51	230,899	117,849	NA
Potassium magnesium sulfate	22	183,931	40,468	NA
Total	XX	926,420	470,339	NA

NA Not available. XX Not applicable.
[1]The Bureau of the Census ceased publication of value data in 1985.

Source: Bureau of the Census.

Table 9.—U.S. exports of potash, by country

Country	Metric tons of product: Potassium chloride		Potassium sulfates, all grades[1]		Total[2]		Total value[3] (thousands)	
	1986	1987	1986	1987	1986	1987	1986	1987
Argentina	4,990	30	5,880	1,500	10,870	1,530		
Australia	6,000	2,700	12,000	7,400	18,090	10,100		
Bahamas	14	--	2,880	500	2,890	500		
Belgium-Luxembourg	80,290	--	52	--	80,340	--		
Belize	620	1,530	320	40	940	1,570		
Brazil	175,510	157,800	11,210	18,010	186,740	175,810		
Canada	730	23,990	43,920	57,810	44,650	81,800		
Chile	5,150	1,040	28,260	19,030	33,410	20,070		
China	54,080	--	9,470	31,930	63,550	31,930		
Colombia	22,060	14,870	19,020	40,850	41,080	55,720		
Costa Rica	4,400	20,070	17,010	16,010	21,410	36,080		
Denmark	--	--	10,250	20	10,250	20		
Dominican Republic	21,690	34,750	2,260	3,450	23,950	38,200		
Ecuador	13,430	6,890	1,040	3,320	14,470	10,210		
El Salvador	2,970	--	460	12,000	3,430	12,000		
France	--	210	--	1,230	--	1,440		
French West Indies	3,890	--	--	--	3,890	--		
Germany, Federal Republic of	--	5,020	--	--	--	5,020		
Greece	--	--	--	5,850	--	5,850		
Guatemala	--	--	3,170	370	3,170	370		
Guyana	--	2,310	--	--	--	2,310		
Haiti	980	--	74	50	1,050	50		
Honduras	1,540	4,250	2,090	270	3,630	4,520	NA	NA
Hong Kong	--	38,410	--	--	--	38,410		
India	84,400	--	--	--	84,400	--		
Ireland	10,010	37,700	--	--	10,010	37,700		
Italy	300	--	1,740	410	2,040	410		
Japan	70,470	58,770	90,950	115,020	161,420	173,790		
Korea, Republic of	--	70	400	180	400	250		
Leeward and Windward Islands	--	8,070	--	--	--	8,070		
Malaysia	--	--	10,910	13,220	10,910	13,220		
Mexico	50,340	11,150	14,950	25,040	65,290	36,190		
Netherlands	16,270	24,350	--	--	16,270	24,350		
New Zealand	25,160	--	360	90	25,520	90		
Pakistan	--	--	--	15,000	--	15,000		
Panama	4,250	3,620	2,230	660	6,480	4,280		
Peru	8,550	50,160	8,730	16,840	17,280	67,000		
Philippines	67	50	11,760	--	11,830	50		
Saudi Arabia	--	--	--	4,740	--	4,740		
Spain	--	3,180	--	3,010	--	6,190		
Sweden	800	400	--	--	800	400		
Switzerland	12,370	--	--	--	12,370	--		
Taiwan	26,230	--	40	--	26,270	--		
Thailand	--	--	3,510	--	3,510	--		
Other	700	200	1,790	980	2,490	1,180		
Total[2]	708,360	511,590	316,670	414,830	1,025,030	926,420	NA	NA

NA Not available.
[1]Includes potassium magnesium sulfate.
[2]Data may not add to totals shown because of independent rounding.
[3]The Bureau of the Census ceased publication of value data in 1985.

Source: Bureau of the Census.

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

Country	Metric tons of product										Total value (thousands)			
	Potassium chloride		Potassium sulfate		Potassium nitrate		Potassium sodium nitrate		Total[1]		Customs		C.i.f.	
	1986	1987	1986	1987	1986	1987	1986	1987	1986	1987	1986	1987	1986	1987
Belgium-Luxembourg	4,000	1,000	6,000	500	--	--	--	--	10,000	1,500	$1,400	$200	$1,600	$200
Canada	6,394,100	6,064,100	40	1,000	97	100	4,400	6,900	6,398,600	6,072,100	340,000	382,700	370,400	415,900
Chile	--	--	--	--	--	3,000	10,700	9,700	10,700	12,700	1,500	1,600	r1,600	1,800
Dominican Republic	--	7,400	--	--	--	--	--	--	--	7,400	--	400	--	400
France	--	--	--	(2)	--	--	--	--	--	--	--	2	--	2
German Democratic Republic	93,000	106,700	--	--	--	--	--	--	93,000	106,700	4,700	5,600	5,500	6,700
Germany, Federal Republic of	5,900	5,400	45,800	49,200	--	--	--	--	51,700	54,600	8,300	9,500	9,400	10,800
Israel	310,000	270,100	--	--	30,000	16,800	--	--	340,000	286,900	27,000	22,400	31,800	25,200
Italy	--	--	--	200	--	--	--	--	--	200	--	10	--	10
Japan	500	--	6	--	--	--	200	700	700	700	100	50	100	80
Netherlands	2,500	1,000	--	--	--	--	--	--	2,500	1,000	200	200	300	200
Spain	1,600	--	6	--	--	--	--	--	1,600	--	200	--	200	--
Switzerland	--	21	--	--	--	--	--	--	--	21	--	2	--	2
Taiwan	--	--	--	19	--	--	--	--	--	19	--	8	--	11
U.S.S.R	24,500	149,500	--	--	--	--	--	--	24,500	149,500	1,500	8,800	1,700	10,900
United Kingdom	400	12,300	2	--	--	--	--	600	400	12,900	300	1,200	300	1,500
Total[1]	6,836,500	6,617,500	51,900	50,900	30,100	19,900	15,300	17,900	6,933,800	6,706,200	385,100	432,700	422,900	473,700

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

Source: Bureau of the Census, as adjusted by the Bureau of Mines.

Table 11.—U.S. imports for consumption of potash

	Approximate average K_2O content (percent)	Quantity (metric tons)		Value (thousands)	
		Product	K_2O equivalent[e]	Customs	C.i.f.
1986:					
Potassium chloride	61	6,836,500	4,170,200	$365,400	$400,780
Potassium sulfate	51	51,900	26,500	8,900	9,900
Potassium nitrate	45	30,100	13,600	8,600	9,800
Potassium sodium nitrate mixtures	14	15,300	2,100	2,200	2,400
Total	XX	6,933,800	4,212,400	385,100	[1]422,900
1987:					
Potassium chloride	61	6,617,500	4,036,000	417,100	456,400
Potassium sulfate	51	50,900	25,900	9,500	10,500
Potassium nitrate	45	19,900	9,000	4,200	4,800
Potassium sodium nitrate mixtures	14	17,900	2,500	2,200	2,400
Total	XX	6,706,200	4,073,400	432,700	474,100

[e]Estimated. XX Not applicable.
[1]Data do not add to total shown because of independent rounding.

Source: Bureau of the Census, as adjusted by the Bureau of Mines.

WORLD REVIEW

World production increased slightly from that of 1986 as consumption of potash returned to 1984 levels. World prices were exemplified by the per ton price of standard muriate of potash, f.o.b. Vancouver, Canada, reported by British Sulphur Corp. Ltd. This price rose from approximately $98 per ton K_2O, or the high $50's per ton of product, in April, to approximately $125 per ton K_2O, or the middle $70's per ton of product, at yearend. The price rise reflected a diminishing of the 1986 oversupply of potash that occurred after the flooding of two mines and some market economy production cutbacks. The Western European potash market started to adjust to the commencement of imports from New Brunswick, Canada; Israel; and New Mexico, United States.[3] With the entrance of Spain into the European Economic Community in 1986, Spanish potash entered the French market.[4]

Argentina.—The Province of Catamarca, in developing the Salar de Hombre Muerto, was investigating the feasibility of making westward shipments to the Chilean Pacific Coast Port of Puerto Caldera, a proposed outlet for the expected production of muriate of potash, sulfate of potash, and lithium carbonate.[5]

Australia.—CRA Ltd. projected the size of its proposed sulfate of potash plant at Dampier, Western Australia, at 30,000 tons per year. It was studying alternative production processes.[6]

Brazil.—The new development at Fazendinha was forecast to cost about $1 billion for a capacity of 1.5 million tons per year of muriate of potash. Reserves have been estimated at 570 million tons, with no mention of average or cutoff ore grade. About 40 kilometers away from Fazendinha, at Arari, is a 600-million-ton reserve of sylvinite, which also was quoted without mention of average ore grade or cutoff ore grade.[7] Metalmin SA and J. S. Redpath Co. of Canada formed a joint venture to investigate a new process for mining sylvinite in water-saturated deposits at the Taquari-Vassouras Mine.[8] This mine has lagged behind the owner's expectations of production.

Canada.—Canadian production was about 50% of capacity for the year because of several events.

1. The Potash Co. of America Inc.'s Patience Lake Mine, the oldest potash mine in Saskatchewan, was flooded by an aquifer and closed during the winter after the mine equipment was salvaged.
2. The International Minerals & Chemical Corp. (Canada) Ltd.'s Esterhazy K-2 Mine continued at 75% capacity while the leak into the mine from an aquifer was slowly plugged.
3. Potash Corp. of Saskatchewan replaced its top management, reduced production, and commenced a reevaluation of its marketing program. The company lost Can$103.4 million in 1986, and the Province of Saskatchewan considered shouldering, in some manner, the Can$810 million accumulated operating debt.

In August, the U.S. Department of Commerce levied antidumping duties on all

Canadian potash producers, ranging from 9% to 85% margins on the declared border price. In September, the Province of Saskatchewan passed The Potash Resource Act, which establishes a production board to set production quotas for all the Saskatchewan potash mines in time of low prices and overproduction.

The ownership of some potash mines changed during the year. The minority owner (40%) of Allan Potash Mine, Saskterra Fertilizers Ltd., was sold to Canterra Energy Ltd. Canada Development Corp. owned 100% of Saskterra Fertilizers before the sale and owned 95.7% of Canterra Energy after the sale through an exchange of Saskterra Fertilizers for stock in Canterra Energy. In August, PPG Inc. chose KAC Holdings Inc. of Great American Management and Investment Inc. (GAMI)—an investment management company that has diversified into finance, manufacturing, and agricultural chemicals—to purchase Kalium Chemicals. GAMI's agricultural subsidiary is Vigoro Industries Inc., and Kaiser Agricultural Chemical Inc. is a division of Vigoro. The principals of Sullivan & Proops Inc. are management consultants to Vigoro, and Sullivan & Proops owns about 20% of Kalium Chemicals.

Table 12.—Salient Canadian potash statistics

(Thousand metric tons of K_2O equivalent)

	1984	1985	1986	1987
Production[1]	7,749	6,637	6,697	7,267
Domestic sales by domestic producers[1]	436	434	327	499
Exports:				
United States[1]	3,892	4,163	4,091	4,223
Overseas[1]	2,544	1,928	2,612	3,133
Imports for consumption[2]	20	14	10	19
Domestic consumption[3]	456	448	337	518
Yearend producers' stocks[1]	1,543	1,766	1,537	1,135

[1]Data supplied by the Potash & Phosphate Institute.
[2]From Bureau of the Census export data. Sulfate of potash and nitrate of potash were landed on the Canadian east coast from European sources.
[3]Domestic sales by domestic producers plus imports.

China.—Some details were released concerning the 118,000-ton-per-year pilot plant at Qarhan Lake in the Qinghai Province.[9] It will produce 59% K_2O (93.5% KCl) from a 9-square-kilometer evaporation field.

Israel.—Haifa Chemicals Ltd. announced plans to increase potassium nitrate capacity from 250,000 to 280,000 tons per year of product.[10] The Dead Sea Works Ltd. announced plans to increase capacity of muriate of potash from 1.23 to 1.4 million tons per year. Plans have resurfaced to extend the railroad network to Eilat for direct shipment of potash and other materials into the Red Sea and the Indian Ocean. The conveyor belt carrying finished product from Sdom to the new rail terminal of Tzefa was completed. A backup system of truck unloading equipment for truck haulage from Sdom was also installed.[11]

Italy.—The sulfate of potash plant at Casteltermini, also known as Campofranco, was closed for modernization.[12] The closure contributed to Italy's production decrease in 1986 and the continuing strength of the sulfate of potash price.

Jordan.—The Arab Potash Co. started the process of increasing plant capacity from 720,000 to 840,000 tons per year of muriate of potash by 1989 by means of increasing carnallite decomposition capacity. Plans were announced to further increase capacity to the range of 1.1 to 1.2 million tons per year by 1993.[13]

Tunisia.—The Government of France loaned an undisclosed sum of money to the Government of Tunisia for the planned 60,000-ton-per-year sulfate of potash plant. The estimated plant cost was $80 million.[14]

U.S.S.R.—Expectations were limited for recovery of the Berezniki 3 Mine of the Uralkaliy Group, north of Perm, which was flooded in 1986. Potash ore from the Berezniki 4 Mine was being hauled to the Berezniki 3 refinery. The Soviet potash warehouse at Nakhodka, near Vladivostok, was damaged by a typhoon in October 1986.[15]

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[1]Physical scientist, Branch of Industrial Minerals.
[2]All tonnages reported in metric tons, K_2O equivalent, unless otherwise noted.
[3]Phosphorus & Potassium. Western Europe Potash Review—A Market in Transition. No. 147, Jan.-Feb. 1987, pp. 14-24.
[4]European Chemical News. V. 49, No. 1287, Aug. 10-17, 1987, p. 12.
[5]Phosphorus & Potassium. Potash Plant & Project News. No. 148, Mar.-Apr. 1987, p. 15.
[6]———. Potash Plant and Project News. No. 150, July-Aug. 1987, p. 16.
[7]———. Potash Plant and Project News. No. 147, Jan.-Feb. 1987, p. 13.
[8]———. Work cited in footnote 7.
[9]———. Potash Plant and Project News. No. 151, Sept.-Oct. 1987, p. 15.
[10]Fertilizer Week. No. 30, Nov. 30, 1987, p. 4.
[11]Phosphorus & Potassium. Dead Sea Works. No. 147, Jan.-Feb. 1987, pp. 27-29.
[12]Piazzese, S. Twenty-five Years of the Italian Potash Industry. Phosphorus & Potassium. No. 150, July-Aug. 1987, p. 47.
[13]Industrial Minerals (London). Mineral Notes. No. 241, Oct. 1987, p. 77.
[14]Ghazaii, A. The Dilemma That Is Tunisia. Chem. Bus. of Eur. Chem. News. Feb. 1987, p. 36.
[15]Phosphorus & Potassium. World Markets. No. 151, Sept.-Oct. 1987, p. 8.

Table 13.—Marketable potash: World production, by country[1]

(Thousand metric tons of K_2O equivalent)

Country	1983	1984	1985	1986[p]	1987[e]
Brazil	--	--	--	10	30
Canada[2]	6,938	7,527	6,661	6,752	7,465
Chile[3]	21	18	[e]21	[e]20	20
China[4]	29	40	[e]40	[e]40	40
France	1,536	1,739	1,750	1,617	1,650
German Democratic Republic	3,431	3,465	3,465	3,485	3,500
Germany, Federal Republic of	2,419	2,645	2,583	2,161	2,140
Israel	1,000	1,100	1,200	1,255	1,300
Italy[5]	184	163	205	158	160
Jordan	172	295	561	660	720
Spain	657	677	659	795	750
U.S.S.R	9,294	9,776	10,367	10,200	10,400
United Kingdom	308	325	343	403	[6]435
United States	1,429	1,564	1,296	1,202	[6]1,262
Total	27,418	29,334	29,151	28,758	29,812

[e]Estimated. [p]Preliminary.
[1]Table includes data available through Apr. 29, 1988.
[2]Official Government figures. Potash & Phosphate Institute production data are given in table 12.
[3]Data represent officially reported output of potassium nitrate product (gross weight basis) converted assuming 14% K_2O equivalent.
[4]Chinese data on production of potassic fertilizers are in terms of nutrient content; small additional quantities may be produced and used by the nonfertilizer chemical industry.
[5]Crude salt.
[6]Reported figure.

Pumice and Pumicite

By Arthur C. Meisinger[1]

Domestic production for pumice and pumicite declined 29% in quantity and 22% in value compared with 1986 production. Imports for consumption of pumice also declined 29%, reflecting the weakened U.S. demand for pumice aggregate in concrete construction products. Greece continued to be the major source of pumice imports with 83%.

Domestic Data Coverage.—Domestic production data for pumice and pumicite are developed by the Bureau of Mines from one voluntary survey of U.S. operations. Of the 24 operations to which a survey request was sent, 19, or 79%, responded, of which 15 were active and represented 95% of total production data shown in table 1. Production for the remaining nonrespondents was estimated using reported prior year data adjusted by trends in employment and other guidelines.

Table 1.—Salient pumice and pumicite statistics

(Thousand short tons and thousand dollars unless otherwise specified)

	1983	1984	1985	1986	1987
United States: Sold and used by producers:					
Pumice and pumicite	449	502	508	554	392
Value (f.o.b. mine and/or mill)	$4,486	$4,929	$4,553	$5,756	$4,493
Average value per ton	$9.99	$9.82	$8.96	$10.39	$11.46
Exports[e]	1	1	1	1	1
Imports for consumption	184	293	242	385	272
Consumption, apparent[1]	632	794	749	938	663
World: Production, pumice and related volcanic materials	[r]12,681	[r]12,800	11,825	[p]11,458	[e]11,753

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Production plus imports, minus exports, plus adjustments for Government and industry stock changes.

DOMESTIC PRODUCTION

Production of pumice and pumicite by domestic producers dropped to its lowest level in 5 years, a decrease of 29% from that of 1986. Value of production declined 22%. Lower market demand for concrete-aggregate-size pumice, primarily from New Mexico operations, contributed significantly to the large decline in domestic output. Twenty mines and/or mills were operated by 18 companies in 7 States, with California, Idaho, New Mexico, and Oregon accounting for 95% of U.S. production.

Principal domestic producers were Glass Mountain Pumice Inc. (formerly Tionesta Aggregates Co.), Tulelake, CA; Hess Pumice Products, Malad City, ID; Producers Pumice Inc., Boise, ID; Copar Pumice Co. Inc., Santa Fe, NM; General Pumice Corp., Santa Fe, NM; Utility Block Co., Albuquerque, NM; Cascade Pumice Co., Bend, OR; and Central Oregon Pumice Co., Bend, OR. Together, these eight companies accounted for 89% of the tonnage and 63% of the value of U.S. pumice and pumicite production.

Table 2.—Pumice and pumicite sold and used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1986		1987	
	Quantity	Value	Quantity	Value
Arizona	2	30	1	7
California	46	1,263	42	1,539
New Mexico	255	2,370	87	991
Other[1]	251	2,094	262	1,956
Total	554	[2]5,756	392	4,493

[1]Includes Hawaii, Idaho, Kansas, Oklahoma (1986), and Oregon.
[2]Data do not add to total shown because of independent rounding.

CONSUMPTION AND USES

U.S. apparent consumption decreased 29% compared with that of 1986. The principal domestic use of pumice as aggregate in concrete products for the construction market declined significantly from 697,000 short tons sold and used in 1986 to 376,000 tons. Weaker local market demands and higher priced imported pumice contributed largely to the decline in consumption.

Pumice and pumicite used as abrasives increased 71%, primarily owing to the large demand for washing designer jeans. Pumice for use as decorative building block increased 15%, partly owing to several producers switching production from aggregate to block for the higher priced block market. Landscaping and other uses had slight sales decreases during the year.

Table 3.—Pumice and pumicite sold and used by producers in the United States, by use

(Thousand short tons and thousand dollars)

Use	1986		1987	
	Quantity	Value	Quantity	Value
Abrasives (includes cleaning and scouring compounds)	17	517	29	719
Concrete admixture and aggregate	316	2,258	122	622
Decorative building block	168	1,893	194	2,295
Landscaping	22	196	19	195
Other[1]	31	892	28	662
Total	554	5,756	392	4,493

[1]Includes heat-or-cold insulating medium, pesticide carriers, road construction material, roofing granules, and miscellaneous uses.

PRICES

The average value, f.o.b. mine or mill, for domestic pumice and pumicite sold and used was $11.46 per ton, a 10% increase compared with the 1986 value. The increase was due to the greater demand for higher priced block pumice.

Prices quoted in Chemical Marketing Reporter remained unchanged from those of 1986 for domestic grades of pumice bagged in 1-ton lots and were, at yearend, $270 per ton for fine and $300 per ton for medium, coarse, and 2-extra coarse. Yearend quoted prices on imported (Italian) pumice, f.o.b. east coast, bagged in 1-ton lots, were $280 per ton for fine, $350 per ton for medium, and $300 per ton for coarse.

The average declared customs value of pumice imported from Greece for use in concrete masonry products increased 28% from $6.87 per ton in 1986 to $8.81 per ton.

FOREIGN TRADE

Pumice imported for consumption decreased 29% compared with that of 1986. Pumice imports for use in concrete masonry products declined one-third from 381,000 tons in 1986 to 254,000 tons, owing to a weakened U.S. market for concrete aggregate pumice and an increase of $4.55 per ton over the 1986 import price.

[1]Industry economist, Branch of Industrial Minerals.

Table 4.—U.S. imports for consumption of pumice, by class and country

Country	Crude or unmanufactured		Wholly or partly manufactured		For use in the manufacture of concrete masonry products		Manufactured, n.s.p.f.
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Value (thousands)
1986:							
Ecuador	645	$54	--	--	--	--	--
Greece	2,555	162	24	$10	352,076	2,418	--
Iceland	177	38	--	--	--	--	--
Italy	83	22	464	163	22,047	166	$178
Mexico	--	--	--	--	6,965	183	5
Other[1]	28	21	21	31	3	9	329
Total	3,488	297	509	204	381,091	2,776	512
1987:							
Ecuador	--	--	--	--	1,588	83	--
Greece	2,402	449	170	51	222,048	1,957	155
Guatemala	3,762	301	264	22	--	--	6
Iceland	332	81	--	--	--	--	--
Italy	42	19	632	201	22,050	235	189
Mexico	7,536	899	--	--	7,051	589	81
Turkey	2,906	512	41	14	683	127	8
Other[2]	373	153	94	92	173	9	460
Total	17,353	2,414	1,201	380	253,593	3,000	899

[1]Includes Austria, Canada, Denmark, France, the Federal Republic of Germany, Hong Kong, Iran, Ireland, Japan, the Netherlands, Niger, Spain, Taiwan, and the United Kingdom.
[2]Includes Australia, Brazil, Canada, France, the Federal Republic of Germany, Indonesia, Japan, the Republic of Korea, the Netherlands, Norway, Singapore, Spain, Taiwan, and the United Kingdom.

Source: Bureau of the Census.

Table 5.—Pumice and related volcanic materials: World production, by country[1]

(Thousand short tons)

Country[2]	1983	1984	1985	1986^{p}	1987^{e}
Argentina[3]	76	60	15	17	18
Austria: Trass	3	11	8	6	7
Cameroon: Pozzolan	NA	NA	116	186	190
Cape Verde Islands: Pozzolan^{e}	11	11	11	11	11
Chile: Pozzolan	192	190	227	245	220
Costa Rica^{e}	2	2	2	2	2
Dominica: Pumice and volcanic ash^{e}	120	120	120	120	110
France: Pozzolan and lapilli	669	551	547	452	500
Germany, Federal Republic of: Pumice (marketable)	243	^{r}386	228	237	190
Greece:					
Pumice	552	691	684	^{e}690	690
Pozzolan	1,004	1,001	1,034	^{e}1,050	1,040
Guadeloupe: Pozzolan^{e}	265	275	240	^{r}244	243
Guatemala:					
Pumice	17	^{e}15	13	12	13
Volcanic ash	([4])	([4])	--	--	--
Iceland	50	61	62	58	55
Italy:					
Pumice and pumiceous lapilli	^{r}1,026	^{r}995	^{e}825	^{e}770	800
Pozzolan	^{r}6,162	^{r}6,296	^{e}5,500	^{e}5,000	5,500

See footnotes at end of table.

Table 5.—Pumice and related volcanic materials: World production, by country[1] —Continued

(Thousand short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Martinique: Pumice[e]	160	150	165	155	145
New Zealand	19	17	[e]22	[e]22	17
Spain[5]	1,105	915	936	1,067	1,050
United States (sold and used by producers)	449	502	508	554	[6]392
Yugoslavia: Volcanic tuff	556	[r]551	562	[e]560	560
Total	[r]12,681	[r]12,800	11,825	11,458	11,753

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.
[1]Table includes data available through May 20, 1988.
[2]Pumice and related volcanic materials are also produced in a number of other countries, including (but not limited to) Ethiopia, Iran, Japan, Mexico, Turkey, and the U.S.S.R., but output is not reported quantitatively, and available information is inadequate for the formulation of reliable estimates of output levels.
[3]Unspecified volcanic materials produced mainly for use in construction products.
[4]Less than 1/2 unit.
[5]Includes Canary Islands.
[6]Reported figure.

Rare-Earth Minerals and Metals

By James B. Hedrick[1]

Domestic production of rare-earth concentrates in 1987 increased as a result of increased demand for television and lighting phosphors, glass-polishing compounds, and permanent magnets. However, mines continued to operate at about two-thirds of their rated production capacity. Foreign sources of rare earths obtained a smaller share of the U.S. market, while domestic exports increased from 1986 levels. Molycorp Inc. and Associated Minerals (USA) Ltd. Inc. were the only domestic mine producers of commercial quantities of rare-earth minerals.

Domestic Data Coverage.—Domestic mine production data for rare earths are developed by the Bureau of Mines from the voluntary "Rare-Earths and Thorium" survey. The two mines to which a survey form was sent responded, representing 100% of total production. Production data are withheld to avoid disclosing company proprietary data.

Table 1.—Salient U.S. rare-earth statistics

(Metric tons of rare-earth oxides (REO) unless otherwise specified)

	1983	1984	1985	1986	1987
Production of rare-earth concentrates[1]	17,083	25,311	13,428	11,094	16,710
Exports:[e]					
Ore and concentrate	2,684	4,304	4,419	3,433	4,534
Ferrocerium and pyrophoric alloys	59	27	23	29	82
Imports for consumption:[e]					
Monazite	2,215	3,114	3,132	1,628	617
Metals, alloys, oxides, compounds	1,857	2,926	1,124	1,155	625
Stocks, Dec. 31: Producers' and processors'	W	W	W	W	W
Consumption, apparent[e]	19,600	21,400	12,100	11,800	9,400
Prices, Dec. 31: Dollars per kilogram:					
Bastnasite concentrate, REO basis	$2.14	$2.14	$2.14	$2.14	$2.31
Monazite concentrate, REO basis	$0.71	$0.64	$1.09	$1.06	$0.90
Mischmetal, metal basis	$12.35	$12.35	$12.35	$12.35	$12.35
Employment, mine and mill[e 2]	266	321	330	283	299
Net import reliance[e 3] as a percent of apparent consumption	12	(4)	(4)	5.94	(4)

[e]Estimated. W Withheld to avoid disclosing company proprietary data.
[1]Comprises only the rare earths derived from bastnasite, as reported in Unocal Corp. annual reports.
[2]Employment at a rare-earth mine in California and at mineral sands operations in Florida and Georgia. The latter mines produced monazite concentrate as a byproduct of mining ilmenite, rutile, and zircon, and employees were not assigned to specific commodities.
[3]Imports minus exports plus adjustments for Government and industry stock changes.
[4]Increase in industry stocks exceeded net imports.

Legislation and Government Programs.—Sales of materials held in the National Defense Stockpile (NDS), including rare earths in sodium sulfate, continued to be suspended during 1987 because the $250 million limit imposed on the NDS Transaction Fund was exceeded during 1985. Under the Department of Defense Authorization Act, 1987 (Public Law 99-661), no rare earths were authorized for disposal in fiscal year 1987. In fiscal year 1988, beginning October 1, 1987, the Department of Defense Authorization Act for fiscal years 1988 and 1989 (Public Law 100-180) continued authorization in effect on September 30, 1987. It authorized the President to change the stockpile requirements by less than 10% by submitting an explanation and justification to Congress, to be effective on or after the first day of the next fiscal year. Changes greater than 10% were to require congressional approval. Public Law 100-180 also directed the President to designate a single Federal office to have responsibility for the NDS. At yearend, it was expected that the Defense Logistics Agency, under the U.S. Department of Defense, would be directed to this task.

Environmental Issues.—The California Desert Protection Act of 1987 proposed to close approximately 8 million acres of California desert to mining exploration and development. Minerals known to occur in the region covered by the act include gold, rare earths, silver, and various industrial minerals. The proposed area is also bordered by the principal world producer of rare earths, the Mountain Pass Mine. The area has been identified as having high-to-moderate resource potential. Exclusion of exploration in this area could be critical if the United States needs additional supplies of rare earths.[2]

DOMESTIC PRODUCTION

In 1987, rare earths were mined and concentrated at Molycorp's Mountain Pass Mine in California and Associated Minerals' Green Cove Springs Mine in Florida. Molycorp, Rhône-Poulenc Inc., W. R. Grace & Co.'s Davison Chemical Div., and Research Chemicals Div. of NUCOR Corp. were the principal processors of rare earths in the United States.

Molycorp, the only domestic producer of the mineral bastnasite, a rare-earth fluocarbonate, announced a 5-year modernization and expansion program to increase its production of refined oxides and metals, especially neodymium, for use in permanent magnets, and cerium for use in automotive catalysts. The company reported sales of rare earths were up 14% from that of 1986.[3]

Australian-owned Associated Minerals was the only commercial mineral sands operation in the United States to recover the mineral monazite, a rare-earth phosphate. Monazite was recovered at Associated Minerals' Florida operations as a byproduct of processing heavy-mineral sands for the titanium minerals ilmenite, leucoxene, and rutile, and for the zirconium mineral zircon.

Neomet Corp., a joint venture of REMACOR and Mitsubishi Metal Corp., began commercial production of neodymium metal for use in high-strength permanent magnets from its plant at West Pittsburgh, PA.

Rhône-Poulenc continued engineering studies at its iron ore tailings deposit at Mineville, NY. Owing to the complex nature of the ore, which is a rare-earth-bearing apatite with magnetite and other iron minerals, a new separation process was being developed. Rhône-Poulenc had not set a date for production, but expected to supplement its existing separation plants in Freeport, TX, and La Rochelle, France.

W. R. Grace, Shin-Etsu Chemical Co. Ltd., and Mitsui & Co. Ltd. announced the opening of a new plant to produce separated rare earths at the Davison Chemical Div. of W. R. Grace's rare-earth-processing facilities in Chattanooga, TN. The new plant will reportedly employ separation technology licensed from Shin-Etsu.[4]

CONSUMPTION AND USES

Domestic rare-earth processors consumed an estimated 9,400 metric tons of equivalent rare-earth oxides (REO) in various forms in 1987, 20% less than was consumed in 1986. Bastnasite consumption was 9% lower and monazite consumption was 164% higher compared with those of 1986.

Shipments of rare-earth products from domestic processors of ore, concentrates, and intermediate concentrates amounted to 14,500 tons of equivalent REO, an increase of 10% from the 1986 shipments of 13,200 tons.

Consumption of mixed rare-earth compounds decreased 88% from the 1986 level, while consumption of purified compounds increased 34%. Higher consumption of purified compounds was the result of continued strong demand for dysprosium, neodymium, samarium, and certain other rare earths used in high-strength permanent magnets, for yttrium and europium oxides used in phosphors, and for yttrium oxides used in high-temperature ceramic and refractory applications.

The producers of mischmetal, rare-earth silicide, and other rare-earth alloys consumed 4% more rare earths in 1987 than in 1986, although shipments of these goods fell 91% during the same period. Shipments of high-purity rare-earth metals decreased 18% during the year.

The approximate distribution of rare earths by use, based on information supplied by primary processors and some consumers, was as follows: catalysts (including petroleum, chemical, and pollution), 53%; metallurgical uses (including iron and steel additives, alloys, and mischmetal), 22%; ceramics and glass (including polishing compounds and glass additives), 18%; and miscellaneous uses (including phosphors, electronics, permanent magnets, lighting, and research), 7%.

Major end uses were in petroleum fluid cracking catalysts, metallurgical applications, glass and ceramics, permanent magnets, and phosphors. Rare earths were used in high-technology applications to produce synthetic crystals used in lasers, high-strength permanent magnets, optical fibers, magnetic resonance imaging scanners, and high-temperature superconductors.

STOCKS

U.S. Government stocks of rare earths in the NDS, all classified as excess to goal, remained at 457 tons throughout 1987. Rare-earth stocks held in the NDS were contained in sodium sulfate and were inventoried on a contained-REO basis.

Industry stocks of rare-earth ores and concentrates held by six producing, processing, and consuming companies increased 28%. Bastnasite stocks held by the principal producer and four other processors increased 167% over the 1986 level. Yearend stocks of monazite increased 10%, while stocks of yttrium concentrates increased 21%. Stocks of other rare-earth concentrates fell 86%.

Stocks of mixed rare-earth compounds increased 23%, while stocks of purified compounds, mostly separated rare-earth oxides, increased 17%. Yearend stocks of mischmetal, rare-earth silicide, and other alloys containing rare earths were down 96%, while inventories of high-purity rare-earth metals were down 82%.

PRICES

The price range of Australian monazite (minimum 55% REO including thoria, f.o.b./f.i.d.),[5] as quoted in Australian dollars (A$),[6] decreased from A$850-A$900 per ton at yearend 1986 to A$660-A$710 per ton by yearend 1987. Changes in the United States-Australian foreign exchange rate in 1987 caused the corresponding U.S. price to decline a lesser amount, about 6 cents on the dollar. The U.S. price range, converted from Australian dollars, decreased from US$565-US$598[7] in 1986 to US$477-US$513[8] in 1987. The average declared value of imported monazite increased in 1987 to $560 per ton, up $186 from the 1986 value.

The yearend price quoted in Industrial Minerals (London) for yttrium concentrate (60% Y_2O_3, f.o.b. Malaysia) was $35 per kilogram. Domestic prices quoted for yttrium concentrate during 1987, developed by the Bureau of Mines from various sources, ranged from $55 to $65 per kilogram of contained yttrium oxide.

Prices quoted by Molycorp for unleached, leached, and calcined bastnasite in truckload or trainload quantities, containing 60%, 70%, and 85% REO, were $1.00, $1.05, and $1.25 per pound of contained REO, respectively, at yearend 1987.

The price of cerium concentrate quoted by American Metal Market was $1.40 per pound of contained cerium oxide at yearend 1987, unchanged for the third consecutive year. The price of lanthanum concentrate was also unchanged at $1.40 per pound of contained REO.

The mischmetal (99.8%, lots over 100 pounds, f.o.b. shipping point) price for 1987, quoted in American Metal Market, remained unchanged from the 1986 price range of $4.90 to $5.60 per pound.

Molycorp quoted prices for lanthanide (rare earth) and yttrium oxides, net 30 days, f.o.b. Louviers, CO, Mountain Pass, CA, or York, PA, effective July 1, 1987, as follows:

Product (oxide)	Percent[1] purity	Quantity (pounds)	Price per pound
Cerium	99.0	200	$8.00
Europium	99.99	25	725.00
Gadolinium	99.99	55	60.00
Lanthanum	99.99	300	8.75
Neodymium	96.0	300	5.00
Do	99.9	50	40.00
Praseodymium	96.0	300	16.80
Samarium	96.0	55	85.00
Terbium	99.9	55	375.00
Yttrium	99.99	50	52.50

[1]Purity expressed as percent of total REO.

Molycorp also quoted prices for lanthanide (rare earth) compounds, net 30 days, f.o.b. York, PA, or Louviers, CO, effective January 2, 1987, as follows:

Product (compound)	Percent purity	Quantity (pounds)	Price[1] per pound
Cerium carbonate	99.0	150	$4.00
Cerium fluoride	Tech grade	250	3.00
Cerium nitrate	95.0	250	2.15
Lanthanide chloride	46.0	525	1.00
Lanthanum carbonate	99.9	300	5.90
Lanthanum chloride	46.0	525	.95
Lanthanum-lanthanide carbonate	60.0	200	2.15
Lanthanum-lanthanide nitrate	39.0	250	1.50
Neodymium carbonate	96.0	300	4.00

[1]Priced on a contained REO basis.

Rhône-Poulenc quoted rare-earth prices, per kilogram, net 30 days, f.o.b. New Brunswick, NJ, or duty paid at point of entry, effective January 1, 1987, as follows:

Product[1] (oxide)	Percent purity	Quantity (kilograms)	Price per kilogram
Cerium	99.5	20	$21.25
Erbium	96.0	50	200.00
Europium	99.99	40	1,960.00
Gadolinium	99.99	50	136.50
Lanthanum	99.99	25	18.10
Praseodymium	96.0	20	38.85
Samarium	96.0	25	132.50
Terbium	99.9	20	880.00
Yttrium	99.99	50	115.50

[1]Dysprosium, holmium, lutetium, thulium, and ytterbium oxide prices on request from Rhône-Poulenc Inc.

Rhône-Poulenc also quoted prices for rare earths produced at its Freeport, TX, plant, net 30 days, f.o.b. Freeport, TX, effective January 1, 1987, as follows:

Product (compound)	Percent[1] purity	Quantity (kilograms)	Price[2] per kilogram
Cerium carbonate	95.0	20	$8.90
Cerium hydroxide	95.0	20	11.25
Cerium nitrate	95.0	200	11.05
Cerium oxide	99.5	20	17.75
Lanthanum carbonate	99.5	20	12.60
Lanthanum-neodymium carbonate	98.0	20	8.70
Lanthanum nitrate	99.5	200	11.90
Lanthanum oxide	99.5	20	13.25
Neodymium carbonate	95.0	20	9.25
Neodymium nitrate	95.0	200	10.05
Neodymium oxide	95.0	20	11.05

[1]Purity expressed as percent of total REO.
[2]Priced on a contained REO basis.

Nominal prices for various rare-earth oxides and metals were quoted per kilogram by Research Chemicals, net 30 days, f.o.b. Phoenix, AZ, effective November 1, 1986, and throughout 1987, as follows:

Element	Oxide[1] price per kilogram	Metal[2] price per kilogram
Cerium	$40	$175
Dysprosium	200	630
Erbium	250	725
Europium	1,900	7,600
Gadolinium	140	500
Holmium	600	1,600
Lanthanum	20	150
Lutetium	4,900	14,200
Neodymium	80	280
Praseodymium	130	400
Samarium	200	395
Terbium	1,200	2,800
Thulium	3,300	8,000
Ytterbium	225	1,000
Yttrium	118	510

[1]Minimum 99.9%-pure, 1- to 20-kilogram quantities.
[2]Ingot form, 1 to 5 kilograms, from 99.9%-grade oxides.

FOREIGN TRADE

Exports of rare-earth concentrates originated mainly from Molycorp's Mountain Pass Mine in California. Exports of rare-earth metal ores, including bastnasite and a variety of mixed and individual rare-earth concentrates, but excluding monazite, decreased from 6.0 million kilograms in 1986 to 4.5 million kilograms in 1987. Exports of rare-earth metal ores, excluding monazite, were valued at $11.8 million in 1987. Major destinations were Japan (60%), Austria (10%), and the United Kingdom (8%).

Exports of ferrocerium and other pyrophoric alloys containing rare earths totaled 81,626 kilograms, 146% higher than 1986 exports. Major destinations for these exports were Japan (31%), Canada (21%), and Venezuela (12%).

Exports of thorium ore, including monazite, were essentially unchanged from the 1986 level. France was the destination of almost all of the reported total of 582,995 kilograms valued at $427,838, or $733.86 per ton.

Table 2.—U.S. import duties on rare earths

Item	TSUS No.	Most favored nation (MFN) Jan. 1, 1987	Non-MFN Jan. 1, 1986
Ore and concentrate[1]	601.12, 601.45	Free	Free.
Cerium chloride, oxide, compounds	418.40, 418.42, 418.44	7.2% ad valorem	35% ad valorem.
Rare-earth oxides except cerium oxide	423.0030	3.7% ad valorem	25% ad valorem.
Rare-earth metals (including scandium and yttrium).	632.38	do	Do.
Alloys wholly or almost wholly of rare-earth metals (mischmetal).	632.78	32 cents per pound.	$2 per pound.
Other alloys wholly or almost wholly of rare-earth metals.	632.79	20 cents per pound plus 2.4% ad valorem.	$2 per pound plus 25% ad valorem.
Ferrocerium and other pyrophoric alloys	755.35	22 cents per pound plus 2.6% ad valorem.	Do.
Yttrium-bearing materials and compounds (includes yttrium concentrates).	907.51	Free	25% ad valorem or 30% ad valorem.[2]

[1]Crude or concentrated by crushing, flotation, washing, or by other physical or mechanical processes that do not involve substantial chemical change.

[2]Tariff is 25% if previous import item classification was 423.00 or 423.96, part 2, schedule 4, or 30% if 603.70, part 1, schedule 6.

Table 3.—U.S. imports for consumption of monazite, by country

Country	1983		1984		1985		1986		1987	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Australia	3,726	$1,395	5,610	$2,156	5,694	$1,984	2,660	$978	--	--
India	--	--	--	--	--	--	300	128	--	--
Malaysia	302	122	--	--	--	--	--	--	527	$298
South Africa, Republic of	--	--	51	46	--	--	--	--	--	--
Thailand	--	--	--	--	--	--	--	--	594	329
Total	4,028	1,517	5,661	2,202	5,694	1,984	2,960	1,106	1,121	627
REO content[e]	2,215	XX	3,114	XX	3,132	XX	1,628	XX	617	XX

[e]Estimated. XX Not applicable.

Source: Bureau of the Census. REO content estimated by the Bureau of Mines.

Table 4.—U.S. imports for consumption of rare earths, by country

Country	1985		1986		1987	
	Quantity (kilograms)	Value	Quantity (kilograms)	Value	Quantity (kilograms)	Value
Cerium chloride:						
Mali	--	--	--	--	34,499	$39,240
Morocco	--	--	--	--	20,892	36,661
Singapore	--	--	34,500	$39,871	105,017	109,982
United Kingdom	--	--	--	--	1,624	5,603
Total	--	--	34,500	39,871	162,032	191,486
Cerium compounds:						
Canada	--	--	11,987	8,328	--	--
France	1,770	$8,981	247,420	354,290	80	1,068
Germany, Federal Republic of	206	34,469	188	32,141	370	34,223
Switzerland	--	--	--	--	2	2,863
United Kingdom	10	2,306	--	--	--	--
Total	1,986	45,756	259,595	394,759	452	38,154
Cerium oxide:						
Austria	--	--	91	1,195	91	1,142
Canada	--	--	117	7,561	--	--
China	--	--	100	1,083	--	--
France	5,327	81,670	4,595	76,014	2,336	37,542
Germany, Federal Republic of	94	2,283	--	--	--	--
Japan	--	--	561	18,844	44,200	1,054,727
United Kingdom	27	1,707	--	--	--	--
Total	5,448	85,660	5,464	104,697	46,627	1,093,411
Cerium salts:						
France	--	--	--	--	5,338	15,378
Japan	--	--	11	4,099	--	--
Netherlands	--	--	5,296	11,647	--	--
Total	--	--	5,307	15,746	5,338	15,378
Rare-earth oxide excluding cerium oxide:						
Belgium-Luxembourg	110	46,342	963	31,269	--	--
Brazil	--	--	500	15,383	--	--
Canada	--	--	22	3,270	430	54,197
Chile	--	--	--	--	100	8,334
China	3,830	348,923	41,943	2,082,324	9,319	1,015,770
France	170,556	11,132,432	200,601	12,535,724	216,869	13,995,531
Germany, Federal Republic of	811	266,213	1,839	486,350	10,848	263,889
Hong Kong	--	--	981	63,551	20	29,188
Italy	--	--	3	3,750	--	--
Ivory Coast	--	--	514	90,074	--	--
Japan	7,814	872,783	10,130	1,094,614	5,595	611,937
Malaysia	6,210	186,534	--	--	5,980	119,364
Netherlands	513	36,372	--	--	3,815	915,912
Norway	5,996	655,382	2,478	402,216	3,073	426,143
South Africa, Republic of	--	--	--	--	3	38,594
Switzerland	318	111,800	35	13,050	--	--
U.S.S.R.	6,506	691,201	22,776	1,809,588	26,516	1,663,127
United Kingdom	197	38,133	5,468	311,050	744	328,392
Total	202,861	14,386,115	288,253	18,942,213	283,312	19,470,378
Rare-earth alloys:[1]						
Argentina	--	--	--	--	2,000	14,231
Brazil	162,998	817,875	47,359	239,274	129,632	609,135
Canada	--	--	--	--	4,535	72,551
China	--	--	--	--	56	13,440
France	1,062	9,946	--	--	--	--
Germany, Federal Republic of	17,211	167,343	3,665	49,148	3,194	63,388
Japan	--	--	11	1,130	737	30,746
United Kingdom	5,057	35,535	15,100	119,729	102	18,367
Total	186,328	1,030,699	66,135	409,281	140,256	821,858
Rare-earth metals including scandium and yttrium:						
Austria	100	2,968	786	24,395	1,284	35,487
China	--	--	5,655	299,929	6,619	392,069
Germany, Federal Republic of	--	--	--	--	1,541	114,011
Hong Kong	--	--	--	--	5	12,738
Ivory Coast	--	--	97	15,611	--	--
Japan	1,000	76,099	1,000	76,099	1,724	181,385
U.S.S.R.	2,061	183,044	9,666	805,497	500	32,469
United Kingdom	24	22,642	2,354	615,271	1,817	581,821
Total	3,185	284,753	19,558	1,836,802	13,490	1,349,980

See footnote at end of table.

Table 4.—U.S. imports for consumption of rare earths, by country —Continued

Country	1985 Quantity (kilograms)	1985 Value	1986 Quantity (kilograms)	1986 Value	1987 Quantity (kilograms)	1987 Value
Other rare-earth metals:						
Austria	--	--	--	--	3,733	$97,314
France	329	$9,870	7,066	$149,562	17,971	593,959
Germany, Federal Republic of	655	15,275	2	1,207	469	13,211
Japan	--	--	80	4,695	72	5,872
United Kingdom	209	9,225	60	2,842	(2)	1,272
Total	1,193	34,370	7,208	158,306	22,245	711,628
Ferrocerium and other pyrophoric alloys:						
Austria	1,000	13,240	655	10,032	--	--
Brazil	45,349	632,014	32,799	434,340	35,890	475,256
Canada	--	--	--	--	10,142	75,057
France	66,771	641,505	50,123	640,986	43,701	656,671
Germany, Federal Republic of	--	--	765	15,092	890	24,633
Hong Kong	--	--	892	2,943	--	--
Japan	20	1,699	796	14,953	202	5,203
Korea, Republic of	--	--	8,778	21,276	--	--
Netherlands	--	--	58	1,153	3,280	43,434
Taiwan	--	--	--	--	319	1,273
Thailand	--	--	--	--	257	2,329
United Kingdom	245	13,080	396	13,526	148	10,301
Total	113,385	1,301,538	95,262	1,154,301	94,829	1,294,157

[1]Essentially all mischmetal.
[2]Less than 1/2 unit.

Source: Bureau of the Census.

WORLD REVIEW

Bastnasite, the world's principal source of rare earths, was mined as a primary product in the United States and as a byproduct of iron ore mining in China. Significant quantities of rare earths were also recovered from monazite, which was primarily a byproduct of mineral sands mined for titanium and zirconium minerals or tin in Australia, Brazil, China, India, and Malaysia. Smaller amounts of rare earths, especially yttrium, were obtained from byproduct xenotime. Xenotime was recovered primarily as a byproduct of processing tin ore in Malaysia and Thailand but was also produced in Australia and China. Small quantities of rare earths, including yttrium (which reportedly is adsorbed on some residual clays), were also produced in China. Yttrium and rare earths were also recovered from spent uranium leach solutions in Canada.

World reserves of rare earths were estimated by the Bureau of Mines at 48 million tons of contained REO, of which 23% is in market economy countries.[9] China, with 76%, had the largest share of world reserves.

Australia.—The Mineral Sands Div. of Renison Goldfields Consolidated Ltd. (RGC) announced that exploration west of its Allied Eneabba Mine, Western Australia, was successful in finding mineral sands resources of 150 million tons grading 3.5% heavy minerals. Further exploration in the area was planned. To optimize mining at its Eneabba properties, RGC reportedly planned to mine selected areas by dredging rather than by its present dry mining method. RGC also completed redesign of its processing plant for mineral sands at Eneabba, which allowed increased recovery of all minerals, including monazite.[10]

RGC continued exploration for heavy-mineral sands on Moreton Island, Queensland. The Queensland government adopted the recommendation of a report that would allow mining on 1,200 hectares (6.4%) of the island as short-term use.[11]

The government of Western Australia announced that Rhône-Poulenc of France was to build a 6,000-ton-(REO)-per-year, rare-earth separation plant at Pinjarra, Western Australia.[12] The plant, scheduled for completion in 1989, reportedly will process monazite by liquid-liquid solvent extraction. Monazite feed for the plant will come primarily from RGC's mineral sands operations in Western Australia.[13]

Mineral Deposits Ltd., a subsidiary of The Broken Hill Pty. Co. Ltd. (BHP), announced the opening of a heavy-mineral sands mining operation at Viney Creek, New South Wales, in 1987. Mineral Deposits recovered heavy-mineral sands, including monazite, using twin dredges connected to a floating, wet concentrator. Monazite and other heavy-mineral concentrates were produced at Mineral Deposits' nearby dry concentrator plant at Hawks Nest.[14]

TiO_2 Corp. completed feasibility studies of its heavy-mineral sands deposit at Cooljarloo, Western Australia, and declared it viable. The deposit reportedly contains 12 million tons of ore with a cutoff grade of 2% heavy-mineral sands.[15]

A rare-earth deposit was discovered in the Northern Territory 100 kilometers east of Alice Springs. The deposit reportedly contains significant quantities of rare earths in the mineral allanite. As part of an Australian consortium formed to study the deposit, Australia's Commonwealth Scientific and Industrial Research Organization is undertaking prefeasibility studies.[16]

West Coast Holdings Ltd. announced plans to install a pilot plant at its Brockman multimineral deposit in Western Australia. The deposit reportedly contains columbium (niobium), gallium, hafnium, rare earths, tantalum, thorium, and zirconium. The Brockman deposit, 15 kilometers southeast of Halls Creek, is a joint venture of West Coast Holdings and Greater Pacific Investments Ltd. If additional feasibility reports are favorable, a plant to process 200,000 tons per year of ore was to be built.[17] West Coast Holdings estimated potential annual rare-earth production at 170 tons of yttrium, 37 tons of mixed heavy rare earths, 24 tons of dysprosium, 17 tons of erbium, 6 tons of samarium, and 3 tons of terbium.[18]

Brazil.—Production of monazite concentrates in 1985 was 3,953 tons. The State of Espírito Santo produced 281 tons, a decrease from the 451 tons produced in 1984. The State of Rio de Janeiro produced 3,672 tons, an increase from the 1984 production of 3,161 tons.

Measured reserves of monazite were 17,274 tons. Estimated REO content based on these reserves was 8,506 tons. Monazite reserves were in the States of Bahia, Espírito Santo, Paraná, and Rio de Janeiro.[19]

Canada.—Joint-venture partners Hecla Mining Co. and Highwood Resources Ltd. continued development of their beryllium-yttrium-rare-earth-zirconium deposit at Thor Lake, Northwest Territories. The partners have already completed pilot plant and market research studies. Funding from Hecla was reportedly allocated to improve chemical processing, full-scale plant design, and market development.[20]

China.—The China Rare Earth Information Centre reported 1987 production of 15,100 tons of REO, an increase from the 11,860 tons produced in 1986. The record-high level of production ranks China a close second to the United States in overall production. China reportedly consumed 4,800 tons of equivalent REO, up 13% from that of 1986. Rare-earth consumption in fertilizers and by the oil industry was 600 tons (250 tons REO) and 900 tons, respectively. Export volume also reportedly increased to 6,500 tons REO with an estimated value of $60 million.[21]

Jiangxi Province announced the startup of a 170-ton-per-year refinery at Shangrao to produce heavy-group rare earths. The annual yttrium oxide capacity of the plant was estimated at 40 tons.[22]

Can-Pacific Rare Earths & Metals Corp. (Canada) announced plans to build a 1,000-ton-per-year REO separation plant in Jiangxi Province. The joint-venture project with China was scheduled to commence in 1988.[23]

Gabon.—A columbium (niobium) deposit containing rare earths was discovered 40 kilometers east of Lambaréné in middle Ogooué. Although the deposit is reportedly sizable, no reserve figures were released.[24]

Japan.—Imports of rare earths in 1987 were reported in the Japan Metal Journal, as follows:

Product	Quantity (kilograms)
Cerium fluoride	1,636
Cerium oxide	257,880
Ferrocerium and other pyrophoric alloys	52,306
Lanthanum oxide	101,922
Rare-earth chloride	3,751,481
Rare-earth metals including yttrium and scandium	278,405
Yttrium oxide	390,998

Principal sources of imported compounds by weight were Brazil, China, India, and the United States.

Data on Japanese demand for rare earths in 1987 was reported as follows:[25] cerium oxide, 3,150 tons; lanthanum oxide, 380 tons; samarium oxide, 350 tons; mischmetal, 250 tons; yttrium oxide, 240 tons; rare-earth fluoride, 60 tons; europium oxide, 10 tons; and other REO's, 450 tons.

Rhône-Poulenc announced that it will build a small rare-earth processing and separation plant on an island off the coast of Osaka. The plant is owned 59% by Rhône-Poulenc's Japanese company, Nippon Rare Earths Co. Ltd., and 41% by Sumitomo Metal Mining Co. Ltd. Construction started in 1987 and was expected to be completed in 1988.

A deposit containing rare-earth-bearing sphene was discovered in 1987 near Kamioka, Gifu Prefecture. The silicate mineral, sphene, reportedly contains 0.5% rare earths. The Agency of Natural Resources and Energy, under the Ministry of International Trade and Industry, announced plans to develop technology to recover rare earths from sphene and determine its commercial feasibility.[26]

Dowa Mining Co. Ltd. announced it would construct a rare-earth extraction plant at Hanaoka, Akita Prefecture. Planned capacity for the separation plant was 300 tons of REO per year. Dowa Mining reportedly will process Chinese concentrates purchased under long-term contract.[27]

Madagascar.—QIT-Fer et Titane Inc. of Canada announced that it had completed initial feasibility studies of a heavy-mineral sands deposit in southeast Madagascar. The joint-venture project was 51% owned by the Government of Madagascar and 49% by QIT. The drilling program confirmed the existence of an ore body containing mineral sands, including monazite. Further drilling and the construction of a pilot plant at the site were planned.[28]

Malaysia.—Environmental concerns over the processing and disposal of radioactive thorium hydroxide, produced as a byproduct of processing the naturally radioactive mineral monazite for rare earths and yttrium, resulted in the 1985-86 closing of Asian Rare Earth's (ARE) refining plant near Ipoh. The ARE plant remained closed from October 1985 through February 1986, while ARE reportedly complied with 12 court-ordered safety measures, including construction of an above-ground temporary storage facility. Radioactive thorium hydroxide was previously shipped for burial to a storage site at Papan. A new, reportedly safer site, was selected 5 kilometers north of the city in 1986.[29] The ARE plant is also a major producer of yttrium concentrate from the mineral xenotime. Production of xenotime from Malaysia through 1986 was as follows:

	Quantity (metric tons)
1982	14
1983	13
1984	384
1985	1,124
1986	145

Thailand.—A heavy-mineral sands mine at Chumphon began operation in November 1986. Monazite production from the mine for the final 2 months of 1986 was 140 tons.[30]

Monazite and xenotime were produced as byproducts of processing mineral sands for tin. Monazite was produced in 1986 at Prachuap Khiri Khan in the central region, and at Chumphon, Phuket, Ranong, and Takua Pa in the southern region. Thailand reportedly exported 1,205 tons of monazite in 1986 to Canada, France, and the United Kingdom. During the same year, xenotime was produced only from the mine at Phuket, and 33 tons was reportedly exported to France and the Netherlands. Production of xenotime concentrates through 1986 was as follows:

	Quantity (metric tons)
1982	46
1983	38
1984	28
1985	158
1986	28

United Kingdom.—Swift Levick Supermagloy Ltd. (SLS), part of the rare-earth permanent magnet division of the Magnetic Materials Group of the United Kingdom, announced the commissioning of a new plant to supply magnets. SLS currently produces 12 tons per year of rare-earth magnets from a plant at Swindon. The new plant, to be built at Rotherham, has a planned capacity of 50 tons per year.[31]

Table 5.—Monazite concentrate: World production, by country[1]

(Metric tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Australia	15,141	16,260	18,735	14,822	12,000
Brazil	5,256	3,622	1,895	1,947	2,000
India[e 3]	4,000	4,000	4,000	4,000	4,000
Malaysia[4]	1,051	[r]4,980	5,808	5,959	6,000
Mozambique[e]	[5]4	4	4	4	4
Sri Lanka[e]	300	[5]147	200	200	200
Thailand	277	298	245	1,609	1,500
United States	W	W	W	W	W
Zaire	15	2	--	--	--
Total	26,044	[r]29,313	30,887	28,541	25,704

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

[1]Table includes data available through Apr. 29, 1988.

[2]In addition to the countries listed, China, Indonesia, North Korea, the Republic of Korea, Nigeria, and the U.S.S.R. may produce monazite, but output, if any, is not reported quantitatively, and available information is inadequate to make reliable estimates of output levels.

[3]Data are for year beginning Apr. 1 of that stated.

[4]The 1983 figure is exports and the 1984-87 figures are production.

[5]Reported figure.

Table 6.—Rare earths: World production, by country

(Metric tons of REO equivalent)

Country	1985	1986[p]	1987[e]
Australia	10,304	8,152	6,600
Brazil	1,042	1,071	1,100
Canada	--	NA	NA
China	8,500	11,860	15,100
India[e]	2,200	2,200	2,200
Malaysia	3,869	3,364	3,300
Mozambique[e]	2	2	2
Sri Lanka[e]	110	110	110
Thailand	230	902	825
United States[1]	13,428	11,094	16,710
Total	39,685	38,755	45,947

[e]Estimated. [p]Preliminary. NA Not available.

[1]Comprises only the rare earths derived from bastnasite as reported in Unocal Corp. annual report, 1987.

TECHNOLOGY

The Rare-Earth Information Center at Iowa State University, Ames, IA, inaugurated a limited circulation monthly newsletter entitled "RIC Insight." The publication will deal with current technological advances and conferences related to rare earths.[32]

Researchers at General Motors Corp. designed a solar-powered car using rare-earth permanent magnets that won the 3,200-kilometer World Solar Challenge in Australia. The high-efficiency (92%) electric motors used in the car each incorporated 6 neodymium-iron-boron magnets and produced 2 horsepower at 4,000 revolutions per minute at a weight of 3.7 kilograms.

A fiber-optic temperature sensor was developed using neodymium-doped glass bonded to two optical fibers: one to deliver laser-emitted radiation and the other to transmit the resulting fluorescence to a receiver. Based on the change of fluorescence decay time with temperature, the sensor used glass doped with 9% neodymium. It was operable in the range of -50° to 300° C.[33]

A magnesium alloy containing zirconium, along with yttrium and other rare earths, was developed by researchers at Magnesium Elektron Ltd. in the United Kingdom. Designated WE54, the new alloy has high-temperature stability up to 300° C, reportedly higher than any magnesium alloy now available. The alloy contains 0.5% zirconium, 5.5% yttrium, and 3.5% other rare earths. The new alloy will probably be used in aerospace applications.[34]

Rare-earth fertilizers have reportedly increased yields of wheat. Agricultural specialists in China's Henan Province conducted experiments on more than 27,300 hectares of land planted in wheat. By adding rare earths over a 3-year period, the crop yield improved 5% to 8% and had higher contents of protein and lysine.[35]

Researchers used rare earths to determine the source of an impact that occurred 65 million years ago at the boundary of the Cretaceous and Tertiary periods (K-T boundary). The cause of the impact, which triggered a mass extinction, including possibly that of the dinosaurs, remains in controversy. The relative abundance of rare-earth elements produces patterns that reflect the origins of the rock.[36] The rare-earth pattern in the K-T boundary indicated material excavated near a continent, possibly in the eastern Pacific. If true, the location of the impact may never be found. Since part of the ocean crust has been subducted beneath North America.[37]

A rare-earth laser system was developed that rapidly detects airborne beryllium particles, a known carcinogen. Scientists at Los Alamos National Laboratory in New Mexico used a neodymium:yttrium-aluminum garnet (Nd:YAG) laser to perform laser-induced spectroscopy to vaporize and analyze material on a target filter. The new rare-earth system can analyze for beryllium in 2.5 minutes compared to as much as 8 hours for chemical analysis.[38]

An Nd:YAG laser was also used in a recently developed measurement system for water depth. The system, known as a scanning lidar bathymeter, is used for airborne hydrographic surveying down to depths of 40 meters in clear coastal water. It operates by emitting a short pulse of infrared and a short pulse of visible (green) radiation from a dual frequency Nd:YAG laser. The infrared pulse is scattered from the water surface, while the green pulse penetrates and is scattered by the bottom. Both pulses are detected by a receiver that computes the water depth based on the time elapsed between pulse scatterings.[39]

Yttria-stabilized composite materials of zirconia bonded-zirconia fibers were produced with highly efficient thermal insulating properties. Able to withstand temperatures up to 2,316° C, the insulation, designated ZZX-4200, was developed by scientists at Martin-Marietta Energy Systems in Oak Ridge, TN. Insulating efficiency was improved by orienting the fibers perpendicularly to the wall thickness of the structure, reportedly halving heat flow when compared to homogeneous and randomly oriented fibers. Comparable materials have been efficient up to about 1,760° C.[40]

A review of processes used to produce neodymium metal and certain neodymium alloys was published. Electrolytic and metallothermic processes were discussed, including calciothermic reduction for producing neodymium commercially for use in high-strength permanent magnets.[41]

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Salt

By Dennis S. Kostick[1]

Production and sales of salt decreased for the second consecutive year because of a decline in demand for salt for water treatment and highway deicing.

Apparent consumption of salt decreased slightly in response to a decline in domestic demand and trade. Exports of salt decreased 54% to the lowest level since 1983. Imports for consumption of salt decreased 14%; the lowest level reported since 1982.

Domestic Data Coverage.—Domestic production data for salt are developed by the Bureau of Mines from two voluntary surveys of U.S. operations. Typical of the surveys is the salt company survey. Of the 74 operations to which a survey request was sent, 71 responded, representing 96% of the total production shown in table 1. Production for the three nonrespondents was estimated on the basis of their prior response to the 1987 production estimate survey.

Table 1.—Salient salt statistics

(Thousand short tons and thousand dollars)

	1983	1984	1985	1986	1987
United States:					
Production[1]	32,973	39,181	39,217	37,282	36,943
Sold or used by producers[1]	34,573	39,225	40,067	36,663	36,493
Value	$597,081	$675,099	$739,609	$665,400	$684,170
Exports	517	820	904	1,165	541
Value	$12,368	$15,299	$15,988	$16,928	$8,217
Imports for consumption	5,997	7,545	6,207	6,665	5,716
Value	$60,194	$74,100	$65,593	$79,709	$66,936
Consumption, apparent[2]	40,053	45,950	45,370	42,163	41,668
World: Production	[r]175,099	[r]190,070	191,628	[p]194,720	[e]195,594

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Excludes Puerto Rico.
[2]Sold or used plus imports minus exports.

DOMESTIC PRODUCTION

The total quantity of all types of salt produced by domestic producers decreased slightly, based on an incomplete survey of the industry. Salt sold or used for captive purposes, primarily chloralkali manufacture, also decreased slightly. According to the Bureau of Mines survey for 1987, 33 companies operated 67 salt-producing plants in 15 States. Eight of the companies and 10 of the plants produced more than 1 million short tons each and accounted for 80% and 60%, respectively, of the U.S. total. Many individual companies and plants produced more than one type of salt. In 1987, 13 companies (19 operations) produced solar-evaporated salt; 7 companies (18 operations), vacuum pan and open pan salt; 10 companies (15 operations), rock salt; and 17 companies (27 operations), salt brine.

The five leading States in quantity of salt sold or used were Louisiana, 34%; Texas, 21%; New York, 13%; Ohio, 9%; and Kansas, 5%. A significant quantity of the salt produced in Alabama, Kansas, Louisiana, New York, North Dakota, Ohio, Texas, Utah, and West Virginia was produced as brine, of which the majority was consumed captively to manufacture chlorine and caustic soda.

The percentage of salt sold or used by U.S. producers, by type, was as follows:

	1986	1987
Salt in brine	49	49
Mined rock	34	33
Vacuum pan salt and grainer or open pan salt	10	11
Solar-evaporated salt	7	7
Total	100	100

Diamond Crystal Salt Co. bought Sol-Aire Salt and Chemical Co. from AMAX Inc. at the beginning of the year. Sol-Aire had a solar salt complex on the Great Salt Lake in Utah. The acquisition allowed Diamond Crystal to expand its market, which predominantly was in the Eastern United States. However, later in the year, Diamond Crystal, once one of the largest domestic salt producers, was sold for $65 million to International Salt Co., a subsidiary of Akzo NV, a large Netherlands chemical corporation. Diamond Crystal, which operated salt facilities in Michigan, North Dakota, Ohio, and Utah, claimed that the sale was necessary because it was no longer competitive with large international salt companies.[2]

Geostow Inc., a joint venture of Geostock, a U.S. affiliate of a French company, and Northeastern Waste Systems Inc. of Buffalo, NY, acquired surface and underground cavity rights to 10,000 acres of mined-out sections of International Salt's Retsof rock salt mine in New York. Geostow plans to store ash containing dioxins from coal-burning powerplants and solid waste incinerators 1,200 feet below the surface, despite objections from the salt company and local residents. The State's Department of Environmental Quality favors incineration over landfills as a long-term solution to solid waste problems, and the Geostow project could accommodate all incinerator ash in New York for the next 28 to 50 years, if approved. The company filed for State permits at yearend.[3]

Table 2.—Salt production in the United States

(Thousand short tons)

Year	Vacuum pans and open pans	Solar	Rock	Brine	Total
1983	3,697	2,053	9,449	17,774	32,973
1984	3,629	2,705	13,653	19,195	[1]39,181
1985	3,613	2,549	13,990	19,065	39,217
1986	3,637	2,679	13,333	17,633	37,282
1987	3,776	3,120	12,230	17,817	36,943

[1]Data do not add to total shown because of independent rounding.

Table 3.—Salt produced in the United States, by product form and type

(Thousand short tons)

Product form	Vacuum pans and open pans	Solar	Rock	Brine	Total
1986					
Bulk	636	1,816	12,751	17,633	32,836
Compressed pellets	923	92	XX	XX	1,015
Packaged	1,769	678	515	XX	2,962
Pressed blocks	309	93	67	XX	469
Total	3,637	2,679	13,333	17,633	37,282
1987					
Bulk	682	2,220	11,671	17,817	32,390
Compressed pellets	984	99	XX	XX	1,083
Packaged	1,787	712	488	XX	2,987
Pressed blocks	324	90	71	XX	485
Total[1]	3,776	3,120	12,230	17,817	36,943

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

Table 4.—Salt sold or used[1] in the United States, by product form and type

(Thousand short tons and thousand dollars)

Product form	Vacuum pans and open pans		Solar		Rock		Brine		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1986										
Bulk	606	25,842	1,701	23,745	11,927	151,786	17,920	92,210	32,154	293,583
Compressed pellets	920	88,686	93	6,194	XX	XX	XX	XX	1,013	94,880
Packaged:										
Less-than-5-pound units	151	NA	1	NA	34	NA	XX	XX	186	NA
More-than-5-pound units	1,600	NA	675	NA	570	NA	XX	XX	2,845	NA
Total	1,751	184,569	676	28,755	604	30,062	XX	XX	3,031	243,386
Pressed blocks:										
For livestock	148	NA	55	NA	1	NA	XX	XX	204	NA
For water treatment	158	NA	37	NA	66	NA	XX	XX	261	NA
Total	306	22,491	92	5,580	67	5,480	XX	XX	465	33,551
Grand total	3,583	321,588	2,562	64,274	12,598	187,328	17,920	92,210	36,663	665,400
1987										
Bulk	661	26,521	1,731	23,927	11,331	141,637	18,124	89,363	31,847	281,448
Compressed pellets	983	95,840	99	6,983	XX	XX	XX	XX	1,082	102,823
Packaged:										
Less-than-5-pound units	156	NA	1	NA	32	NA	XX	XX	189	NA
More-than-5-pound units	1,653	NA	705	NA	529	NA	XX	XX	2,888	NA
Total[2]	1,809	202,940	706	33,512	561	28,863	XX	XX	3,076	265,315
Pressed blocks:										
For livestock	156	NA	54	NA	1	NA	XX	XX	211	NA
For water treatment	167	NA	36	NA	72	NA	XX	XX	275	NA
Total[2]	323	22,857	90	6,090	73	5,637	XX	XX	487	34,584
Grand total[2]	3,776	348,158	2,627	70,513	11,965	176,137	18,124	89,363	36,493	684,170

NA Not available. XX Not applicable.

[1]As reported at salt production locations. The term "sold or used" indicates that some salt, usually salt brine, is not sold but is used for captive purposes by the plant or company. Because data do not include salt imported, purchased, or sold from inventory from regional distribution centers, salt sold or used by type may differ from totals shown in tables 7 and 8, which are derived from company reports.

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

Table 5.—Salt sold or used[1] by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1986		1987	
	Quantity	Value	Quantity	Value
Kansas[2]	1,656	68,887	1,689	70,148
Louisiana	11,608	103,611	12,498	108,999
New York	5,071	122,601	4,918	119,962
Ohio	4,115	126,757	3,276	104,099
Texas	8,520	62,996	7,810	60,857
Utah	1,112	31,830	1,108	34,264
Other[3]	4,581	148,718	5,194	185,841
Total	36,663	665,400	36,493	684,170
Puerto Rico[e]	40	880	40	900

[e]Estimated.
[1]The term "sold or used" indicates that some salt, usually salt brine, is not sold but is used for captive purposes by the plant or company.
[2]Quantity and value of brine included with "Other."
[3]Includes Alabama, Arizona, California, Kansas (brine only), Michigan, Nevada, New Mexico, North Dakota, Oklahoma, and West Virginia.

Table 6.—Evaporated salt sold or used[1] by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1986		1987	
	Quantity	Value	Quantity	Value
Kansas	856	60,221	893	61,263
Louisiana	193	18,747	212	20,086
New York	739	62,884	775	63,184
Utah	1,068	30,901	1,055	33,734
Other[2]	3,289	213,109	3,466	240,403
Total	6,145	385,862	[3]6,403	418,670
Puerto Rico[e]	40	880	40	900

[e]Estimated.
[1]The term "sold or used" indicates that some salt, usually salt brine, is not sold but is used for captive purposes by the plant or company.
[2]Includes Arizona, California, New Mexico, Michigan, North Dakota, Ohio, Oklahoma, and Texas.
[3]Data do not add to total shown because of independent rounding.

CONSUMPTION AND USES

Increased demand for caustic soda and chlorine in the alumina and pulp-bleaching markets, respectively, contributed to higher salt brine production and consumption for chloralkali manufacture. However, because of incomplete survey results, salt brine production and consumption totals are underreported for 1987. The chlorine and caustic soda industry, which traditionally has been the largest end-use market, required about 19.7 million tons of salt for feedstock, based on the stoichiometric calculation of 1.8 tons of salt needed to produce 1 ton of chlorine and 1.1 tons of coproduct caustic soda. Because many chloralkali companies closed or placed on standby plants that were uneconomic to maintain, the industry reached a record high 98% average effective capacity utilization in 1987 compared with 89% achieved in 1986.

Production of chlorine gas and sodium hydroxide, as reported by the Bureau of the Census, was as follows, in thousand short tons:

	1986[r]	1987
Chlorine gas (100%)	10,436	10,980
Sodium hydroxide, liquid (100%)	10,691	11,518

[r]Revised.

Chevron Chemical Co. began producing a new road deicer made of calcium-magnesium-acetate (CMA), which is reportedly one-fifteenth as corrosive as salt. Although CMA costs about $400 per ton and rock salt sells for only about $15 per ton, tests proceeded on CMA as a salt substitute on roads in environmentally sensitive areas in California, Michigan, and Wisconsin.

Table 7.—Distribution of domestic and imported salt by producers in the United States, by end use and type

(Thousand short tons)

End use	SIC	Vacuum pans and open pans		Solar		Rock		Salt in brine	Total[1]		
		Domestic	Imported	Domestic	Imported	Domestic	Imported		Domestic	Imported	Grand
1986											
Chemical:											
Chloralkali producers	2812	40	--	406	W	1,313	W	16,856	18,615	368	18,983
Other chemical	28 (excludes 2812, 2899)	373	W	91	W	241	W	51	757	62	818
Total		413	W	497	228	1,554	W	16,907	19,372	430	19,801
Food-processing industry:											
Meat packers	201	159	W	93	11	164	W	--	417	19	436
Dairy	202	94	--	2	3	3	(2)	--	100	3	103
Canning	2091, 203	118	(2)	39	27	79	5	1	238	33	271
Baking	205	116	(2)	7	W	8	W	--	132	2	134
Grain mill products	204 (excludes 2047)	61	--	(2)	W	16	W	--	77	2	79
Other food processing	206-208, 2047, 2099	130	W	14	9	41	W	(2)	186	16	202
Total[1]		680	5	157	53	312	17	1	1,150	75	1,225
General industrial:											
Textiles and dyeing	22	85	W	30	W	35	(2)	4	154	72	226
Metal processing	33, 34, 35, 37	14	(2)	12	9	265	4	(2)	291	13	304
Rubber	2822, 30 (excludes 3079)	2	--	2	1	3	--	125	132	1	133
Oil	13, 29	40	--	288	11	63	1	222	614	13	627
Pulp and paper	26	20	W	178	29	73	(2)	5	276	31	307
Tanning and/or leather	311	11	(2)	62	2	76	W	--	148	4	152
Other industrial	9621	85	(2)	77	W	51	W	1	214	54	268
Total[1]		256	41	649	131	566	16	357	1,829	188	2,017
Agricultural:											
Feed retailers and/or dealers-mixers		374	W	245	33	279	W	(2)	898	42	940
Feed manufacturers	2048	66	W	147	W	157	(2)	--	370	18	388
Direct-buying end users	02	17	W	11	W	7	(2)	--	36	1	37
Total		457	8	403	W	443	W	(2)	1,304	61	1,365

See footnotes at end of table.

Table 7.—Distribution of domestic and imported salt by producers in the United States, by end use and type —Continued

(Thousand short tons)

End use	SIC	Vacuum pans and open pans		Solar		Rock		Salt in brine	Total[1]		
		Domestic	Imported	Domestic	Imported	Domestic	Imported		Domestic	Imported	Grand
1986 —Continued											
Water treatment:											
Government (Federal, State, local)	2899	22	W	100	W	223	5	1	347	20	367
Commercial or other	2899	19	--	66	W	37	W	13	135	23	158
Total[1]		41	W	166	37	261	W	14	483	43	525
Ice control and/or stabilization:											
Government (Federal, State, local)	9621	6	W	132	W	7,979	1,826	1	8,118	2,079	10,197
Commercial or other	5159	19	W	12	W	288	W	--	319	24	343
Total		25	1	144	277	8,267	1,826	1	8,437	2,104	10,541
Distributors:											
Agricultural distribution	5159	70	W	80	W	82	W	--	232	54	286
Grocery wholesalers and/or retailers	514, 54	629	W	136	55	120	W	--	885	61	946
Institutional wholesalers and end users.	58, 70	25	W	4	W	114	W	--	143	6	150
Water-conditioning distribution	7399	291	W	259	216	249	W	(2)	799	229	1,028
U.S. Government resale	9199	6	--	1	W	1	W	--	8	1	9
Other wholesalers and/or retailers	5251	660	W	138	185	552	W	--	1,350	206	1,556
Total[1]		1,681	22	619	478	1,118	59	(2)	3,418	559	3,975
Other n.e.s.[3]		77	7	138	16	209	19	329	753	42	795
Grand total[1]		3,629	101	2,776	1,273	12,730	2,127	17,610	36,745	[4]3,501	40,246

1987											
Chemical:											
Chloralkali producers	2812	48	--	355	W	1,361	W	16,066	17,830	125	17,955
Other chemical	28 (excludes 2812, 2899)	355	W	94	41	216	W	422	687	73	760
Total		383	W	449	41	1,577	W	16,108	18,517	198	18,715
Food-processing industry:											
Meat packers	201	172	W	46	8	216	W	--	434	18	452
Dairy	202	103	--	3	2	3	W	([2])	108	2	110
Canning	2091, 203	133	W	38	26	92	W	1	264	32	296
Baking	205	139	--	9	W	9	W	--	157	1	158
Grain mill products	204 (excludes 2047)	64	--	1	W	11	--	--	76	([2])	76
Other food processing	206-208, 2047, 2099	148	W	25	10	40	W	([2])	213	16	229
Total		759	5	122	46	371	17	1	1,252	69	1,321
General industrial:											
Textiles and dyeing	22	95	W	11	33	39	W	5	150	87	237
Metal processing	33, 34, 35, 37	14	W	11	12	269	W	([2])	294	17	311
Rubber	2822, 30 (excludes 3079)	1	--	3	W	3	W	138	145	W	145
Oil	13, 29	44	--	267	W	66	W	201	577	20	597
Pulp and paper	26	25	W	228	36	82	W	13	348	39	387
Tanning and/or leather	311	14	W	39	W	68	W	--	120	4	124
Other industrial	9621	100	W	63	17	58	W	3	224	23	247
Total[1]		293	56	622	119	585	16	361	1,858	191	2,049
Agricultural:											
Feed retailers and/or dealers-mixers		401	W	201	37	345	W	--	947	48	995
Feed manufacturers	2048	66	--	95	W	233	W	--	394	22	416
Direct-buying end users	02	18	--	13	W	10	W	--	41	1	42
Total		485	W	309	59	588	W	--	1,382	71	1,453

See footnotes at end of table.

Table 7.—Distribution of domestic and imported salt by producers in the United States, by end use and type —Continued

(Thousand short tons)

End use	SIC	Vacuum pans and open pans		Solar		Rock		Salt in brine	Total[1]		
		Domestic	Imported	Domestic	Imported	Domestic	Imported		Domestic	Imported	Grand
1987 —Continued											
Water treatment:											
Government (Federal, State, local)	2899	22	--	27	13	162	W	2	212	15	227
Commercial or other	2899	18	--	81	14	40	W	11	150	15	165
Total		40	--	108	27	202	W	13	362	30	392
Ice control and/or stabilization:											
Government (Federal, State, local)	9621	5	1	138	168	7,645	1,508	3	7,791	1,676	9,467
Commercial or other	5159	13	1	28	16	272	82	--	313	98	411
Total		18	2	166	184	7,917	1,590	3	8,104	1,774	9,878
Distributors:											
Agricultural distribution	5159	78	W	71	W	105	W	--	254	48	302
Grocery wholesalers and/or retailers	514, 54	646	W	175	W	121	W	--	942	65	1,007
Institutional wholesalers and end users.	58, 70	28	--	4	W	99	W	(2)	130	7	137
Water-conditioning distribution	7399	309	W	276	W	229	W	(2)	814	249	1,063
U.S. Government resale	9199	7	--	3	W	1	W	(2)	11	1	12
Other wholesalers and/or retailers	5251	703	W	114	W	647	W	(2)	1,463	197	1,660
Total		1,771	18	643	471	1,202	79	(2)	3,614	567	4,181
Other n.e.s.[3]		104	4	348	27	162	24	1,080	1,694	55	1,749
Grand total[1]		3,851	116	2,767	975	12,603	1,867	17,567	36,788	[4]2,957	39,747

W Withheld to avoid disclosing company proprietary data; included in "Total" and "Grand Total."
[1]Data may not add to totals shown because of independent rounding. Because data includes salt imported, produced, and/or sold from inventory from regional distribution centers, salt sold or used by type may differ from totals shown in tables 1, 4, 5, and 6, which are derived from plant reports at salt production locations. Data may differ from totals shown in table 8 because of changes in inventory and/or incomplete data reporting.
[2]Less than 1/2 unit.
[3]Includes exports.
[4]Imported for distribution by U.S. producers; included in totals in tables 11, 12, and 13.

Table 8.—Distribution of domestic and imported evaporated and rock salt[1] in the United States, by destination

(Thousand short tons)

Destination	1986 Evaporated: Vacuum pans and open pans	1986 Evaporated: Solar	1986 Rock	1987 Evaporated: Vacuum pans and open pans	1987 Evaporated: Solar	1987 Rock
Alabama	48	(2)	330	52	(2)	354
Alaska	3	W	--	1	W	--
Arizona	6	58	3	7	61	W
Arkansas	31	1	56	33	W	60
California	150	842	1	157	900	W
Colorado	19	125	51	19	101	80
Connecticut	11	11	223	11	11	283
Delaware	2	32	7	2	14	28
District of Columbia	1	(2)	W	1	(2)	W
Florida	90	W	30	93	67	29
Georgia	67	W	81	77	28	88
Hawaii	W	W	--	W	W	--
Idaho	5	78	W	6	60	W
Illinois	358	79	1,134	372	67	1,002
Indiana	149	32	650	154	40	605
Iowa	151	43	250	162	43	211
Kansas	93	17	259	96	20	299
Kentucky	39	W	388	41	W	440
Louisiana	44	W	320	54	W	352
Maine	6	W	223	6	64	150
Maryland	46	W	163	47	107	237
Massachusetts	33	46	531	36	8	656
Michigan	W	W	1,527	242	19	927
Minnesota	145	127	369	168	130	282
Mississippi	23	(2)	W	21	(2)	115
Missouri	112	17	302	120	19	418
Montana	2	34	W	2	42	W
Nebraska	86	32	172	93	35	133
Nevada	W	W	W	W	186	W
New Hampshire	2	W	W	2	22	191
New Jersey	126	153	295	118	172	281
New Mexico	6	W	2	5	W	2
New York	248	W	W	258	97	2,092
North Carolina	152	85	W	173	102	71
North Dakota	37	10	5	53	11	7
Ohio	W	19	1,596	328	24	1,351
Oklahoma	38	W	6740	W	69	
Oregon	W	55	--	11	56	1
Pennsylvania	162	104	1,015	172	119	1,039
Rhode Island	6	4	W	5	3	105
South Carolina	38	W	12	40	9	13
South Dakota	39	26	39	44	26	35
Tennessee	67	(2)	625	69	(2)	610
Texas	153	82	197	160	92	208
Utah	4	169	W	4	192	W
Vermont	6	W	189	6	W	152
Virginia	75	120	106	77	117	201
Washington	W	406	(2)	18	222	(2)
West Virginia	16	W	172	14	W	181
Wisconsin	223	48	927	223	53	707
Wyoming	W	24	1	1	28	1
Other[3]	598	835	2,720	71	375	404
Total[4]	3,716	3,713	15,040	3,965	3,742	14,470

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Each salt type includes domestic and imported quantities. Excludes brine because it usually is not shipped out of State.
[2]Less than 1/2 unit.
[3]Includes shipments to overseas areas administered by the United States, Puerto Rico, exports, some shipments to unspecified destinations, and shipments to States indicated by symbol W.
[4]Data may not add to totals shown because of independent rounding. Because data includes salt imported, purchased, and/or sold from inventory from regional distribution centers, evaporated and rock salt distributed by State may differ from totals shown in tables 1, 4, 5, and 6, which are derived from plant reports at salt production locations. Data may differ from totals shown in table 7 because of changes in inventory and/or incomplete data reporting.

The reported percent distribution of salt by major end use in 1987 was chemicals, 47%; ice control, 25%; distributors, 11%; food and agricultural, 7%; industrial, 5%; water treatment, 1%; and other combined with exports, 4%. For a complete end-use analysis in table 7, specific sectors of distribution, such as agricultural and water-treatment conditioning, can be combined with the primary agricultural and water categories.

STOCKS AND PURCHASES

Total yearend stocks reported by producers were 2.0 million tons. Most of these stocks were rock salt and solar salt. Many States, municipalities, distributors, and road-deicing contractors stockpiled additional quantities of salt in anticipation of adverse weather conditions.

Intraindustry purchases of salt amounted to 1.7 million tons, of which 65% was salt brine; rock salt, 23%; vacuum pan salt, 8%; and solar salt, 4%.

PRICES

Price quotations are not synonymous with average values reported to the Bureau of Mines. The quotations do not necessarily represent prices at which transactions actually occurred, nor do they represent bid and asked prices. They are quoted here to serve only as a reference to yearend price levels. The following yearend prices were quoted in Chemical Marketing Reporter.[4]

Salt, evaporated, common, 80-pound bags, carlots or truckloads, North, works, 80 pounds	$4.02
Salt, chemical-grade, same basis, 80 pounds	4.30
Salt, rock, medium coarse, same basis, 80 pounds	2.70
Bulk, same basis, per ton	$18.00-25.00
Sodium chloride, USP granular bags, per pound	0.29

Table 9.—Average values[1] of salt, by product form and type

(Dollars per short ton)

Product form	Vacuum pans and open pans	Solar	Rock	Brine
1986				
Bulk	42.65	13.95	12.73	5.15
Compressed pellets	96.37	66.66	XX	XX
Packaged	105.44	42.53	49.77	XX
Average[2]	91.27	23.76	14.51	5.15
Pressed blocks	73.61	60.47	81.49	XX
1987				
Bulk	40.12	13,82	12.50	4.93
Compressed pellets	97.50	70.54	XX	XX
Packaged	112.18	47.47	51.45	XX
Average[2]	94.21	25.40	14.34	4.93
Pressed blocks	70.76	67.67	77.22	XX

XX Not applicable.
[1]Net selling value, f.o.b. plant, excluding container costs.
[2]Salt value data previously reported were an aggregate value per ton of bulk, compressed pellets, and packaged salt. For time series continuity, an average of these three types of product forms is presented, which is based on the aggregated values and quantities of the product form for each type of salt shown in table 4.

FOREIGN TRADE

Although the United States imported nearly 11 times the quantity of salt that it exported, reduced domestic demand for salt resulted in a decrease in salt imports, primarily from Canada. This decrease in imports from Canada created a surplus in the Canadian salt supply, thereby affecting U.S. exports to Canada, which represented about 88% of the total U.S. export market. The balance of exports was distributed to 37 other countries.

More than 99% of total salt imports was bulk rock salt and solar salt. The Bahamas, Canada, Chile, and Mexico supplied 84% of total imports. The total for imports of bulk salt was adjusted by the Bureau of Mines to correct for an August 1987 shipment from Italy through the Philadelphia customs district, which was erroneously reported as 2.2 million tons instead of 22,000 tons.

Imports of salt in bags, sacks, barrels, and brine, primarily from Canada, the Federal Republic of Germany, the Republic of Korea, the Netherlands, and the United Kingdom, represented the remainder of imports.

Table 10.—U.S. exports of salt, by country

(Thousand short tons and thousand dollars)

Country	1986		1987	
	Quantity	Value	Quantity	Value
Argentina	(1)	20	1	13
Australia	(1)	14	(1)	30
Bahamas	(1)	45	1	28
Brazil	42	704	--	--
Canada	1,091	13,265	477	6,839
Costa Rica	(1)	99	(1)	8
Denmark	2	17	(1)	22
Dominican Republic	(1)	31	3	65
Ecuador	1	234	--	--
Honduras	(1)	10	(1)	14
Kenya	(1)	171	--	--
Mexico	10	334	26	489
Netherlands Antilles	1	82	(1)	27
Saudi Arabia	6	1,170	24	421
South Africa, Republic of	(1)	4	--	--
United Arab Emirates	(1)	10	1	12
United Kingdom	6	195	--	--
Venezuela	(1)	22	(1)	4
Other	6	501	8	245
Total	1,165	16,928	541	8,217

[1]Less than 1/2 unit.

Source: Bureau of the Census; figures adjusted by the Bureau of Mines.

Table 11.—U.S. imports for consumption of salt

(Thousand short tons and thousand dollars)

Year	In bags, sacks, barrels, or other packages (dutiable)		Bulk (dutiable)	
	Quantity	Value	Quantity	Value
1984	71	2,386	[1]7,474	[1]71,714
1985	66	3,794	[2]6,141	[2]61,799
1986	70	3,170	[3]6,595	[3]76,539
1987	44	5,122	[4]5,672	[4]61,814

[1]Includes salt brine from Hong Kong, Iceland, and the United Kingdom through New York, NY, customs district, 500 pounds ($940); from the Federal Republic of Germany and Norway, through Chicago, IL, customs district, 110 short tons ($3,299); from Denmark through Detroit, MI, customs district, 23 short tons ($191); and from Japan through Charleston, SC, customs district, 110 pounds ($527).

[2]Includes salt brine from Spain through New York, NY, customs district, 1,987 short tons ($27,620); from Denmark through Cleveland, OH, customs district, 935 short tons ($76,714); from Japan through Charleston, SC, customs district, 691 short tons ($4,620); from Switzerland through Chicago, IL, customs district, 28 short tons ($2,533); and from the Federal Republic of Germany through Washington, DC, customs district, an undisclosed quantity valued at $5,444.

[3]Includes salt brine from Norway through Los Angeles, CA, customs district, 200 pounds ($1,606); from Denmark through Cleveland, OH, 3 short tons ($16,360); from the Federal Republic of Germany through Chicago, IL, 277 short tons ($12,834); and from Switzerland through Chicago, IL, 1,000 pounds ($3,588).

[4]Includes salt brine from Canada through Buffalo, NY, customs district, 79 short tons ($3,389); from Norway through Los Angeles, CA, customs district, 10 short tons ($1,396); from Denmark through Cleveland, OH, customs district, 4 short tons ($48,221); and from the Federal Republic of Germany through New York, NY, customs district, 708 short tons ($14,472). Data were adjusted to correct for erroneous notation of shipment from Italy in August.

Source: Bureau of the Census; figures adjusted by the Bureau of Mines.

Table 12.—U.S. imports for consumption of salt, by country

(Thousand short tons and thousand dollars)

Country	1986		1987	
	Quantity	Value	Quantity	Value
Bahamas	915	9,798	965	7,765
Canada[1]	2,944	26,932	2,002	24,330
Chile	312	3,153	415	3,682
France[2]	101	1,974	66	546
German Democratic Republic	--	--	14	63
Germany, Federal Republic of[3]	6	315	7	394
Italy[4]	135	2,289	[5]204	417
Mexico[6]	1,711	26,339	1,409	16,212
Netherlands	213	4,047	203	4,002
Netherlands Antilles	61	1,100	230	3,350
Spain[7]	124	1,351	41	446
Other	143	2,411	5,716	66,936
Total	6,665	79,709	5,716	66,936

[1]Includes salt in bags, sacks, and barrels through 7 customs districts, 34,241 short tons ($2,187,191) in 1986; and 10 customs districts, 32,050 short tons ($2,242,384) in 1987.
[2]Includes salt in bags, sacks, and barrels through 5 customs districts, 3,041 short tons ($69,401) in 1986; and 3 customs districts, 222 short tons ($77,933) in 1987.
[3]Includes salt in bags, sacks, and barrels through 8 customs districts, 6,152 short tons ($287,031) in 1986; and 6 customs districts, 2,542 short tons ($304,426) in 1987.
[4]Includes salt in bags, sacks, and barrels through 3 customs districts, 10 short tons ($156,204) in 1986; and 2 customs districts, 85 short tons ($28,123) in 1987.
[5]Adjusted to correct erroneous notation of shipment in August.
[6]Includes salt in bags, sacks, and barrels through 2 customs districts, 67 short tons ($12,295) in 1986; and 1 customs district, 273 short tons ($38,155) in 1987.
[7]Includes salt in bags, sacks, and barrels through 1 customs district, 1 short ton ($1,038) in 1986; and 2 customs districts, 32 short tons ($14,279) in 1987.

Source: Bureau of the Census; figures adjusted by the Bureau of Mines.

Table 13.—U.S. imports for consumption of salt, by customs district

(Thousand short tons and thousand dollars)

Customs district	1986		1987	
	Quantity	Value	Quantity	Value
Anchorage, AK	(1)	90	(1)	12
Baltimore, MD	311	3,241	269	2,643
Boston, MA	43	989	11	924
Buffalo, NY	1	61	5	85
Chicago, IL	355	4,137	165	2,125
Cleveland, OH	23	240	48	616
Detroit, MI	1,256	11,543	640	8,234
Duluth, MN	59	554	79	798
Los Angeles, CA	132	2,306	127	1,949
Milwaukee, WI	859	5,546	456	5,435
New Orleans, LA	194	2,424	203	2,545
New York, NY	345	6,696	508	5,678
Norfolk, VA	73	877	144	1,262
Ogdensburg, NY	11	130	118	1,318
Philadelphia, PA	189	2,552	[2]579	3,182
Portland, ME	510	4,265	465	5,092
Portland, OR	595	8,884	427	5,361
Providence, RI	259	2,754	255	2,682
St. Albans, VT	6	174	1	54
San Juan, PR	21	381	16	287
Savannah, GA	361	3,797	396	3,625
Seattle, WA	639	11,680	464	5,369
Tampa, FL	129	1,401	56	1,066
Wilmington, NC	287	4,838	255	4,242
Other	7	149	29	2,352
Total	6,665	79,709	5,716	66,936

[1]Less than 1/2 unit.
[2]Adjusted to correct erroneous notation of shipment from Italy in August.

Source: Bureau of the Census; figures adjusted by the Bureau of Mines.

WORLD REVIEW

Botswana.—The Government formed a joint venture with African Explosives and Chemical Industries Inc. of the Republic of South Africa to produce soda ash and salt from underground brines in the Sua Pan. The project was anticipated to produce 600,000 tons of salt annually.[5]

China.—The largest known salt deposit in China was discovered in Jiangsu Province. The deposit contained reserves of 200 to 400 million tons of salt. Two other deposits with reserves of 44 million and 3 million tons were also discovered in Jiangsu.[6] Near Laizhou Bay in Shandong Province, an underground salt brine deposit was discovered containing about 400,000 tons of salt.[7] Once developed, these deposits are expected to provide salt as feedstock for many proposed chemical and industrial projects in China.

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

(Thousand short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Afghanistan[e]	11	11	11	11	11
Albania[e]	80	80	80	82	83
Algeria	[e]165	193	185	209	220
Angola[e]	60	55	11	11	11
Argentina:					
Rock salt	1	1	1	1	1
Other salt	746	[r]1,032	1,595	1,342	1,300
Australia (marine salt and brine salt)	5,699	6,278	[e]6,800	[e]6,800	6,800
Austria:					
Rock salt	1	1	1	2	1
Evaporated salt	396	462	483	536	500
Salt in brine	155	263	254	276	280
Bahamas[e]	950	960	940	[3]1,092	[3]894
Bangladesh[4]	268	741	539	[e]550	550
Benin[e]	([5])	([5])	([5])	([5])	([5])
Brazil:					
Rock salt	[6]1,023	1,046	1,097	[e]1,100	1,100
Marine salt	[6]3,592	3,944	1,911	[e]2,800	2,800
Bulgaria	95	98	98	100	100
Burma[7]	317	309	353	354	370
Cambodia[e]	45	45	45	45	45
Canada	9,482	11,282	11,117	11,389	11,000
Chile	788	690	831	1,138	960
China[e]	17,780	17,950	[3]15,924	19,070	19,800
Colombia:					
Rock salt	[r]299	299	260	250	[3]226
Marine salt	[r]466	[r]732	545	552	[3]496
Costa Rica (marine salt)[e]	120	120	[3]33	33	33
Cuba	198	204	244	254	250
Cyprus	--	--	8	7	7
Czechoslovakia	265	268	[e]270	[e]270	270
Denmark	449	577	586	[e]550	550
Dominican Republic[e]	70	70	[3]52	60	60
Egypt	1,012	953	1,170	[e]1,400	1,400
El Salvador[e]	2	3	3	3	3
Ethiopia:[e 4]					
Rock salt	17	17	17	17	17
Marine salt	121	130	130	130	130
France:					
Rock salt	311	249	407	425	410
Brine salt	1,184	1,240	1,272	1,240	1,250
Marine salt	1,493	1,522	1,569	1,775	1,820
Salt in solution	4,673	4,869	4,593	4,368	4,410
German Democratic Republic:					
Rock salt	3,384	3,390	3,395	3,390	3,390
Marine salt	62	64	64	65	65
Germany, Federal Republic of: Marketable:					
Rock salt	6,906	7,837	10,642	10,048	10,100
Marine salt and other salt	5,074	5,624	3,765	4,395	4,400
Ghana[e]	55	55	55	55	55
Greece	176	146	165	[e]165	165
Guatemala	17	[e]18	19	43	[3]41
Honduras[e]	35	35	35	35	35
Iceland	1	1	1	[e]2	2

See footnotes at end of table.

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

(Thousand short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
India:					
Rock salt[e]	[3]5	6	4	[r]2	2
Marine salt	7,725	8,514	10,885	11,151	12,100
Indonesia	681	408	[e]660	550	
Iran[8]	752	762	775	[r] [e]770	770
Iraq[e]	90	90	80	80	80
Israel[e]	160	160	170	170	170
Italy:					
Rock salt and brine salt	3,807	3,588	3,501	3,784	3,600
Marine salt[9]	811	797	628	[e]660	640
Japan[10]	1,015	1,053	[e]1,300	1,510	[3]1,540
Jordan	37	24	35	[e]35	35
Kenya:					
Rock salt	[e]70	80	73	[r] [e]70	70
Other salt	[e]26	31	28	39	40
Korea, North[e]	630	630	630	630	630
Korea, Republic of	530	571	709	804	[3]732
Kuwait	[e]22	23	23	[e]23	23
Laos[e]	11	9	11	33	33
Lebanon[e]	6	6	6	6	6
Leeward and Windward Islands[e]	55	55	55	55	55
Libya[e]	13	13	13	13	13
Madagascar[e]	33	33	33	33	33
Mali[e]	5	5	5	5	5
Malta	([5])	([5])	([5])	[e]([5])	([5])
Mauritania[e]	6	6	6	6	6
Mauritius[e]	7	7	7	7	7
Mexico	6,287	6,798	7,129	6,533	6,600
Mongolia[e]	18	18	18	18	18
Morocco	77	69	102	106	[3]119
Mozambique[e]	30	30	30	30	30
Namibia (marine salt)	151	97	168	[e]150	150
Netherlands	3,444	4,050	4,579	4,148	[3]4,386
Netherlands Antilles[e]	[3]312	390	390	390	390
New Zealand	89	63	[e]70	[e]70	70
Nicaragua[e]	20	17	17	17	17
Niger[e]	3	3	3	3	3
Pakistan:[4]					
Rock salt	629	659	643	635	550
Other salt	[e]210	[e]200	296	267	320
Panama (crude)	[11]94	20	18	11	11
Peru	165	279	226	440	440
Philippines	421	442	464	866	550
Poland:					
Rock salt	1,246	1,306	1,323	1,346	[3]1,357
Other salt	2,750	3,887	4,040	4,630	[3]5,442
Portugal:					
Rock salt	467	502	510	506	510
Marine salt[e]	120	120	130	120	120
Romania	5,066	5,373	5,532	5,903	5,950
Senegal	190	182	176	160	110
Sierra Leone[e]	220	220	220	220	220
Somalia[e]	33	33	33	33	33
South Africa, Republic of	820	679	796	829	[e]776
Spain:					
Rock salt	2,214	2,376	2,381	[e]2,300	2,300
Marine salt and other evaporated salt	1,267	1,359	1,190	[e]1,100	1,100
Sri Lanka	142	118	85	115	[3]127
Sudan	80	80	[3]42	44	44
Switzerland	349	410	412	[e]400	410
Syria	96	96	[e]100	[e]100	100
Taiwan	87	241	206	150	[3]240
Tanzania	31	24	23	24	25
Thailand:					
Rock salt	6	11	14	2	5
Other salt[e]	180	180	180	180	180
Tunisia	413	364	421	457	460
Turkey	1,390	1,422	1,311	1,292	[3]1,342
Uganda[e]	6	6	6	6	6
U.S.S.R	17,857	18,200	17,747	[e]17,700	17,700
United Kingdom:					
Rock salt	1,451	1,730	2,238	[e]2,200	2,200
Brine salt[12]	1,537	1,569	1,711	[e]1,700	1,700
Other salt[12]	3,969	4,557	3,928	[e]3,900	3,900

See footnotes at end of table.

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

(Thousand short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
United States including Puerto Rico (sold or used by producers):					
Rock salt	9,941	13,355	14,690	12,598	[3]11,965
Other salt:					
United States	24,632	25,871	25,377	24,065	[3]24,527
Puerto Rico[e]	32	30	35	40	40
Venezuela[e]	[3]342	360	390	[r]463	440
Vietnam[e]	980	880	[r]320	[r]500	250
Yemen (Aden)[e]	80	80	80	80	80
Yemen (Sanaa)[e]	155	160	[3]165	[3]331	[3]180
Yugoslavia	459	419	450	556	550
Total	[r]175,099	[r]190,070	191,628	194,720	195,594

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through July 8, 1988.
[2]Salt is produced in many other countries, but quantities are relatively insignificant and reliable production data are not available. Some salt brine production data for the manufacture of chlorine, caustic soda, and soda ash are not reported because of incomplete data reporting by many countries.
[3]Reported figure.
[4]Data are for year ending June 30 of that stated.
[5]Less than 1/2 unit.
[6]Data represent sales.
[7]Brine salt production as reported by the Burmese Government was as follows, in short tons: 1983—221,502; 1984—89,470; 1985—49,061; 1986—57,413; and 1987—70,289.
[8]Data are for year beginning Mar. 21 of that stated.
[9]Does not include production from Sardinia and Sicily, estimated at 220,000 short tons annually.
[10]Data are for fiscal year ending Mar. 31 of that stated.
[11]Crude salt.
[12]Data captioned "Brine salt" for the United Kingdom are the quantities of salt obtained from the evaporation of brines; that captioned "Other salt" are the salt content of brines used for purposes other than production of salt by evaporation.

TECHNOLOGY

The Alabama Electric Cooperative planned to develop the Nation's first compressed-air energy storage facility in a salt dome near McIntosh, AL. Electricity from coal-fired generators will drive compressors to store the air in solution-mined salt formations during periods of low energy demand. The energy would be reclaimed during peak demand periods by passing the air through a combustion turbine to generate electricity. The facility would generate 50 megawatts of electricity, have a storage capacity of 26 hours, and be in operation by 1989.[8]

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[1]Physical scientist, Branch of Industrial Minerals.
[2]Free Press (Detroit, MI). Salt Division of Diamond Crystal Sold. July 30, 1987.
[3]Livonia Gazette (New York). Plans To Dump Ash Opposed by Salt Mine. Oct. 20, 1987.
[4]Chemical Marketing Reporter. V. 232, No. 26, Dec. 28, 1987, p. 35.
[5]European Chemical News. U.S. Cartel Tries To Halt Botswana Soda Ash Project. V. 49, No. 1297, Oct. 26, 1987, p. 6.
[6]Mining Magazine (London). World Highlights. Large Salt Find. V. 157, No. 2, 1987, p. 114.
[7]Industrial Minerals (London). Mineral Notes. Chinese Brine Deposit. No. 243, 1987, p. 94.
[8]The Daily Sentinel (Scottsboro, AL). Salt Dome is Storage Bin for Energy. Feb. 25, 1987.

Sand and Gravel

By Valentin V. Tepordei[1]

A total of 896 million short tons of construction sand and gravel was produced in the United States in 1987, the fifth consecutive year of growth. This level of production was a result of the growth that occurred in the last several years in the construction industry, mostly in highway maintenance and construction work, housing, and commercial construction.

Exports of construction sand and gravel decreased slightly in 1987, while imports for consumption increased by 38%, but remained at a very low volume. Domestic apparent consumption of construction sand and gravel in 1987 was 895 million tons.

Production of industrial sand and gravel increased about 2% over that of 1986, but remained below the production levels of 1984 and 1985. The production increase in 1987 was due to a slight improvement in demand for silica sand.

Exports of industrial sand and gravel in 1987 decreased 11%, while imports for consumption increased 18%. Domestic apparent consumption of industrial sand and gravel in 1987 was 27.4 million tons. Apparently, the low value of the U.S. dollar did not have any significant impact on the volume of exports and imports of sand and gravel, construction or industrial.

Table 1.—Salient U.S. sand and gravel statistics[1]

(Thousand short tons and thousand dollars)

	1983	1984	1985	1986	1987
Sold or used:					
Construction sand and gravel:					
Quantity	[e]655,100	773,900	[e]800,100	883,000	[e]896,200
Value	[e]$1,935,000	$2,244,000	[e]$2,438,000	$2,747,200	[e]$3,002,500
Industrial:					
Sand:					
Quantity	26,080	28,680	29,070	26,940	27,380
Value	$329,500	$370,370	$370,730	$354,460	$357,660
Gravel:					
Quantity	537	705	357	484	631
Value	$5,667	$6,844	$3,340	$4,853	$6,424
Total industrial:[2]					
Quantity	26,620	29,380	29,430	27,420	28,010
Value	$335,200	$377,200	$374,070	$359,300	$364,100
Exports:					
Quantity	2,350	3,038	2,379	2,015	1,895
Value	$32,487	$37,981	$31,515	$28,201	$31,786
Imports for consumption:					
Quantity	181	177	327	293	387
Value	$2,666	$2,529	$3,085	$2,426	$3,438

[e]Estimated.
[1]Puerto Rico excluded from all sand and gravel statistics.
[2]Data may not add to totals shown because of independent rounding.

Domestic Data Coverage.—Domestic production data for construction and industrial sand and gravel are developed by the Bureau of Mines from voluntary surveys of U.S. producers. Full surveys of construction sand and gravel producers are conducted for even-numbered years only. For odd-numbered years, preliminary surveys are conducted that collect production information on a sample basis in order to generate only annual preliminary estimates at the State level. Industrial sand and gravel producers are surveyed every year. Of the 170 industrial sand and gravel operations surveyed, 155, or 91%, reported to the Bureau of Mines. Their combined production represented 94% of the U.S. total published in table 1. The nonrespondents' production was estimated using mostly employment data. Of the 170 operations, 166, or 98%, were active and 4 were idle.

Legislation and Government Programs.—On April 2, the U.S. Congress enacted the 1987 Surface Transportation Assistance Act that extended the Federal-Aid Highway Program for 5 more years at a total funding level of $68 billion, with annual authorizations ranging between $13.6 and $13.9 billion. On December 31, the Airport Improvement Program (AIP) legislation was enacted that appropriated $1.7 billion funding level for fiscal years 1988 to 1990, and $1.8 billion for fiscal years 1991 and 1992. The total of $8.7 billion represented a 65% increase in funding over the previous AIP program. The program funding levels for fiscal year 1988 were later reduced by the Continuing Resolution (Public Law 100-202) by $0.57 billion for the highway program and by $0.43 billion for the airport program.

Responding to requests made by the industry, the Occupational Safety and Health Administration (OSHA) extended a partial stay to July 21, 1988, for the new provisions of its revised asbestos standards for nonasbestos forms of actinolite, anthophyllite, and tremolite minerals. The stay was issued to allow OSHA time to review additional information and to collect more data, including that on the feasibility of regulating these nonasbestos-form minerals. The extension of the stay was needed because of the range of the affected industries and the lack of mineralogic and exposure data in these industries. The former asbestos standard remains in effect throughout the extension of the stay.

The introduction of the revised OSHA regulations regarding the airborne asbestos standards that include nonasbestos forms of actinolite, anthophyllite, and tremolite would have a significant impact on the aggregates as well as on the construction industries. The resulting costs to society in the form of increased construction costs and disruption of supply of aggregates were considered potentially enormous.

CONSTRUCTION SAND AND GRAVEL

DOMESTIC PRODUCTION

Revised production estimates for 1986 indicate that U.S. output of construction sand and gravel increased 1.5% in 1987. Production increased in New England, West North Central, South Atlantic, Pacific, and Middle Atlantic, and decreased in Mountain, East North Central, East South Central, and West South Central. The Pacific region continued to lead the Nation, followed by East North Central and the Mountain region.

Among the four major geographic regions, the West again led the Nation in the production of construction sand and gravel with 36% of the U.S. total. The Midwest region was next with 27%, and the South was third with 23%. Construction sand and gravel was produced in every State, and the 10 leading States were, in descending order of volume, California, Texas, Michigan, Arizona, Ohio, New York, Florida, Illinois, Alaska, and Washington. Their combined estimated production represented 50% of the national total.

Tarmac PLC of Wolverhampton, United Kingdom, purchased a 60% interest in Lone Star Industries Inc. of Greenwich, CT, aggregates, cement, concrete, and concrete products operations in North Carolina, South Carolina, and Virginia. The purchase agreement included a provision that will allow Tarmac to acquire the remaining 40% interest after January 1, 1990.

J. L. Shiely Co. of St. Paul, MN, acquired the Freidheim Co. of St. Paul, MN, a producer of aggregates, ready-mixed concrete, and concrete blocks in the Minneapolis-St. Paul area. In December, J. L. Shiely agreed to be acquired by English China Clays Ltd. of Cornwall, United Kingdom.

ARC America Corp. of Newport Beach, CA, a subsidiary of Consolidated Gold Fields

Ltd. of the United Kingdom, acquired American Aggregates Corp. of Greenville, OH, a producer of sand and gravel and crushed stone with operations in California, Indiana, Michigan, and Ohio.

Blue Circle Industries PLC of Reading, United Kingdom, through a U.S. subsidiary, acquired Raia Industries Inc., a New Jersey aggregates and ready-mixed concrete producer with extensive aggregates reserves in the State.

On May 12, 1987, following the recommendation made by the association's board of directors, the members of the National Sand and Gravel Association (NSGA) approved dissolving the 71-year-old organization and reinstating it as the National Aggregates Association. As the reserves of available sand and gravel continue to diminish, more and more NSGA members are becoming crushed stone producers as well. Concern for the long-term future of the association and the sand and gravel industry convinced its members to open NSGA membership to all aggregate producers by amending the bylaws and changing the name of the organization.

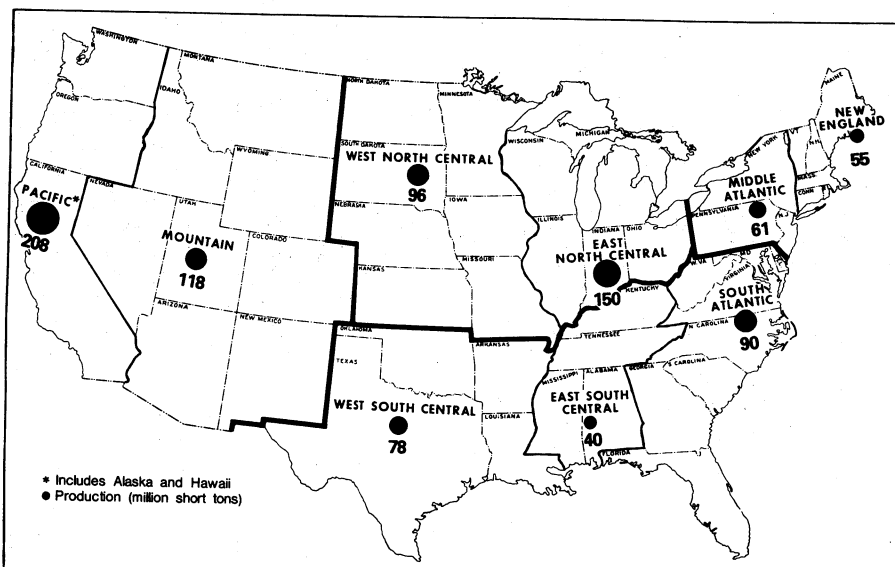

Figure 1.—Production of construction sand and gravel in the United States in 1987, by geographic region.

FOREIGN TRADE

Exports.—Exports of construction sand decreased 12% to 593,000 tons. Canada was the major destination, receiving 81% of the total, while Mexico received 9%. Exports of construction gravel increased by 11% to 544,000 tons, 91% of which went to Canada, and 3% to the Leeward Islands.

Imports.—Imports of construction sand and gravel increased 38% to 283,000 tons, 70% of which came from Canada and 14% from Antigua.

TECHNOLOGY

In response to a joint request from the House Committee on Merchant Marine and Fisheries and the House Committee on Science, Space, and Technology of the U.S. Congress, the Office of Technology Assessment evaluated the near-term development potential of selected offshore minerals within the U.S. Exclusive Economic Zone (EEZ). The report examined the current knowledge about the hard mineral resources within the EEZ, explored the economic and security potential of seabed resources, assessed the technologies available to explore and mine those resources, identified the issues facing the Congress and the executive branch of the Government, and presented options for dealing with these issues. The report concluded that progress in seabed mining would require Government commitment to ocean exploration, resolution of data secrecy problems, an improved demand for some minerals, and perhaps new legislation. The report ranked sand and gravel first among six minerals with development potential, and indicated that around high-growth, high-density areas in the Northeast and the west coast of the United States, marine sand and gravel may soon prove profitable to mine and may attract the interest of the aggregates industry. But without assurances that the Federal Government will actively support ocean exploration and provide a statutory framework to encourage private development of seabed minerals, the economic prospect is bleak for most seabed mining.[2]

During the 71st Annual Convention of the National Sand and Gravel Association that was held on February 8-11, 1987, in San Francisco, CA, a comprehensive program of educational seminars covering technical, financial, legal, marketing, and self-improvement subjects was organized by the association. Some of the topics covered included new methods of exploring for sand and gravel, economic transportation from pit to plant, dispatching and batching in the computer age, methods for measuring fleet maintenance efficiency, and computerized maintenance operations.

The introduction of sophisticated electronic equipment and computer systems for improved efficiency of mining and processing operations continued in the sand and gravel industry. Computer programs are used for plant design, including selection of flow diagrams, types and sizes of crushing and screening equipment, and to produce blueprints of plant drawings. Operations such as blasting, excavation, crushing and screening, loading, and hauling have advanced into highly technical disciplines that use a wide range of automated equipment. Computerized systems that provide a high degree of plant automation in day-to-day operation, quality control, and truck dispatch systems are being used more and more by producers. Most producers are significantly improving the efficiency of their operations, not only by investing in larger equipment, but also through automation.

Construction of a pilot plant that will convert phosphogypsum, a waste product of the phosphate industry, into aggregates for road and building construction was started in August. The pilot plant is being built in Convent, LA, by Freeport-McMoRan Inc. to test a new proprietary technology developed by Davy McKee Corp. and the Florida Institute of Phosphate Research. The pilot plant is designed to convert 35 tons per day of phosphogypsum into 29 tons per day of sulfuric acid and 25 tons per day of aggregates. The pilot plant will cost $2 million to construct and another $1 million to operate for 6 months. The breakthrough in developing an economical process to convert phosphogypsum into useful products comes at a time when disposal of the byproduct waste has become an environmental issue in Louisiana.[3]

Table 2.—Construction sand and gravel sold or used in the United States, by geographic region

Geographic region	1986				1987			
	Quantity (thousand short tons)	Percent of total	Value (thousands)	Percent of total	Quantity[e] (thousand short tons)	Percent of total	Value[e] (thousands)	Percent of total
Northeast:								
New England	50,546	5	$154,857	6	55,300	6	$189,400	6
Middle Atlantic	60,544	7	226,374	8	61,400	7	247,000	8
Midwest:								
East North Central	151,742	17	421,712	15	150,300	17	457,700	15
West North Central	88,444	10	205,825	8	95,500	11	255,000	9
South:								
South Atlantic	83,992	10	276,964	10	90,100	10	297,300	10
East South Central	40,415	5	115,193	4	40,000	4	126,700	4
West South Central	92,791	11	307,573	11	78,100	9	270,300	9
West:								
Mountain	117,972	13	356,615	13	117,700	13	399,800	13
Pacific	196,556	22	682,060	25	207,800	23	759,300	25
Total[1]	883,000	100	2,747,200	100	896,200	100	3,002,500	100

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

Table 3.—Construction sand and gravel sold or used in the United States, by State

(Thousand short tons and thousand dollars)

State	1986 Quantity	1986 Value	1987[e] Quantity	1987[e] Value
Alabama	10,781	30,807	10,300	35,600
Alaska	27,762	61,954	27,200	73,400
Arizona	40,468	140,004	38,100	141,300
Arkansas	8,571	26,999	7,200	23,900
California	128,407	498,456	141,600	561,300
Colorado	23,233	70,095	22,800	84,300
Connecticut	7,254	25,984	8,400	37,000
Delaware	1,547	4,156	2,300	6,400
Florida	28,233	67,898	30,000	74,900
Georgia	8,126	23,222	9,000	26,900
Hawaii	605	2,666	700	3,500
Idaho	5,708	14,830	7,200	28,000
Illinois	27,867	82,523	28,300	93,300
Indiana	19,642	61,232	18,900	65,200
Iowa	14,511	40,418	19,000	63,800
Kansas	15,609	33,721	15,600	37,800
Kentucky	7,194	16,986	7,100	15,200
Louisiana	14,292	46,134	12,200	43,600
Maine	8,572	22,843	8,600	22,100
Maryland	18,173	86,925	19,600	92,900
Massachusetts	19,200	60,464	21,800	75,300
Michigan	42,514	91,886	42,800	105,300
Minnesota	24,055	53,116	25,200	67,400
Mississippi	15,080	42,809	14,700	47,000
Missouri	9,746	24,065	10,900	30,400
Montana	8,066	19,391	6,800	18,800
Nebraska	9,675	23,912	10,300	26,300
Nevada	12,197	35,692	10,600	30,700
New Hampshire	8,418	26,089	9,100	33,300
New Jersey	13,999	53,746	15,200	61,200
New Mexico	8,471	25,862	8,600	31,000
New York	31,172	103,748	31,400	112,900
North Carolina	7,543	23,127	8,600	30,100
North Dakota	5,135	10,741	4,900	10,200
Ohio	36,806	126,747	36,400	136,900
Oklahoma	10,366	24,585	10,500	24,200
Oregon	13,441	42,597	13,000	42,200
Pennsylvania	15,373	68,880	14,800	72,900
Rhode Island	2,269	8,252	2,700	10,900
South Carolina	7,200	19,783	7,500	19,500
South Dakota	9,713	19,853	9,600	19,100
Tennessee	7,360	24,592	7,900	28,900
Texas	59,562	209,855	48,200	178,600
Utah	16,452	39,763	21,000	56,700
Vermont	4,834	11,226	4,700	10,800
Virginia	11,670	46,488	12,100	43,400
Washington	26,342	76,387	25,300	78,900
West Virginia	1,501	5,365	1,000	3,200
Wisconsin	24,913	59,325	23,900	57,000
Wyoming	3,377	10,977	2,600	9,000
Total[1]	883,000	2,747,200	896,200	3,002,500

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

Table 4.—U.S. exports of construction sand and gravel, by country

(Thousand short tons and thousand dollars)

Country	Construction sand		Gravel	
	Quantity	F.a.s. value[1]	Quantity	F.a.s. value[1]
1986				
Bahamas	--	--	11	86
Canada	646	2,606	392	1,264
French West Indies	--	--	26	144
Germany, Federal Republic of	(2)	77	(2)	8
Japan	3	489	--	--
Leeward and Windward Islands	--	--	4	82
Mexico	12	514	50	524
Netherlands Antilles	(2)	11	9	120
Peru	5	264	--	--
Saudi Arabia	(2)	53	(2)	17
Trinidad and Tobago	3	152	(2)	39
Other	5	1,280	(2)	108
Total	674	5,446	492	2,392
1987				
Argentina	6	667	--	--
Australia	1	69	--	--
Brazil	6	43	--	--
Canada	480	2,930	496	1,497
Colombia	2	16	--	--
French West Indies	8	83	12	173
Japan	3	185	--	--
Leeward and Windward Islands	2	14	17	228
Mexico	55	765	10	768
Netherlands	3	647	--	--
Netherlands Antilles	1	23	4	87
Panama	8	192	--	--
Peru	5	252	--	--
Saudi Arabia	(2)	13	--	--
Taiwan	5	68	--	--
Trinidad and Tobago	1	88	(2)	8
United Kingdom	1	96	3	37
Venezuela	1	317	--	--
Other	4	1,143	1	126
Total[3]	593	7,610	544	2,923

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

Source: Bureau of the Census.

Table 5.—U.S. imports for consumption of construction sand and gravel, by country

(Thousand short tons and thousand dollars)

Country	1986		1987	
	Quantity	C.i.f. value[1]	Quantity	C.i.f. value[1]
Antigua	34	103	41	267
Australia	--	--	2	470
Bahamas	--	--	13	78
British Virgin Islands	5	62	3	59
Canada	157	707	198	965
Costa Rica	--	--	19	87
Japan	4	88	--	--
Spain	(2)	3	--	--
Taiwan	--	--	2	33
Other	5	449	5	408
Total	205	1,412	283	2,367

[1]Value of material at U.S. 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.
[2]Less than 1/2 unit.

Source: Bureau of the Census.

INDUSTRIAL SAND AND GRAVEL

DOMESTIC PRODUCTION

The total output of industrial sand and gravel increased by approximately 2% to 28 million tons. The Midwest major geographic region continued to lead the Nation with about 41% of the U.S. total, followed by the South with about 36% and the West with 12%. Two major geographic regions, the Midwest and the South, produced 77% of the total U.S. industrial sand output. Compared with 1986, the output of industrial sand and gravel increased 7% in the South, 2% in the West, and 1% in the Midwest, but decreased 7% in the Northeast.

Based on the 1985 census estimations on population, 1987 U.S. per capita industrial sand and gravel production was 0.12 ton. Per capita production by major geographic region was 0.19 ton in the Midwest, followed by the South with 0.12 ton, the West with 0.07 ton, and the Northeast with 0.06 ton.

The five leading States in the production of industrial sand and gravel in 1987, in descending order of volume, were Illinois, Michigan, California, New Jersey, and Florida. Their combined production represented 48% of the national total. Of the major producing States, significant increases were recorded in Florida, 28%, and Texas, 16%, while production decreased significantly in Michigan, 16%, New Jersey, 10%, and California, 5%.

The Bureau of Mines canvassed 94 producers of industrial sand and gravel with 166 active operations. About 73% of the industrial sand and gravel was produced by 43 operations, each with an annual production of more than 200,000 tons. The 10 leading producers of industrial sand and gravel were, in descending order of tonnage, Unimin Corp., U.S. Silica Co., The Morie Co. Inc., Fairmount Minerals Ltd., Standard Sand & Silica Co., Badger Mining Corp., Oglebay Norton Co., Construction Aggregates Corp., and Owens-Illinois Inc. Their combined production, from 61 operations, represented 74% of the U.S. total.

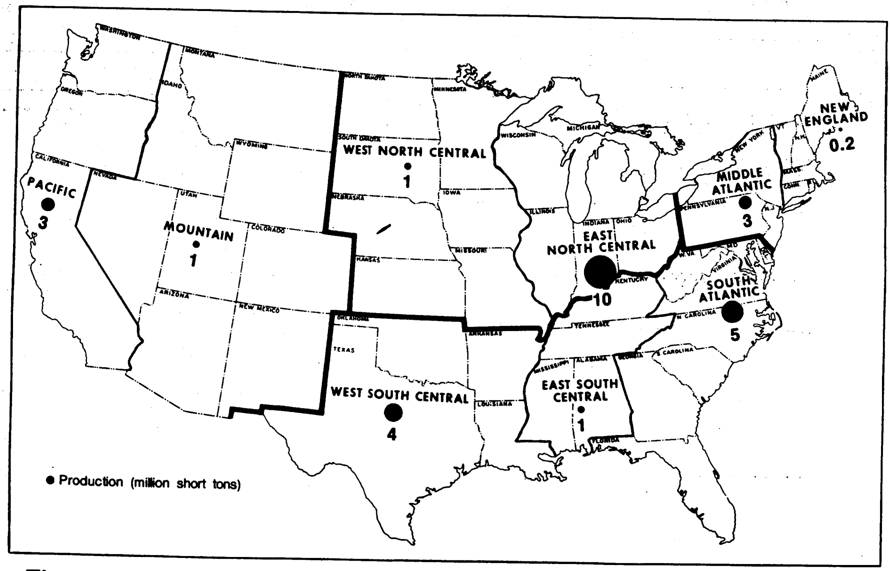

Figure 2.—Production of industrial sand and gravel in the United States in 1987, by geographic region.

U.S. Silica, a subsidiary of Pacific Coast Resources Corp. of Los Angeles, CA, purchased Warrior Sand Co. of Hurtsboro, AL, a major producer of foundry sands in the South. This acquisition extended its network of plants in the United States to 17 industrial sand operations in 14 States.

The top two companies, Unimin and U.S. Silica, hold a large proportion of the industrial sand production capacity in the United States.

California Silica Products Co., a subsidiary of Oglebay Norton of Cleveland, OH, announced the completion of an expansion to its silica sand operation at San Juan Capistrano, CA. The plant, which was designed to produce glass sand, will also supply some new markets, including the construction industry.

CONSUMPTION AND USES

Sand and gravel production reported by producers to the Bureau of Mines is actually material sold or used by the companies or their customers. Stockpiled material is not reported until it is consumed or sold.

Of the 28 million tons of industrial sand and gravel sold or used, 42% was consumed as glassmaking sand and 25% as foundry sand. Other important uses were abrasive sand, 7%, and hydraulic fracturing sand, 5%. Because some producers did not report a breakdown by end use, their total production as well as the estimated production for nonrespondents were included in "Other uses, unspecified," which represent about 8% of the U.S. total. On the regional level, most of the glassmaking sand was produced in the South, 39%, and the Midwest, 27%, followed by the West and the Northeast. Most of the foundry sand was produced in the Midwest, 73%, and the South, 18%. Of the smaller by volume but important uses, most of the hydraulic fracturing sand was produced in the Midwest, 73%, and most of the abrasive sand was produced in the South, 46%, and the Midwest, 28%.

TRANSPORTATION

Of the total industrial sand and gravel produced, 63% was transported by truck from the plant to the site of first sale or use, down from 66% in 1986; 34% was transported by rail, up from 31% in 1986; and 3% by waterway, unchanged from 1986. Because most of the producers did not report shipping distances or cost per ton per mile, no transportation cost data were available.

PRICES

The average value, f.o.b. plant, of U.S. industrial sand and gravel decreased slightly to $13.00 per ton. Average unit values for industrial sand and industrial gravel were $13.06 and $10.18 per ton, respectively. Nationally, industrial sand used as fillers for rubber, paint, and putty, etc., had the highest value per ton, $57.62, followed by silica sand used in ceramics, $38.25, fiberglass (ground), $30.49, silica flour, $28.72, and scouring cleansers, $25.21.

FOREIGN TRADE

Exports.—Exports of industrial sand decreased 11% to 758,000 tons, while the value increased 4% to $21.3 million. Of this, 79% went to Canada, 7% went to Mexico, and 7% went to several European countries.

Imports.—Imports for consumption of industrial sand increased 18% to 104,000 tons valued at $1.1 million. Of this, 52% came from Antigua, 18% from the Bahamas, and 17% from Australia.

TECHNOLOGY

The technology of glass manufacturing is changing almost continuously. These changes require improvements in the processing of raw silica sands to meet the new specifications imposed by the changing technology. A review of the glass sand industry in the United Kingdom that includes physical and chemical specification, deposit evaluation, plant design, plant operation, and quality management was published.[4]

The most important considerations concerning raw material selection for the glass industry are cost, availability, purity and consistency of chemical composition, and grain size. Except for the specialty glasses, glass is a low-cost, high-bulk product that requires low-cost raw materials. Although the choices of raw materials for common glass may be similar, the conditions of supply and demand among countries are often quite different for a variety of reasons. Using technological innovation and aggressive marketing policy, the glass industry in certain parts of the world is consolidating. A comprehensive review of the flat glass, container glass, glass fibers, and specialty glass industries in the major producing countries or regions of the world was published.[5]

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[1]Physical scientist, Branch of Industrial Minerals.

[2]U.S. Congress. Marine Minerals: Exploring Our New Ocean Frontier. Off. Technol. Assess., OTA-O-342, 1987, 349 pp.

[3]Rukavina, M. Phosphate Industry Hopes To Turn Phosphogypsum Waste Into Aggregates. Rock Prod., v. 90, No. 9, Sept. 1987, pp. 17, 78.

[4]Kirby, C., and Lavender, M. Developments in the Glass Sands Supply Industry. Ind. Miner. (London), No. 242, Nov. 1987, pp. 55-63.

[5]O'Driscoll, M. Glass Markets—Added Value Impetus. Ind. Miner. (London), No. 239, Aug. 1987, pp. 33-63.

Table 6.—Industrial sand and gravel sold or used in the United States, by geographic region

Geographic region	1986 Quantity (thousand short tons)	1986 Percent of total	1986 Value (thousands)	1986 Percent of total	1987 Quantity (thousand short tons)	1987 Percent of total	1987 Value (thousands)	1987 Percent of total
Northeast:								
New England	129	1	$3,541	1	161	1	$3,921	1
Middle Atlantic	3,088	11	41,132	11	2,830	10	38,155	10
Midwest:								
East North Central	9,990	36	116,698	32	9,931	35	105,815	29
West North Central	1,340	5	16,011	4	1,516	5	20,263	6
South:								
South Atlantic	5,452	20	71,292	20	5,545	20	75,505	21
East South Central	945	3	9,198	3	1,098	4	10,719	3
West South Central	3,161	11	42,929	12	3,545	13	49,065	13
West:								
Mountain	694	3	9,251	3	847	3	13,980	4
Pacific	2,621	10	49,257	14	2,535	9	46,658	13
Total[1]	27,420	100	359,300	100	28,010	100	364,100	100

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

Table 7.—Industrial sand and gravel sold or used in the United States, by State

(Thousand short tons and thousand dollars)

State	1986 Quantity	1986 Value	1987 Quantity	1987 Value
Alabama	433	3,388	580	5,025
Arizona	W	W	W	W
Arkansas	400	3,975	505	5,147
California	2,364	44,813	2,241	41,472
Colorado	W	W	W	W
Connecticut	W	W	W	W
Florida	1,467	14,930	1,884	19,713
Georgia	W	W	W	W
Idaho	W	W	W	W
Illinois	4,039	52,133	4,346	45,547
Indiana	193	1,490	230	1,357
Kansas	132	1,155	127	1,400
Kentucky	W	W	W	W
Louisiana	256	4,225	289	3,997
Maryland	W	W	W	W
Massachusetts	45	739	56	922
Michigan	3,343	29,493	2,792	22,451
Minnesota	W	W	W	W
Mississippi	W	W	W	W
Missouri	517	6,230	622	7,786
Montana	W	W	W	W
Nebraska	W	W	W	W
Nevada	518	W	578	W
New Jersey	2,341	29,878	2,112	27,872
New York	59	1,164	58	651
North Carolina	1,464	16,656	1,184	15,329
North Dakota	W	W	W	W
Ohio	1,221	21,183	1,249	21,292
Oklahoma	1,203	16,454	1,243	17,078
Pennsylvania	688	10,091	W	W
Rhode Island	22	143	W	W
South Carolina	800	14,081	844	15,188
Tennessee	488	5,523	W	W
Texas	1,302	18,274	1,509	22,843
Utah	6	123	6	111
Virginia	W	W	W	W
Washington	W	W	294	5,186
West Virginia	W	W	W	W
Wisconsin	1,194	12,399	1,314	15,168
Other	2,927	50,768	3,945	68,545
Total[1]	27,420	359,300	28,010	364,100

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Data may not add to totals shown because of independent rounding.

Table 8.—Industrial sand and gravel production in the United States in 1987, by size of operation

Size range	Number of operations	Percent of total	Quantity (thousand short tons)	Percent of total
Less than 25,000	41	24.7	370	1.3
25,000 to 49,999	28	16.9	1,023	3.7
50,000 to 99,999	28	16.9	2,179	7.8
100,000 to 199,999	26	15.7	3,851	13.7
200,000 to 299,999	8	4.8	1,903	6.8
300,000 to 399,999	9	5.4	3,117	11.1
400,000 to 499,999	8	4.8	3,528	12.7
500,000 to 599,999	8	4.8	4,315	15.4
600,000 to 699,999	5	3.0	3,369	12.0
700,000 and over	5	3.0	4,354	15.5
Total	166	100.0	[1]28,010	100.0

[1]Data do not add to total shown because of independent rounding.

Table 9.—Number of industrial sand and gravel operations and processing plants in the United States in 1987, by geographic region

Geographic region	Mining operations on land				Dredging operations	Total active operations
	Stationary	Portable	Stationary and portable	No plants or unspecified		
Northeast:						
New England	4	--	--	1	--	5
Middle Atlantic	9	--	2	2	4	17
Midwest:						
East North Central	39	--	1	--	3	43
West North Central	8	--	--	--	3	11
South:						
South Atlantic	17	--	--	3	8	28
East South Central	10	--	--	1	3	14
West South Central	15	--	--	1	10	26
West:						
Mountain	6	1	--	--	1	8
Pacific	11	--	--	1	2	14
Total	119	1	3	9	34	166

Table 10.—Industrial sand and gravel sold or used by U.S. producers, by major use

Major use	Northeast: Quantity (thousand short tons)	Northeast: Value (thousands)	Northeast: Value per ton	Midwest: Quantity (thousand short tons)	Midwest: Value (thousands)	Midwest: Value per ton	South: Quantity (thousand short tons)	South: Value (thousands)	South: Value per ton	West: Quantity (thousand short tons)	West: Value (thousands)	West: Value per ton	U.S. total[1]: Quantity (thousand short tons)	U.S. total[1]: Value (thousands)	U.S. total[1]: Value per ton
1987															
Sand:															
Glassmaking:															
Containers	1,344	$17,068	$12.70	1,980	$15,705	$7.93	2,906	$33,152	$11.41	2,095	$36,418	$17.38	8,326	$102,344	$12.29
Flat (plate and window)	W	W	13.05	842	7,511	8.92	1,095	12,293	11.23	W	W	14.97	2,156	22,821	10.58
Specialty	W	W	14.76	153	2,008	13.12	190	2,474	13.02	W	W	17.57	512	6,996	13.66
Fiberglass (unground)	W	W	9.41	216	2,054	9.51	153	1,731	11.31	W	W	15.97	538	6,005	11.16
Fiberglass (ground)	--	--	--	W	W	33.59	W	W	30.44	W	W	20.75	341	10,398	30.49
Foundry:															
Molding and core	523	6,963	13.31	4,804	42,642	8.88	1,217	12,436	10.22	129	2,186	16.95	6,673	64,227	9.62
Molding and core facings (ground)	W	W	W	--	--	--	--	--	--	--	--	--	W	W	W
Refractory	W	W	10.00	258	1,422	5.51	--	--	--	W	W	W	259	1,437	5.55
Metallurgical:															
Silicon carbide	--	--	--	130	831	6.39	--	--	--	--	--	--	130	831	6.39
Flux for metal smelting	--	--	--	W	W	8.93	W	W	1.88	77	2,319	30.12	114	2,593	22.75
Abrasives:															
Blasting	281	4,560	16.23	431	4,930	11.44	860	15,094	17.55	214	4,122	19.26	1,786	28,708	16.07
Scouring cleansers (ground)	W	W	33.00	W	W	24.41	W	W	40.50	--	--	--	62	1,563	25.21
Sawing and sanding	--	--	--	W	W	20.00	--	--	--	--	--	--	W	W	20.00
Chemicals (ground and unground)	W	W	13.31	W	W	12.86	222	3,618	16.30	W	W	14.58	513	7,438	14.50
Fillers (ground):															
Rubber, paint, putty, etc	W	W	39.05	71	3,087	43.48	46	4,378	95.17	W	W	18.38	147	8,470	57.62
Silica flour	W	W	18.29	221	6,488	29.36	W	W	25.05	--	--	--	247	7,093	28.72
Ceramic (ground):															
Pottery, brick, tile, etc	W	W	37.87	108	4,886	45.24	101	3,144	31.13	W	W	8.00	225	8,606	38.25
Filtration	226	2,953	13.07	49	738	15.06	153	2,126	13.90	6	172	28.67	433	5,989	13.83
Traction (engine)	W	W	9.09	299	2,391	8.00	132	1,325	10.04	W	W	12.09	465	4,081	8.78
Coal washing	--	--	--	W	W	12.00	W	W	4.00	--	--	--	45	228	5.07
Roofing granules and fillers	51	1,709	33.51	12	155	12.92	251	4,479	17.84	77	1,438	18.68	392	7,782	19.85
Hydraulic fracturing	W	W	W	1,014	19,584	19.31	375	6,968	18.58	W	W	26.43	1,396	26,742	19.16
Other uses, specified	525	7,748	14.76	466	6,783	19.32	451	11,049	24.50	480	8,244	17.18	XX	XX	XX
Other uses, unspecified[2]	31	794	25.61	270	3,525	13.06	1,596	16,676	10.45	245	5,277	21.54	2,142	26,273	12.27
Total[1] or average	2,982	41,797	14.02	11,324	124,740	11.02	9,747	130,943	13.43	3,324	60,178	18.10	27,377	357,657	13.06

See footnotes at end of table.

Table 10.—Industrial sand and gravel sold or used by U.S. producers, by major use —Continued

Major use	Northeast			Midwest			South			West			U.S. total[1]		
	Quantity (thousand short tons)	Value (thousands)	Value per ton	Quantity (thousand short tons)	Value (thousands)	Value per ton	Quantity (thousand short tons)	Value (thousands)	Value per ton	Quantity (thousand short tons)	Value (thousands)	Value per ton	Quantity (thousand short tons)	Value (thousands)	Value per ton
1987 —Continued															
Gravel: Metallurgical:															
Silicon, ferrosilicon	--	--	--	W	W	$10.00	W	W	$9.73	--	--	--	454	$4,436	$9.77
Filtration	9	$279	$31.00	W	W	W	W	W	7.42	--	--	--	W	W	16.86
Other uses	--	--	--	58	$686	11.83	W	W	12.08	58	$460	$7.93	W	W	10.43
Total[1] or average	9	279	31.00	123	1,339	10.89	441	$4,346	9.85	58	460	7.93	631	6,424	10.18
Grand total[1] or average	2,991	42,076	14.07	11,447	126,078	11.01	10,188	135,289	13.28	3,382	60,638	17.93	28,010	364,100	13.00

W Withheld to av‹ id disclosing company proprietary data; included with "Other uses, specified"; also included in "U.S. total" by use. XX Not applicable.
[1]Data may not add to totals shown because of independent rounding.
[2]Mostly estimated total production, plus other uses (small quantities) as reported by the producers.

Table 11.—Transportation of industrial sand and gravel in the United States in 1987 to site of first sale or use

Method of shipment	Quantity (thousand short tons)	Percent of total
Truck	17,470	63
Rail	9,562	34
Waterway	903	3
Not transported	72	--
Total	[1]28,010	100

[1]Data do not add to total shown because of independent rounding.

Table 12.—U.S. exports of industrial sand, by country

(Thousand short tons and thousand dollars)

Country	1986		1987	
	Quantity	F.a.s. value[1]	Quantity	F.a.s. value[1]
North America:				
Bahamas	(2)	40	1	18
Canada	713	9,224	600	8,638
Costa Rica	(2)	8	(2)	7
Dominican Republic	4	104	2	96
Leeward and Windward Islands	1	56	3	35
Mexico	63	1,708	50	1,388
Netherlands Antilles	8	106	8	174
Panama	13	254	8	273
Other	r2	r198	3	262
Total[3]	804	11,698	676	10,890
South America:				
Argentina	(2)	29	2	340
Chile	(2)	265	1	372
Colombia	(2)	132	1	174
Ecuador	(2)	100	(2)	97
Peru	1	124	1	135
Venezuela	3	159	6	341
Other	1	95	(2)	217
Total[3]	5	904	11	1,675
Europe:				
Belgium	7	778	17	1,176
France	(2)	182	(2)	198
Germany, Federal Republic of	1	425	8	874
Italy	3	145	8	531
Netherlands	3	1,164	6	1,722
Norway	(2)	8	(2)	37
United Kingdom	10	520	9	334
Yugoslavia	2	811	(2)	98
Other	2	776	3	551
Total[3]	28	4,809	52	5,522
Asia:				
Indonesia	1	256	(2)	8
Japan	2	835	6	770
Korea, Republic of	1	198	1	328
Singapore	1	286	5	888
Other	r1	r702	1	367
Total	6	2,277	13	2,361
Middle East and Africa:				
Saudi Arabia	(2)	16	(2)	7
South Africa, Republic of	2	10	3	344
United Arab Emirates	2	152	1	48
Other	r1	r277	1	152
Total	5	455	5	551
Oceania	1	220	1	253
Grand total[3]	849	20,363	758	21,253

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

Source: Bureau of the Census.

Table 13.—U.S. imports for consumption of industrial sand, by country

(Thousand short tons and thousand dollars)

Country	1986		1987	
	Quantity	C.i.f. value[1]	Quantity	C.i.f. value[1]
Antigua	28	173	54	134
Australia	22	387	18	407
Bahamas	--	--	19	30
Canada	3	87	6	51
Germany, Federal Republic of	--	--	6	365
Japan	23	27	--	--
United Kingdom	12	102	([2])	38
Other	([2])	238	1	45
Total	88	1,014	104	[3]1,071

[1]Value of material at U.S. 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.
[2]Less than 1/2 unit.
[3]Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

Silicon

By Clark R. Neuharth[1]

Demand for silicon ferroalloys and silicon metal overall increased compared with that of 1986 owing to increased production of aluminum, iron and steel, and silicon-base chemicals. Domestic producers increased production to meet demand since exports of both ferrosilicon and silicon metal increased and imports of silicon materials overall were only slightly higher than those of 1986.

Domestic Data Coverage.—Domestic production data for the silicon commodity are developed by the Bureau of Mines by means of monthly and annual voluntary domestic surveys. Typical of these surveys is the monthly "Silicon Alloys" survey. Of the 17 canvassed operations to which a survey collection request was made, all responded, representing 100% of the total production shown in table 1.

Table 1.—Production, shipments, and stocks of silvery pig iron, ferrosilicon, and silicon metal in the United States in 1987

(Short tons, gross weight, unless otherwise specified)

Alloy	Silicon content (percent)		Producers' stocks, Dec. 31, 1986[r]	Gross production	Net shipments	Producers' stocks, Dec. 31, 1987
	Range	Typical				
Silvery pig iron	5-24	18	W	W	W	W
Ferrosilicon	25-55	48	57,211	312,330	254,996	40,759
Do	56-95	76	22,730	47,584	51,408	16,801
Silicon metal (excluding semiconductor grades)	96-99	98	5,193	150,080	149,713	4,135
Miscellaneous silicon alloys (excluding silicomanganese)	32-65	--	15,408	73,525	68,461	16,090

[r]Revised. W Withheld to avoid disclosing company proprietary data.

Legislation and Government Programs.—House bill (H.R.) 3 and its counterpart, Senate bill (S.) 490 entitled "Omnibus Trade Act of 1987," were introduced in the U.S. House of Representatives and Senate. The purpose of S. 490, which was subsequently passed by the Senate and incorporated into H.R. 3, was to revise trade remedy statutes, such as dumping and subsidy laws. H.R. 3 would create sweeping changes in existing trade laws governing import relief and other aspects of international competitiveness. S. 556 and its counterpart, H.R. 1580, were subsequently introduced for the purpose of prohibiting U.S. investment in the Republic of South Africa, as well as exports to and imports from that country. However, these sanction bills included clauses exempting any minerals or materials considered by the President and Congress to be strategic to defense needs. This exemption would very likely include ferroalloys and related ores.

On July 1, the United States removed imports of Brazilian silicon metal from the Generalized System of Preferences exemption list, placing a 5.3% duty on imports of silicon metal in the 99.0% to 99.7% purity category.

A West Virginia law was passed giving a tax break to power companies that supply ferroalloy producers in that State. Under the new law, power companies were not subject to gross sales tax on power distributed to produce ferroalloys. However, the power companies were required to pass along the savings to the ferroalloy producers through rate reductions.

DOMESTIC PRODUCTION

Production and shipments of silicon-containing ferroalloys and silicon metal overall showed significant increases compared with those of 1986. The standard 50% (25% to 55%) grade and miscellaneous silicon alloy production levels increased over 20%. Magnesium ferrosilicon accounts for the major portion of miscellaneous silicon alloys. Production of silicon metal also increased nearly 20%, although that of 75% (56% to 95%) grade decreased by about one-quarter. Producers' stocks of silicon-containing materials were down overall at yearend owing to high demand from consuming industries.

Applied Industrial Minerals Corp. shut down its Kimball, TN, ferrosilicon plant early in the year owing to competition from low-priced imports. SKW Alloys Inc. started silicon metal production in January after completing the conversion of one of its ferrosilicon furnaces in Niagara Falls, NY. Universal Consolidated Cos. purchased M. A. Hanna Co.'s ferronickel smelter in Riddle, OR, which the company had previously closed. However, Universal planned to reactivate the facility to produce ferrosilicon in 1988.

Moore McCormack Resources Inc. completed the sale of Globe Metallurgical Inc., a silicon and ferrosilicon producer, to a management group backed by Lee Capital Corp., an investment banking firm based in Boston, MA. Globe planned to continue producing silicon metal, magnesium ferrosilicon, and 50% ferrosilicon at its facilities in Beverly, OH, and Selma, AL.

Foote Mineral Co. sold both of its ferrosilicon production facilities at the end of the year. The Graham, WV, plant, which had been closed since 1985, was purchased by an employee group under the name American Alloys Inc. The new company planned to start production of 50% ferrosilicon by March 1988 and possibly convert some of its capacity to silicon metal production later in the year. Keokuk Ferro-Sil Inc., a group formed by former Foote employees, purchased the Keokuk, IA, facility and planned to continue production of silvery pig iron and 50% ferrosilicon.

Nippon Kokan K.K. indefinitely postponed construction of its $60 million polysilicon production facility in Millersburg, OR, owing to sluggishness in U.S. demand for the semiconductor starting material.[2]

Estimated ferrous scrap consumption by the domestic silicon ferroalloys industry to produce silicon ferroalloys was 250,000 tons in 1987, compared with 220,000 tons in 1986.

Table 2.—Producers of silicon alloys and/or silicon metal in the United States in 1987

Producer	Plant location	Product
Aluminum Co. of America, Northwest Alloys Inc	Addy, WA	FeSi and Si.
Applied Industrial Minerals Corp	Bridgeport, AL	FeSi.
Do	Kimball, TN	Do.
Dow Corning Corp	Springfield, OR	Si.
Elkem Metals Co	Alloy, WV	FeSi and Si.
Do	Ashtabula, OH	FeSi.
Do	Marietta, OH	Do.
Foote Mineral Co., Ferroalloys Div	Graham, WV[1]	Do.
Do	Keokuk, IA[2]	FeSi and silvery pig iron.
Globe Metallurgical Inc	Beverly, OH	FeSi and Si.
Do	Selma, AL	Si.
M. A. Hanna Co., Silicon Div	Wenatchee, WA	FeSi and Si.
Ohio Ferro-Alloys Corp	Montgomery, AL	Si.
Reactive Metals & Alloys Corp	West Pittsburgh, PA	FeSi.
Reynolds Metals Co	Sheffield, AL	Si.
SKW Alloys Inc	Calvert City, KY	FeSi.
Do	Niagara Falls, NY	FeSi and Si.

[1]Sold to American Alloys Inc. at yearend.
[2]Sold to Keokuk Ferro-Sil Inc. at yearend.

CONSUMPTION AND USES

Apparent consumption (demand) of silicon-containing ferroalloys and silicon metal increased compared with that of 1986. The overall increase, about 5%, reflected higher production levels in the aluminum, iron and steel, and silicon-base chemical industries. Significant increases were seen in the consumption of standard 50% grade ferrosilicon and miscellaneous silicon alloys that are used in the production of iron and steel. Ferrous applications accounted for about two-thirds of all the silicon materials consumed, based on silicon content. Metallurgical-grade silicon metal produced by tonnage methods is used as the basic raw material in the manufacturing of many chemical products and intermediates such as silicones and silanes. Silanes are used in the production of high-purity silicon for semiconductor devices and solar cells (photovoltaic cells). The Bureau of Mines does not collect data on electronic grades of silicon, which are relatively low in quantity but have a high unit value. The aluminum industry uses silicon metal in the production of wrought and cast products.

PRICES

Prices for silicon-containing ferroalloys and silicon metal were generally higher than those of 1986 owing to tight supplies created by increased demand from the aluminum, iron and steel, and silicon-base chemical industries. The published prices for domestically produced 50% and 75% grade ferrosilicon remained essentially unchanged through the first half of the year, but increased nearly 20% through the second half to 47 cents per pound of contained silicon. The respective average yearly prices of 41.3 and 40.3 cents per pound for 50% and 75% grade ferrosilicon were only slightly higher than those of 1986. The published prices for domestically produced silicon metal remained unchanged throughout the year, ranging from 62.0 to 67.35 cents per pound, depending on iron content.

Posted import prices for 50% and 75% grade ferrosilicon started the year much lower than those of domesti ally produced material, but both ended the year in line with the domestic list price of 47 cents per pound. The respective average prices for imported 50% and 75% grade ferrosilicon, 37.8 and 36.2 cents per pound, were about 10% higher than those of 1986. The posted price for imported silicon metal also increased steadily during the year to a level of 63 cents per pound, averaging 57.6 cents per pound. The average price was 4% higher than the average for 1986.

FOREIGN TRADE

Exports of ferrosilicon increased 33% in terms of gross weight, although the value of exported ferrosilicon was 40% higher than that of 1986. Over one-half of that material was shipped to Canada. Ferrosilicon was exported to 23 other countries. Silicon metal exports increased 72%, although the value increased 63%. Nearly 70% of the silicon metal exported was shipped to Japan, with the remainder distributed among 33 other countries.

Imports for consumption of ferrosilicon increased slightly compared with those of 1986, and at 230,658 tons was the largest amount ever imported by the United States. Although imports of most ferrosilicon categories increased, imports of 75% grade ferrosilicon (over 60% but not over 80% silicon), which normally account for the largest share of imports, decreased 7%. Imports of silicon metal overall decreased 10%, owing mostly to a significant decrease in shipments from Brazil.

Table 3.—U.S. exports of ferrosilicon and silicon metal

Year	Quantity (short tons)	Value (thousands)
FERROSILICON		
1983	13,338	$10,712
1984	29,364	21,135
1985	12,969	12,671
1986	11,331	8,306
1987	15,049	11,647
SILICON METAL		
1983	2,767	47,826
1984	4,420	88,543
1985	2,120	61,647
1986	5,378	65,157
1987	9,247	106,213

Source: Bureau of the Census.

Table 4.—U.S. imports for consumption of ferrosilicon and silicon metal, by grade and country

Grade and country	1986 Quantity (short tons) Gross weight	1986 Quantity (short tons) Silicon content	1986 Value (thousands)	1987 Quantity (short tons) Gross weight	1987 Quantity (short tons) Silicon content	1987 Value (thousands)
Ferrosilicon:						
Over 8% but not over 30% silicon:						
Brazil	22	6	$17	3,527	575	$1,080
Canada	--	--	--	51	15	9
China	--	--	--	22	6	8
Germany, Federal Republic of	65	11	62	--	--	--
Japan	--	--	--	2	1	2
South Africa, Republic of	--	--	--	73	11	33
United Kingdom	17	3	24	--	--	--
Total[1]	103	19	103	3,675	607	1,132
Over 30% but not over 60% silicon, with over 2% magnesium:						
Brazil	2,638	1,194	1,351	5,577	2,523	2,908
Canada	130	60	26	495	266	145
France	442	202	388	76	36	80
Germany, Federal Republic of	287	150	746	608	331	1,859
Italy	40	18	27	60	27	46
Japan	55	25	97	109	48	202
Mexico	17	8	11	22	10	15
Norway	189	84	135	--	--	--
United Kingdom	--	--	--	18	10	30
Total[1]	3,797	1,741	2,781	6,965	3,252	5,286
Over 30% but not over 60% silicon, not elsewhere classified:						
Argentina	--	--	--	1,683	943	832
Brazil	4,647	2,437	2,707	14,778	7,494	6,894
Canada	15,321	7,303	4,159	7,541	3,660	2,304
France	1,792	1,017	1,387	2,379	1,326	1,794
Germany, Federal Republic of	837	461	876	105	59	141
Iceland	5,512	3,029	1,715	--	--	--
Japan	18	8	34	188	92	308
Mexico	11	6	7	--	--	--
Spain	1,115	640	1,012	1,068	615	1,045
U.S.S.R	15,425	7,338	3,638	31,003	14,887	9,137
Venezuela	5,013	2,406	1,182	--	--	--
Total[1]	49,690	24,644	16,717	58,747	29,076	22,456

See footnote at end of table.

Table 4.—U.S. imports for consumption of ferrosilicon and silicon metal, by grade and country —Continued

Grade and country	1986 Quantity (short tons) Gross weight	1986 Quantity (short tons) Silicon content	1986 Value (thousands)	1987 Quantity (short tons) Gross weight	1987 Quantity (short tons) Silicon content	1987 Value (thousands)
Ferrosilicon —Continued						
Over 60% but not over 80% silicon, with over 3% calcium:						
Argentina	300	181	$308	1,317	820	$1,235
Brazil	7,151	4,438	6,179	8,260	5,326	6,294
Canada	54	34	51	273	208	153
France	1,925	1,194	1,741	1,606	990	1,450
Germany, Federal Republic of	1,069	674	913	150	99	124
Italy	570	352	508	663	405	540
Mexico	5	4	4	--	--	--
Netherlands	19	12	16	19	13	15
Spain	134	83	126	148	90	139
Venezuela	--	--	--	2,756	2,067	1,316
Total[1]	11,227	6,971	9,846	15,191	10,019	11,267
Over 60% but not over 80% silicon, not elsewhere classified:						
Argentina	--	--	--	10,552	8,069	4,897
Belgium-Luxembourg	--	--	--	666	503	311
Brazil	35,203	26,492	15,822	44,289	33,083	20,246
Canada	23,158	17,653	11,424	17,689	13,438	8,846
Chile	882	683	336	--	--	--
China	--	--	--	2,872	2,163	1,294
Dominican Republic	--	--	--	3	2	18
France	3,456	2,626	1,752	242	175	722
Germany, Federal Republic of	633	465	1,318	703	500	1,916
Iceland	8,271	6,331	3,602	7,320	5,367	3,440
Italy	--	--	--	132	87	123
Japan	36	22	67	--	--	--
Norway	42,299	32,157	18,454	33,784	25,793	15,089
Philippines	--	--	--	20	15	11
South Africa, Republic of	5,707	4,298	2,355	817	613	411
Spain	--	--	--	52	39	37
United Kingdom	--	--	--	1,113	835	502
Venezuela	34,030	24,901	13,818	23,584	17,525	9,682
Yugoslavia	2,646	1,992	1,273	2,018	1,550	864
Total[1]	156,322	117,620	70,221	145,855	109,755	68,410
Over 90% but not over 96% silicon:						
Brazil	209	201	151	154	145	135
Canada	--	--	--	2	2	3
Germany, Federal Republic of	56	55	46	--	--	--
Mexico	1,626	1,545	713	--	--	--
Norway	--	--	--	70	67	62
Total[1]	1,892	1,800	910	226	214	200
Total ferrosilicon	223,031	152,795	100,578	230,658	152,923	108,749
Silicon metal:						
Over 96% but not over 99% silicon:						
Argentina	552	NA	445	--	NA	--
Brazil	255	NA	254	--	NA	--
Canada	5,849	NA	5,784	1,901	NA	1,816
France	48	NA	59	32	NA	41
Norway	--	NA	--	451	NA	388
United Kingdom	205	NA	244	278	NA	339
Yugoslavia	1,948	NA	1,610	--	NA	--
Total[1]	8,856	NA	8,397	2,662	NA	2,584
Over 99% but not over 99.7% silicon:						
Argentina	3,192	3,167	3,005	6,235	6,180	5,880
Belgium-Luxembourg	([2])	([2])	r3	--	--	--
Brazil	12,620	12,526	12,200	4,807	4,765	4,527
Canada	6,012	5,960	6,795	9,836	9,754	10,632
China	--	--	--	1,331	1,319	1,209
France	2,282	2,265	2,321	512	509	510
Germany, Federal Republic of	11	11	17	([2])	([2])	4
Japan	--	--	--	55	55	48
Norway	70	70	60	180	179	208
Portugal	2,756	2,728	2,818	--	--	--

See footnotes at end of table.

Table 4.—U.S. imports for consumption of ferrosilicon and silicon metal, by grade and country —Continued

Grade and country	1986 Quantity (short tons) Gross weight	1986 Quantity (short tons) Silicon content	1986 Value (thousands)	1987 Quantity (short tons) Gross weight	1987 Quantity (short tons) Silicon content	1987 Value (thousands)
Silicon metal —Continued						
Over 99% but not over 99.7% silicon —Continued						
South Africa, Republic of	1,766	1,751	$1,756	2,738	2,713	$2,469
Spain	349	346	331	--	--	--
Sweden	768	762	714	1,794	1,776	1,830
Switzerland	--	--	--	19	18	21
Yugoslavia	1,436	1,423	1,488	5,941	5,876	5,621
Total[1]	31,263	31,006	31,507	33,448	33,144	32,960
Over 99.7% silicon:						
Belgium-Luxembourg	2	NA	21	3	NA	54
Canada	([2])	NA	1	2	NA	4
China	--	NA	--	2	NA	36
Denmark	2	NA	120	([2])	NA	97
France	1	NA	212	7	NA	1,036
Germany, Federal Republic of	513	NA	19,054	694	NA	27,685
Hong Kong	--	NA	--	([2])	NA	3
Italy	56	NA	3,409	55	NA	7,624
Japan	146	NA	1,866	55	NA	2,168
Korea, Republic of	([2])	NA	14	([2])	NA	6
Malaysia	--	NA	--	([2])	NA	11
Norway	6	NA	12	--	NA	--
Sweden	1	NA	8	([2])	NA	14
Switzerland	5	NA	466	([2])	NA	4
Taiwan	--	NA	--	1	NA	10
U.S.S.R	([2])	NA	3	([2])	NA	2
United Kingdom	([2])	NA	90	--	NA	--
Total[1]	733	NA	25,276	820	NA	38,754
Total silicon metal[1]	40,851	XX	65,180	36,930	XX	74,298

[r]Revised. NA Not available. XX Not applicable.
[1]Data may not add to totals shown because of individual rounding of converted units.
[2]Less than 1/2 unit.

Source: Bureau of the Census.

WORLD REVIEW

Demand for silicon-containing ferroalloys and silicon metal increased in many countries compared with that of 1986 owing to increased steel and aluminum production. Prices for both ferrosilicon and silicon metal rose steadily as supplies tightened. However, a continuing production shift from traditional suppliers to developing countries helped to keep the overall market in check.

The European Economic Community (EEC) imposed a 6.2% import duty on Yugoslav ferrosilicon and announced that it would make permanent a provisional antidumping duty of $58 per ton against 75% grade ferrosilicon coming into Europe from Brazil. The EEC also imposed a $58 per ton antidumping duty against ferrosilicon from the U.S.S.R. after imports were found to be entering Western Europe at significantly reduced prices.[3] The United States threatened to impose additional duties on silicon-containing materials from Brazil in retaliation to Brazil's strict import regulations on U.S. computer software.[4]

Argentina.—Silarsa S.A., a new company formed by Stein Ferroalloys S.A. and two units of the A. Johnson & Co. Group of the United States, planned a new venture to produce 16,000 tons per year of silicon metal, primarily for sale in the United States. Startup was scheduled for 1988. Electrometalurgica Andina S.A. increased silicon metal production capacity to 11,000 tons per year by activating a new 12,000-kilovolt-ampere (kV•A) furnace at its San Juan facility.[5]

Australia.—The country's first silicon metal smelter, a joint venture between Pioneer Concrete Ltd. and French metals producer Pechiney, started production in Tasmania. The plant's single 14-megawatt furnace is capable of producing 12,000 tons per year.[6] Agnew Clough Ltd. and the Australian Industry Development Corp. established a trust to build a 25,000-ton-per-year silicon metal production facility in the Wundowie area. Total cost of the project was projected to be $70 million with construction beginning in 1988.[7]

Brazil.—Production of both ferrosilicon (300,000 tons) and silicon metal (44,000 tons) increased 8% compared with that of 1986. Currently the world's fifth largest ferroalloy producer, Brazil continued to capture more of the world market for silicon products as exports of ferrosilicon and silicon metal increased nearly 25%.

Comargo Correa Metals S.A. neared completion on the construction of its new silicon metal production facility. The plant consists of four 18,000-kV•A furnaces with a combined capacity of 35,000 tons per year. Startup of the facility was scheduled for April 1988. The company also planned for a second phase of the project with an equal amount of capacity to be brought on-line in 1990.[8] Bozel Mineracao e Ferroligãs S.A. started a new 15,000-kV•A silicon metal furnace in Minas Gerais, with the capacity to produce 9,000 tons annually.[9]

Several Brazilian companies planned ferrosilicon capacity expansions, including Cia. de Cimento Portland Maringa, which completed construction of a 15,000-kV•A furnace at its ferroalloy plant in São Paulo.[10]

China.—Silicon metal producers in China, after more than doubling their production capacity over the past several years, continued to increase exports and captured nearly one-half of the Japanese market. Exports of silicon metal to Japan were 61,704 tons, a 68% increase over those of 1986. China also significantly increased its exports of silicon metal to the United States and Western Europe. China increased production of ferrosilicon to meet increasing demand from its domestic steel industry while further expanding into world markets. Ferrosilicon shipments to Japan were nearly five times the amount reported in 1986. The Chinese Government considered strict export controls and significant capacity expansions as means of ensuring material for domestic needs.[11]

France.—Pechiney Électrométallurgie considered a plan to switch production at its Dunkirk plant from ferrosilicon to either silicomanganese or charge chrome. The company decided to close its Saint Beron facility owing to high energy and labor costs and the availability of low-cost imports from Brazil and China. A decision on future production at the temporarily closed Laudon plant was pending. [12]

India.—Ferrosilicon production increased 20% during fiscal year 1986-87, despite electric power shortages caused by the country's worst drought in nearly 100 years. One of the country's major ferrosilicon producers, VBC Alloy Co., announced plans to diversify into specialty ferroalloy products.[13]

Japan.—Consuming industries demanded more ferrosilicon and silicon metal than in 1986 owing to increased steel and aluminum production. The Japanese Ferroalloy Association reported that overall production of ferrosilicon dropped more than 25% in 1987 to 87,900 tons. However, a significant increase in imports helped close the demand gap. Japanese silicon metal imports also increased nearly 10% compared with those of 1986.

Norway.—Elkem A/S, the world's largest silicon metal producer, announced that it would temporarily cut production at its Meraker plant from 35,000 to 19,000 tons per year owing to market conditions. Despite the cut, Elkem's share of world silicon metal production was expected to remain above 20%.[14] Tinfos Jernverk A/S announced the permanent closure of its ferrosilicon and silicon metal plant at Notodden. Production at the Notodden plant, which had a combined ferrosilicon-silicon capacity of over 90,000 tons per year, was stopped at the end of 1986.[15]

Portugal.—Cia. Portuguesa de Fornos Electricos S.A.R.L.'s Nelas facility, which was shut down in late 1986, remained closed pending a court decision on the company's future viability. High electrical power costs and totally depleted stocks were stated as Fornos' major obstacles to reactivating the plant.[16]

South Africa, Republic of.—Rand Carbide Ltd. decided to cut ferrosilicon production by 20% owing to an appreciation of the rand on exchange markets. The company said it would concentrate on selling its remaining production locally.[17]

Spain.—Facing high labor and power costs, ferroalloy producers entered rationalization talks with the Government. Industry sources expected the talks to result in production cutbacks and possible plant closures.[18]

U.S.S.R.—Owing to increased demand from its domestic steel industry, the Soviet Union was believed to be planning a 20%

cut in ferrosilicon exports. Exports of Soviet ferrosilicon to the United States and Japan had significantly increased over the past several years.[19]

Venezuela.—C.V.G. Ferrosilicio de Venezuela C.A. (FESILVEN) planned to increase its ferrosilicon production capacity from 65,000 to 95,000 tons by 1988. FESILVEN also began the initial planning of a silicon metal project.[20]

TECHNOLOGY

Silicon remains the material of choice in the world semiconductor industry owing mostly to its natural ability to form a surface oxide. The insulating properties of this oxide are important to the planar technology involved in device manufacturing. A number of materials are being considered as replacements for silicon in semiconductor devices because of more attractive semiconductive properties. Gallium arsenide devices have proven to be five times faster than those made of silicon and have a significantly higher radiation hardness (i.e., will withstand greater amounts of radiation). However, with its natural oxide-forming ability and other manufacturing advantages, silicon still holds a comfortable lead in device manufacturing. One of the most recent thrusts of research has been attempts to deposit layers of gallium arsenide onto a silicon substrate in order to take advantage of the most desirable properties of both materials.[21]

Advanced ceramic materials, such as silicon carbide and silicon nitride, have a low density and offer unique properties needed for these materials to become replacements for metals in engineering applications. High strength, hardness, and temperature stability make these materials potentially useful for cutting tools, gas turbine engine components, turbocharger rotors, and heat exchangers. Ceramics are also very corrosion resistant, making them attractive for pump and valve applications in which highly corrosive chemicals are present.[22] Although ceramics offer many desirable properties, their usefulness in engineering applications has been restricted because of brittleness. Ceramic materials can also be very costly and difficult to fabricate into usable products. These failings have slowed the development of the once envisioned completely ceramic internal combustion engine. Recent work has been centered on the development of specific components to improve overall engine efficiency[23] and the joining of ceramic and metal parts.[24]

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Silver

By Robert G. Reese Jr.[1]

Domestic silver production increased owing in part to byproduct silver production at many of the new gold mines opened during the year and to the reopening of several silver mines in response to the higher silver price. Several companies consolidated their precious metals holdings into subsidiary companies and then either sold the stock of the new subsidiaries directly to the public or distributed it to the parent companies' shareholders. These sales or stock distributions resulted in an improved balance sheet for the parent company and/or an infusion of capital. New labor agreements continued to be characterized by immediate wage and benefit reductions, although many, if not most, new contracts tied worker compensation to the silver price and to mine productivity.

Table 1.—Salient silver statistics

	1983	1984	1985	1986	1987
United States:					
Mine production ---- thousand troy ounces --	43,431	44,592	39,433	[r]34,524	39,790
Value ---- thousands --	$496,850	$362,976	$242,205	[r]$188,846	$278,930
Percentage derived from:					
Precious metals ores	76	80	70	63	W
Base metal ores	24	20	30	37	W
Placers	([1])	([1])	([1])	([1])	([1])
Refinery production:					
Domestic and foreign ores and concentrates thousand troy ounces --	57,759	59,331	53,808	42,413	44,838
Secondary (old scrap) ---- do ----	29,415	27,842	27,830	[r]24,494	26,034
Exports:					
Refined ---- do ----	13,658	10,340	12,611	10,109	11,240
Other ---- do ----	18,294	14,107	12,145	15,005	15,853
Imports for consumption:					
Refined ---- do ----	161,199	93,546	137,398	125,365	67,959
Other ---- do ----	18,692	21,420	15,203	19,525	13,867
Stocks, Dec. 31:					
Industry ---- do ----	17,449	21,217	18,467	[r]17,671	15,034
Futures exchanges ---- do ----	151,232	137,631	173,144	162,089	169,731
Consumption:					
Industry and the arts ---- do ----	116,440	114,841	118,555	[r]121,743	118,500
Coinage ---- do ----	2,128	2,665	[r]362	[r]7,535	15,074
Price, average per troy ounce[2]	$11.44	$8.14	$6.14	$5.47	$7.01
Employment[3]	2,400	2,600	3,000	2,200	1,800
World:					
Mine production ---- thousand troy ounces --	[r]387,711	[r]413,930	422,093	[p]415,929	[e]429,091
Consumption:[4]					
Industry and the arts ---- do ----	340,700	353,300	357,200	380,700	384,600
Coinage ---- do ----	[r]18,200	8,700	12,700	[r]26,000	31,100

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Less than 1/2 unit.
[2]Handy & Harman.
[3]Mine Safety and Health Administration.
[4]Market economy countries only. Source: Handy & Harman.

Domestic Data Coverage.—Domestic mine production data for silver are developed by the Bureau of Mines from four separate voluntary surveys of U.S. operations. Typical of these surveys is the lode mine production survey of copper, gold, lead, silver, and zinc. Of the 255 silver-producing lode mines to which a survey form was sent, 200 responded. Of these, 119 were active, accounting for an estimated 99% of the total U.S. mine production shown in tables 1, 2, 3, 5, 6, and 7.

Legislation and Government Programs.—The U.S. Supreme Court ruled in the case of *California Coastal Commission* v. *Granite Rock Co.* that the States have some regulatory authority over mining activity on Federal lands. The decision upheld the California Coastal Commission's authority to require that Granite Rock get a State permit before mining limestone in Los Padres National Forest. The U.S. Forest Service had granted permission for the mining activity. The decision stated that States could regulate for environmental purposes on Federal lands unless State regulation was prohibited by Congress or unless the State's regulations conflicted with Federal regulations. The Court said that, although the State's power in this area was limited, future litigation would be necessary to define the limits. The decision was expected to make it easier for the States to defend their regulation of private commercial enterprises, including precious metals mines, on Federal lands.

On October 28, the President signed Public Law 100-141, the 1988 Olympic Commemorative Coin Act, which authorized the U.S. Mint to produce 10 million silver coins and 1 million gold coins to commemorate the 1988 summer Olympics, scheduled to be held in Seoul, Republic of Korea. The silver and gold coins were to contain 0.77 ounce[2] silver and 0.34 ounce gold, respectively. Both coins were to be legal tender. A surcharge was authorized to be added to the price of each coin to help support U.S Olympic athletes.

DOMESTIC PRODUCTION

Silver was produced from precious metals ores at 89 lode mines, while 30 lode mines produced silver as a byproduct of the processing of copper, lead, and zinc ores. The 25 largest mines accounted for 93% of total domestic mine output. In 1987, 12 mines each produced more than 1 million ounces of silver; their aggregated production equaled 76% of total domestic production. Silver was also produced at 14 placer operations.

Arizona.—In April, ASARCO Incorporated purchased Anamax Mining Co.'s interest in the Eisenhower Mine, thereby acquiring total ownership of the four copper mines that share the pit at its Mission Complex. Acquisition of Eisenhower increased Asarco's reserves at Mission by an estimated 39 million tons of ore, grading 0.63% copper and 0.12 ounce of silver per ton. Asarco also acquired the Mineral Hill deposit adjacent to Mission, which contains an estimated 14 million tons of ore, grading 0.94% copper and 0.14 ounce of silver per ton.

The Copperstone Mine, owned by Cyprus Minerals Co., began production in the fourth quarter, just 7 months after Cyprus began construction at the mine. The mine used agitation leaching to recover gold and a small quantity of byproduct silver.

In June, Cyprus purchased the Lakeshore copper-silver mine from Noranda Inc., changing its name to Casa Grande. Production at the mine was limited to the copper recovered from in situ leaching of oxide ore, but Cyprus planned to use a 150,000-ton-per-year roaster at the mine to treat some of the copper concentrates produced at Cyprus' nearby Sierrita copper-silver-molybdenum mine.

Newmont Mining Corp., as part of a restructuring program that has been shifting the corporation's emphasis from copper to gold and silver, merged its wholly owned Pinto Valley Copper Corp. subsidiary with its Magma Copper Co. subsidiary and transferred 80% of the ownership of Magma to Newmont's shareholders. Newmont retained a 15% interest in Magma, while the remaining 5% of Magma's shares was to be used in an incentive program for Magma's management. The assets of Magma included a copper smelter and several copper-silver-molybdenum mines in Arizona.

Consolidated Gold Fields PLC, a South Africa-based company, increased its holding in Newmont, a significant domestic silver producer, from 26.2% to nearly 49.4%.

Idaho.—Asarco negotiated a new 3-year agreement with workers at the Galena Mine. Reportedly, the contract reduced wages by $3.30 per hour, reduced benefits, and suspended cost-of-living adjustments. The contract also provided for partial wage restorations in 1988 and 1989.

Coeur d'Alene Mines Corp. and Hecla Mining Co. terminated exploration and development of properties, including the Silver Summit Mine, owned by Consolidated Silver Corp. Poor exploration results were cited as a factor in the decision. Control of the properties was to revert to Consolidated in early 1988.

Coeur d'Alene's Thunder Mountain Mine received a first-place award for the protection of Idaho's natural resources. The award was given by the Pacific Northwest Pollution Control Association for the mine's successful use of new and/or improved environmental engineering methods.

Commercial operations resumed at Hecla's Lucky Friday Mine in June. The improved silver price was cited as one factor in the decision to reopen the mine, which had been closed since April 1986. A new mining method, called the underhand longwall mining method, was implemented on the 5300 level. The new method, developed jointly by Hecla and the U.S. Bureau of Mines, was expected to reduce Lucky Friday's operating costs and improve safety through the use of mechanized equipment, a ramp system, and cemented sandfill. Workers at Lucky Friday ratified a new 3-year labor agreement. The new contract, while reducing wages and benefits 15% during its first year and by an additional amount the second year, established a profit-sharing plan.

NERCO Inc. completed construction of a heap-leaching facility at the DeLamar Mine. Heap leaching was to be used in tandem with the existing agitation leaching system. Over the next 7 years, heap leaching was expected to recover an additional 65,000 ounces of gold and 1.4 million ounces of silver from the low-grade reserves.

Although the Sunshine Mine was closed most of the year, Sunshine Mining Co. negotiated a new contract with the members of the International Brotherhood of Electrical Workers (IBEW). The new contract contained a flexible wage scale based on the silver price and the production of the mine. The IBEW was one of two unions representings workers, the other union being the United Steelworkers of America (USWA). Like the IBEW contract, the USWA contract expired in April; however, a new agreement was not reached. In late November, Sunshine began recalling workers preparatory to reopening the Sunshine Mine. Owing to the expiration of the USWA contract and the impasse in negotiations, Sunshine based the recalled workers' compensation on its last contract offer, which was similar to the compensation in the IBEW contract.

Montana.—Production began in April at the Montana Tunnels gold-silver-lead-zinc mine. The milling process at the mine initially consisted of producing a sulfide concentrate, by bulk flotation, leaching the concentrate with cyanide to recover gold and silver, and then producing separate lead and zinc concentrates by selective flotation. The mill began producing separate lead and zinc concentrates before the leaching step, and, as a result, most of the precious metals were contained in the lead and zinc concentrates.

Silver production at the Zortman-Landusky Mine declined in 1987, in part because of the lower grade of the ore treated, despite a longer than usual operating season. Production of silver and gold was aided by a new carbon adsorption and stripping facility and the use of a buried drip system. The system allowed extension of heap leaching, although at less than full capacity, into the winter months.

The Black Pine Mine was reopened in May in response to the higher silver price.

Nevada.—AMAX Inc. formed AMAX Gold Inc. to handle precious metals activities. AMAX subsequently sold a 13% interest in AMAX Gold, reducing its interest in the company to 87%. AMAX Gold's only operating mine was the Sleeper Mine in Humboldt County, where heap-leaching capacity was increased from 750,000 tons to 4.5 million tons per year and additional gold-silver reserves, approximately one-quarter of a mile south of the original Sleeper pit, were developed. The increase in heap-leaching capacity along with production from the new pit, called the Wood pit, was expected to increase Sleeper's metal production by more than 30%.

Precious metals production began in January at Atlas Corp.'s Gold Bar Mine primarily through a mill using carbon-in-leach technology; however, heap leaching was used to process low-grade ore. By the end of June, the mill was operating at its design capacity of 1,500 tons per day.

Battle Mountain Gold Co. began production at the Surprise Mine in August. The mine, approximately 10 miles northeast of the company's Fortitude Mine, produced a gold-silver ore by conventional open pit methods. Mill-grade ore was treated at the Fortitude mill. Lower grade ore was stockpiled for possible future heap leaching.

At the Round Mountain Mine, Echo Bay Mines Ltd. began several projects to increase its ore processing capacity from 18,000 to 35,000 tons per day in order to enable heap leaching of Type II ore. Included in the expansion were construction of additional crushing, heap-leaching, and recovery facilities.

FMC Corp. combined its precious metals assets and formed FMC Gold Co. FMC subsequently sold 11.4% of FMC Gold's shares. Among FMC Gold's holdings were the Paradise Peak silver-gold mine (100% ownership) in Nye County, the Jerritt Canyon Mine (30% ownership) in Elko County, and the Austin Mine (27.6% ownership) in Churchill County. Jerritt Canyon and Austin were both gold mines that produced some byproduct silver.

Heap-leaching operations began in September at the Big Springs Mine, a joint venture of Freeport-McMoRan Gold Co. (60% interest) and Bull Run Mining Co. (40% interest). Construction of a fluid-bed roasting system and conventional milling facilities was begun during the year and was expected to be operational in 1988. Reserves at yearend 1987, were 2.4 million tons of ore.

At the Alligator Ridge Mine, a 1,000-ton-per-day carbon-in-leach plant was constructed by the mine's joint-venture partners, Nerco and BP Gold Co., to permit recovery of precious metals from some carbon-bearing reserves; it was expected to extend the mine's life to the end of the decade.

New Mexico.—In September, St. Cloud Mining Co. and Cyprus formed a joint venture to develop and mine St. Cloud's Pinos Altos property. Concentrate production from the copper-silver-gold ore commenced in November; the ore was milled at the St. Cloud Mine.

Limited mining was resumed at the St. Cloud Mine during the second quarter. Almost all of the mine's production was sold directly to regional copper smelters as siliceous convertor flux.

Other States.—Fluor Corp. substantially completed the restructuring program it had begun in 1985, returning to its "core" businesses of engineering, construction, and technical services and divesting itself of natural resource industries. It sold its domestic zinc operations to Horsehead Industries Inc. Included in the sale were the Balmat and Pierrepont Mines in New York, both of which produce byproduct silver. In October, it sold its remaining 90.3% holding in St. Joe Gold Corp. and its interest in other gold properties to Dallhold Investments Pty. Ltd. St. Joe Gold owned El Indio gold-silver mine in Chile.

Mining began at the Portland Pit, a joint venture of Texasgulf Minerals and Metals Inc. and Golden Cycle Gold Corp. in Colorado. Mined ore was stockpiled pending completion of a leach pad and construction of a mill. The new mill was being constructed using a part of the Carlton mill and was to produce a doré product from the higher graded ore through cyanide leaching. Heap leaching was to be used for lower grade ore. Production of gold and silver was expected to begin in the spring of 1988.

A yearend surface subsidence at the Ropes Mine in Michigan resulted in the mine's temporary closure. As a result of the subsidence, Callahan Mining Corp. decided to change the mining system for Ropes to a continuous caving system with backfilling to assure ground stability.

The Sweetwater Mine, a byproduct silver producer in Missouri, was reopened by Asarco in December. The mine, formerly known as the Milliken Mine when it was owned by Kennecott, had been closed since 1983. Annual capacity for Sweetwater was 75,000 tons of lead and 4,500 tons of zinc in concentrates.

British Petroleum Co. PLC (BP) acquired the remaining 45% of Standard Oil Co. of Ohio. The acquisition gave BP total ownership of the Bingham Canyon copper-gold-silver mine in Utah.

At the Knob Hill Mine in Washington, Hecla opened the Golden Promise shaft, installed a new backfill storage and delivery system, and made improvements to the pumping system. The new shaft provided access to the higher grade Golden Promise area of the mine. Gold and silver output increased significantly as mining operations moved into this area.

CONSUMPTION AND USES

Domestic consumption of silver remained steady in 1987, with only five industries indicating more than a 10% change from 1986 consumption levels.

STOCKS

At yearend 1987, Commodity Exchange Inc. (COMEX) stocks were 156.4 million ounces, having ranged from a month-end low of 150.2 million ounces in January to a month-end high of 160.1 million ounces in August. Yearend stocks held by the Chicago Board of Trade (CBT) were 13.5 million ounces, having ranged from a low of 12.6 million ounces on the last trading days of September, October, and November to a high of 16.8 million ounces on the last trading day of January.

The quantity of silver held in the National Defense Stockpile continued to decline in 1987, as the U.S. Mint drew down the silver for use in two Government coinage programs. Refiner, fabricator, and dealer stocks, as reported to the Bureau of Mines, declined throughout the year possibly owing in part to the higher silver price.

PRICES

The domestic silver price as quoted by Handy & Harman increased, reversing the declining trend of the previous 4 years. The price began the year at $5.44 and was $6.70 at yearend. Analysts attributed the rising price to numerous factors, including the weakening of the U.S. dollar in relation to certain foreign currencies, larger U.S. trade deficits, strong speculative demand, chart-guided technical trading, investor concerns about the U.S. inflation rate, increased Middle East tensions, possible labor disruptions in the Republic of South Africa, and the possibility that some major silver-producing nations might withhold some of their production.

Notable in the second half of 1987 was the lack of silver price movement following the record drop in the stock market's Dow Jones Industrial Average on October 19. The price, instead of rising owing to the increased uncertainty following the stock market drop, declined, possibly indicating the need by many investors to liquidate their commodity holdings to cover stock market losses.

As with the domestic price, the London spot price increased during the year and followed a pattern similar to that of the Handy & Harman price. The U.S. dollar equivalent of the London spot price, as quoted in Metals Week, began 1987 at $5.37 per ounce and ended the year at $6.70. The low and high prices of $5.36 and $10.93 occurred on January 7 and April 17, respectively. The average for 1987 was $7.03.

The amount of silver represented by the futures contracts traded on COMEX increased nearly one-third in 1987 to 25.3 billion ounces. Trading volume at the CBT increased about 17% in 1987 to 597 million ounces. Silver futures trading volume on the Mid-America Commodity Exchange increased from 10 to 11 million ounces.

FOREIGN TRADE

U.S. silver exports increased slightly in 1987 as the weaker U.S. dollar made domestic silver more competitive in the global market. The United Kingdom, France, and Japan recorded the largest increases in receipts of U.S. silver exports. Shipments to the United Kingdom increased by more than 2 million ounces, of which nearly 1.9 million ounces was in the form of refined bullion. U.S. silver exports to France increased by nearly 1.6 million ounces, of which nearly 1.4 million ounces was contained in waste and scrap material. Japan increased its purchases of refined bullion from the United States by nearly 1.3 million ounces.

In addition to helping make U.S. silver exports more competitive, the weaker U.S. dollar was probably a significant factor in the decrease in U.S. silver imports for consumption. Silver sellers in countries whose currencies were appreciating in terms of the U.S. dollar could obtain a higher silver price in terms of their local currencies by selling their silver in markets other than those in the United States. As a result, U.S. silver imports dropped 44% to their lowest level since 1980, when 79 million ounces was imported. The countries with the largest decreases in silver exports to the United States were Canada with a 26.2-million-ounce decrease and the United Kingdom and Belgium-Luxembourg with decreases of 11.7 million and 11.5 million ounces, respectively. The lower exports from these three countries primarily represented decreased refined bullion shipments.

WORLD REVIEW

World mine production of silver increased slightly in 1987 owing in part to the recovery of byproduct silver at many of the new gold mines opened during the year. Other factors included the reopening of several mines, primarily in the United States, in response to the higher silver price and the increased world production of base metals such as copper, lead, and zinc, from which silver is recovered as a byproduct. Although not generally a primary exploration target, potential new silver sources continued to be discovered, most often associated with gold. Australia, Canada, Mexico, Oceania, and Peru were among the most active exploration areas in the world.

Total consumption of silver in market economy countries, according to Handy & Harman, was 415.7 million ounces, an increase of 9 million ounces over the revised figure for 1986. Of the total, 384.6 million ounces was used in industrial applications, an increase of 3.9 million ounces over the 1986 level. The quantity of silver used for coinage increased from 26 million ounces in 1986 to 31.1 million ounces in 1987.[3]

The total silver required by all market economy countries, including the United States, for industrial use, coinage, bullion stocks, and net exports to centrally planned economy countries exceeded their primary production by 96.8 million ounces. The shortfall was met with silver obtained from the following sources, according to Handy & Harman: old scrap, 75.9 million ounces; outflow from stock held in India, 11.3 million ounces; demonetized coin, 2 million ounces; and withdrawals from Government stocks, 7.6 million ounces. Estimated net exports to centrally planned economy countries was 2 million ounces.

Australia.—At the Hellyer Mine, the Luina mill (formerly the Cleveland mill) was expanded from a pilot plant to a flotation concentrator with a capacity of 276,000 tons of ore per year. Commercial production began in April. Aberfoyle Ltd. decided to expand the capacity at Hellyer to 1.1 million tons per year. Construction of a new mill was a major component of the project, which was expected to be completed in early 1989.

Battle Mountain began production at the Pajingo Mine in September. The mine, an open pit operation in Queensland, was expected to produce 60,000 ounces of gold and 200,000 ounces of silver at full capacity in 1988.

The Broken Hill Proprietary Co. Ltd. (BHP) completed the restructuring of its Australian and New Zealand gold assets, forming BHP Gold Mines Ltd. Included in BHP Gold Mines were three operating mines, four advanced exploration projects, and other properties. Although these assets were primarily gold properties, most either produced or contained byproduct silver. BHP retained a 56% interest in BHP Gold Mines at yearend.

The Woodlawn zinc-copper-silver-lead mine was sold by CRA Ltd. to Denehurst Ltd.

Trial mining began at Mount Isa Mine Ltd.'s (MIM) Hilton Mine in June. Initial testing involved the cut-and-fill mining method at a rate in excess of 2,000 tons per week. Additional testing was expected to include the sublevel open-stoping method.

North Broken Hill Holdings Ltd. (NBHH) formed Norgold Ltd. to conduct its precious metals exploration and development activities. NBHH subsequently sold 37% of Norgold's shares to NBHH's stockholders, thereby reducing its holding in Norgold to 63%.

An agreement between Renison Goldfields Consolidated Ltd. and the Government of the State of Tasmania on an aid package along with confirmation of higher grade reserves below the mine's current operating levels was expected to enable the Mount Lyell Mine to remain open through 1994. The aid package reportedly included provisions for the State government to fund a portion of the capital investment needed to mine the deeper reserves and to defer some tax and royalty payments. Another factor in the decision to extend operations at Mount Lyell reportedly was currency exchange rates. The declining value of the Australian dollar resulted in an improved domestic copper price.

Canada.—Hudson Bay Mining & Smelting Co. Ltd. (HBMS) completed the purchase of the Ruttan Mine from Sherritt Gordon Mines Ltd. The Ruttan Mine in Manitoba produced copper, zinc, and silver and was a major source of copper and zinc concentrates for the HBMS smelter at Flin Flon, Manitoba. Prior to the purchase, Sherritt announced plans to close the mine. At yearend 1987, Ruttan had nearly 9 million tons of reserves containing almost 2 million ounces of silver.

In response to the increasing importance of precious metals, especially gold, to its operation, Inco Ltd. consolidated its precious metals activities in a new subsidiary called Inco Gold Co. Inco Gold was to continue exploration and development of Inco's precious metals properties, eventually becoming a mine operator. By yearend, Inco Gold was involved in over 50 precious metals ventures and prospects in Brazil, Canada, Indonesia, and the United States.

In 1987, Inco completed the conversion of its Crean Hill Mine in Ontario to an all-electric operation and reactivated the mine. Among the metals expected to be produced at Crean Hill were copper and small quantities of gold and silver. Crean Hill's last full year of operation was 1977.

A fire in April at the Gaspé Mine resulted in the death of one miner and the destruction of the underground conveyor system. The mine was subsequently closed owing in part to low copper prices and to the high cost of rehabilitating the mine. Although the Quebec government reportedly made financial aid available to Noranda Inc. to assist in reopening the mine, it remained closed through yearend.

Placer Dome Inc. was formed by the amalgamation of Placer Development Ltd., Dome Mines Ltd., and Campbell Red Lake Mines Ltd. Following the merger, Placer Dome became one of the world's largest gold-producing companies, as well as a significant silver-copper-molybdenum producer with operations worldwide.

Teck Corp. signed an agreement transferring its Highmont Mine and mill to Highland Valley Copper Co. With this agreement, Highland Valley Copper consolidated all the major copper-silver mining and milling facilities in the Highland Valley area of British Columbia. Following the merger, Cominco Ltd.'s interest in Highland Valley was reduced from 55% to 50% to accommodate Teck's 5% interest in the company. Lornex Mining Corp.'s interest in Highland Valley remained at 45%.

Other Countries.—Asarco sold its 51% interest in the Quioma Mine in Bolivia to its partners in the venture. The lead-zinc-silver mine was closed in 1986 in response to the low lead and zinc prices. Reportedly, the mine was reopened in 1987 when the price of lead and zinc increased.

In September, the Mexican Government began selling "Certificados de Plata" (Ceplata's). These certificates were backed by silver and were similar to an earlier Mexican financial product that was backed by oil. Each certificate represented 100 ounces of 99.9% pure silver and could be either sold for cash or exchanged for silver. The initial offering was for 40,000 certificates and reportedly sold out in 1 day. The certificates enabled investment in silver without having to take physical possession or be concerned about the security of the metal. The Government encouraged the purchase of the certificates by granting them a favored tax status. Following the success of the initial offering, additional larger issues were being considered.

TECHNOLOGY

Silver-related research and development was extensive in 1987. A sample of the reported work included the development of several silver alloys for use in electrical contacts, investigations into the antibacterial effect of silver in some medical applications, and applications for various silver catalysts.

These and numerous other reports on silver-related research were summarized by the staff of the Silver Institute in its "New Silver Technology" publication.[4]

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[1]Physical scientist, Branch of Nonferrous Metals.

[2]Ounce as used throughout this chapter refers to the troy ounce.

[3]Handy & Harman. The Silver Market, 1987. 72d Annual Report. 26 pp.

[4]Silver Institute. New Silver Technology. Silver Summaries From the Current World Literature monthly publication; available from the Silver Institute, 1026 16th St. NW, Washington, DC 20036.

Table 2.—Mine production of recoverable silver in the United States, by State

(Troy ounces)

State	1983	1984	1985	1986	1987
Alaska	4,123	W	W	W	10,010
Arizona	4,491,532	4,246,616	4,885,310	r4,506,197	3,667,077
California	26,899	W	115,478	155,176	121,817
Colorado	2,145,616	2,199,888	548,696	644,574	860,562
Idaho	17,684,278	18,869,186	18,827,948	11,206,851	W
Illinois	W	W	W	W	W
Michigan	--	--	W	W	W
Missouri	2,021,343	1,401,070	1,635,301	1,459,185	1,180,584
Montana	5,707,963	5,652,847	4,009,979	4,773,264	5,837,418
Nevada	5,179,394	6,477,032	4,946,523	6,408,783	12,189,822
New Mexico	W	W	W	W	W
New York	33,137	W	W	W	W
Oregon	856	W	--	--	W
South Carolina	--	--	W	W	W
South Dakota	62,314	50,036	63,156	W	W
Tennessee	W	W	W	W	W
Utah	4,566,610	W	W	W	W
Washington	W	W	W	W	W
Total	43,430,937	44,591,671	39,432,973	r34,523,896	39,790,269

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

Table 3.—Mine production of recoverable silver in the United States, by month

(Thousand troy ounces)

Month	1983	1984	1985	1986r	1987
January	3,101	3,774	3,429	3,703	2,846
February	3,051	3,897	3,049	3,257	2,755
March	3,776	4,202	3,389	3,282	2,997
April	3,681	4,027	3,211	3,183	3,437
May	3,675	3,892	3,355	2,879	3,282
June	3,767	3,780	3,234	2,778	3,340
July	3,588	3,576	3,238	2,704	3,666
August	3,755	3,719	3,359	2,611	3,518
September	3,563	3,245	2,922	2,623	3,603
October	3,408	3,662	3,847	2,635	3,457
November	3,414	3,323	3,122	2,372	3,345
December	4,652	3,495	3,278	2,497	3,544
Total	43,431	44,592	39,433	34,524	39,790

rRevised.

Table 4.—Twenty-five leading silver-producing mines in the United States in 1987, in order of output

Rank	Mine	County and State	Operator	Source of silver
1	Troy	Lincoln, MT	ASARCO Incorporated	Silver-copper ore.
2	Rochester	Pershing, NV	Coeur Rochester Inc	Silver ore.
3	Galena	Shoshone, ID	ASARCO Incorporated	Do.
4	Candelaria	Mineral, NV	Nerco Metals Inc	Do.
5	Paradise Peak	Nye, NV	FMC Gold Corp	Gold ore.
6	Coeur	Shoshone, ID	ASARCO Incorporated	Copper ore.
7	Escalante	Iron, UT	Hecla Mining Co	Silver ore.
8	Bingham Canyon	Salt Lake, UT	Kennecott	Copper ore.
9	DeLamar	Owyhee, ID	Nerco DeLamar Co	Gold-silver ore.
10	Tyrone	Grant, NM	Phelps Dodge Corp	Copper ore.
11	Battle Mountain	Lander, NV	Battle Mountain Gold Co	Gold ore.
12	White Pine	Ontonagon, MI	Copper Range Co	Copper ore.
13	Morenci	Greenlee, AZ	Phelps Dodge Corp	Do.
14	Lucky Friday	Shoshone, ID	Hecla Mining Co	Silver ore.
15	Mission Complex[1]	Pima, AZ	ASARCO Incorporated	Copper ore.
16	Bagdad	Yavapai, AZ	Cyprus Bagdad Copper Co	Do.
17	Montana Tunnels	Jefferson, MT	Montana Tunnels Mining Inc	Gold ore.
18	Sierrita	Pima, AZ	Cyprus Sierrita Corp	Copper ore.
19	Continental	Silver Bow, MT	Montana Resources Inc	Do.
20	San Manuel	Pinal, AZ	Magma Copper Co	Do.
21	Sunnyside	San Juan, CO	Sunnyside Gold Corp	Gold ore.
22	Buick	Iron, MO	The Doe Run Co	Lead ore.
23	Ray	Pinal, AZ	ASARCO Incorporated	Copper ore.
24	Chino	Grant, NM	Phelps Dodge Corp	Do.
25	Republic Unit	Ferry, WA	Hecla Mining Co	Gold ore.

[1]Includes Eisenhower, Mission, Pima, and San Xavier Mines.

Table 5.—Silver produced in the United States, by State, type of mine, and class of ore

Year and 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
1983	4,035	18,329,722	1,146,835	1,129,756	1,794,753	7,528,125	30,079,569
1984	1,503	24,581,032	1,333,227	1,587,850	2,890,407	7,804,144	31,328,954
1985	6,434	26,888,194	1,647,506	1,043,854	2,039,797	4,302,681	24,012,856
1986	6,490	42,914,649	3,858,979	869,099	1,809,687	5,555,677	15,835,513
1987:							
Alaska	10,010	--	--	--	--	--	--
Arizona	W	W	W	--	--	--	--
California	1,811	8,339,669	120,006	--	--	--	--
Colorado	--	W	W	--	--	--	--
Idaho	--	W	77,319	W	W	W	W
Illinois	--	--	--	--	--	--	--
Michigan	--	W	W	--	--	--	--
Missouri	--	--	--	--	--	--	--
Montana	W	14,206,230	753,903	--	--	W	W
Nevada	5,000	23,531,695	4,941,656	--	--	8,150,597	7,242,117
New Mexico	--	W	W	W	W	--	--
New York	--	--	--	--	--	--	--
Oregon	W	W	W	--	--	--	--
South Carolina	--	W	W	--	--	--	--
South Dakota	--	W	W	--	--	--	--
Tennessee	--	--	--	--	--	--	--
Utah	--	W	W	--	--	W	W
Washington	--	W	W	--	--	--	--
Total	22,786	58,573,667	7,145,044	W	W	8,695,125	13,785,316
Percent of total silver	([1])	XX	18	XX	W	XX	35

Year and State	Lode: Copper ore Short tons	Lode: Copper ore Troy ounces of silver	Lode: Other[2] [3] Short tons	Lode: Other[2] [3] Troy ounces of silver	Total Short tons	Total Troy ounces of silver
1983	[4]171,614,767	[4]7,344,180	9,659,845	3,061,565	208,262,215	43,430,937
1984	[4]166,255,710	[4]6,526,427	21,573,113	2,511,153	221,801,849	44,591,671
1985	154,658,676	9,659,224	12,313,173	2,067,156	199,206,578	39,432,973
1986	[4]146,673,936	[r] [4]11,104,036	6,045,883	1,909,191	202,059,244	[r]34,523,896
1987:						
Alaska	--	--	--	--	--	10,010
Arizona	162,367,487	3,529,883	W	W	162,686,453	3,667,077
California	--	--	--	--	8,339,669	121,817
Colorado	--	--	W	W	4,337,092	860,562
Idaho	W	W	--	--	2,536,037	W
Illinois	--	--	W	W	W	W
Michigan	W	W	--	--	W	W
Missouri	--	--	W	1,180,584	W	1,180,584
Montana	W	W	W	W	30,161,624	5,837,418
Nevada	--	--	63	1,049	31,682,355	12,189,822
New Mexico	W	W	--	--	W	W
New York	--	--	W	W	W	W
Oregon	--	--	--	--	W	W
South Carolina	--	--	--	--	W	W
South Dakota	--	--	--	--	W	W
Tennessee	--	--	W	W	W	W
Utah	W	W	--	--	W	W
Washington	--	--	--	--	W	W
Total	239,174,186	15,330,720	W	W	315,625,693	39,790,269
Percent of total silver	XX	38	XX	W	XX	100

[r]Revised. W Withheld to avoid disclosing company proprietary data; included in "Total." XX Not applicable.
[1]Less than 1/2 unit.
[2]Includes lead, zinc, copper-lead, lead-zinc, copper-zinc, and copper-lead-zinc ores.
[3]Includes silver recovered from tungsten and fluorspar ores.
[4]Includes copper-zinc ore and silver recovered from copper-zinc ore.

Table 6.—Silver produced in the United States by cyanidation[1]

Year	Leaching in vats, tanks, and closed containers[2 3]		Leaching in open heaps or dumps[4]	
	Ore treated (thousand short tons)	Silver recovered (troy ounces)	Ore treated (thousand short tons)	Silver recovered (troy ounces)
1983	9,733,730	7,058,108	12,727,412	2,201,221
1984	11,172,695	7,752,063	18,222,366	2,986,172
1985	15,421,903	6,819,904	14,875,363	2,701,360
1986	19,269,750	7,504,350	27,620,640	3,641,741
1987	15,558,436	8,957,240	49,730,775	8,212,971

[1]May include small quantities recovered by leaching with thiourea, by bioextraction, and by proprietary processes.
[2]Including autoclaves.
[3]May include small quantities recovered by gravity methods.
[4]May include tailings and waste ore dumps.

Table 7.—Lode silver produced in the United States, by State

Year and State	Amalgamation: Ore treated (short tons)	Amalgamation: Silver recovered (troy ounces)	Cyanidation: Ore treated (short tons)	Cyanidation: Silver recovered (troy ounces)	Smelting of concentrates: Ore concentrated (short tons)	Smelting of concentrates: Concentrates smelted (short tons)	Smelting of concentrates: Silver recovered (troy ounces)	Smelting of ore: Ore smelted (short tons)	Smelting of ore: Silver recovered (troy ounces)	Total ore processed[1] (short tons)	Total silver recovered (troy ounces)
1983	3,400	50	22,461,142	9,259,329	185,513,477	4,939,007	33,338,651	284,196	[2]829,030	208,262,215	[2]43,427,060
1984	--	--	29,395,061	10,738,235	192,253,620	4,108,133	33,373,850	153,168	478,083	221,801,849	44,590,168
1985	--	--	30,297,266	9,521,264	168,650,998	4,523,641	29,313,819	258,314	591,456	199,206,578	39,426,539
1986	752,421	10,396	46,890,390	11,146,091	154,212,790	3,904,999	[r]23,065,267	203,643	295,652	202,059,244	[r]34,517,406
1987:											
Arizona	--	--	W	W	148,258,252	2,374,838	3,531,561	W	W	162,686,453	[2]3,667,077
California	--	--	8,339,069	116,415	600	10	3,591	--	--	8,339,669	120,006
Colorado	W	W	W	W	W	W	W	W	W	4,337,092	860,562
Idaho	--	--	2,120,911	W	W	W	W	W	W	2,536,037	W
Illinois	--	--	--	--	W	W	W	--	--	W	W
Michigan	--	--	W	W	W	W	W	--	--	W	W
Missouri	--	--	--	--	W	W	1,180,584	--	--	W	1,180,584
Montana	--	--	12,471,506	316,662	W	W	W	W	W	30,161,624	[2]5,837,418
Nevada	--	--	31,682,292	12,183,773	--	--	--	63	1,049	31,682,355	12,184,822
New Mexico	--	--	W	W	W	W	W	W	W	W	W
New York	--	--	--	--	W	W	W	--	--	W	W
Oregon	--	--	--	--	--	--	--	W	W	W	W
South Carolina	--	--	W	W	--	--	--	--	--	W	W
South Dakota	--	--	W	W	--	--	--	--	--	W	W
Tennessee	--	--	--	--	W	W	W	--	--	W	W
Utah	--	--	W	W	W	W	W	W	W	W	W
Washington	--	--	W	W	W	W	W	--	--	W	W
Total	W	W	65,289,211	17,170,211	236,327,243	4,912,522	22,051,734	W	W	312,443,833	39,773,448

[r]Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."
[1]Includes old tailings and some non-silver-bearing ores not separable, in amounts ranging from 0.04% to 0.12% of the totals for the years listed. Excludes fluorspar, molybdenum, and tungsten ores from which silver was recovered as a byproduct and excludes ores leached for recovery of copper.
[2]Includes some placer production to avoid disclosing company proprietary data.

Table 8.—U.S. refinery production of silver

(Thousand troy ounces)

Raw material	1983	1984	1985	1986	1987
Concentrates and ores:					
Domestic and foreign	57,759	59,331	53,808	42,413	44,838
Old scrap	29,415	27,842	27,830	r24,494	26,034
New scrap	38,158	42,091	44,643	r46,563	42,319
Total	[1]125,331	129,264	126,281	r113,470	113,191

rRevised.
[1]Data do not add to total shown because of independent rounding.

Table 9.—U.S. consumption of silver, by end use

(Thousand troy ounces)

End use[1]	1983	1984	1985	1986	1987
Electroplated ware	3,154	3,542	3,660	3,724	3,010
Sterlingware	7,022	3,638	3,527	3,935	3,897
Jewelry	6,861	5,773	5,779	r4,666	4,514
Photographic materials	51,827	55,322	57,895	r58,554	61,377
Dental and medical supplies	1,532	1,569	1,480	1,474	1,409
Mirrors	970	970	970	970	1,000
Brazing alloys and solders	5,837	5,889	5,593	r6,467	5,591
Electrical and electronic products:					
Batteries	2,800	2,671	2,470	r3,309	2,413
Contacts and conductors	26,298	25,633	27,509	r27,429	23,457
Bearings	170	260	190	375	317
Catalysts	2,424	2,448	2,409	2,313	2,474
Coins, medallions, commemorative objects	2,979	2,564	2,514	3,957	4,194
Miscellaneous[2]	4,567	4,562	4,559	r4,569	4,847
Total net industrial consumption[3]	116,440	114,841	118,555	r121,743	118,500
Coinage	2,128	2,665	r362	r7,535	15,074
Total consumption[3]	118,568	117,506	r118,917	r129,278	133,574

rRevised.
[1]End use as reported by converters of refined silver.
[2]Includes silver-bearing copper, silver-bearing lead anodes, ceramics, paint, etc.
[3]Data may not add to totals shown because of independent rounding.

Table 10.—Yearend stocks of silver in the United States

(Thousand troy ounces)

	1983	1984	1985	1986	1987
Industry	17,449	21,217	18,467	r17,671	15,034
Futures exchanges	151,232	137,631	173,144	162,089	169,731
Department of the Treasury	34,565	31,889	32,621	33,819	39,517
Department of Defense	100	342	460	2,500	2,400
National Defense Stockpile	137,500	137,500	137,500	127,306	113,082

rRevised.

Table 11.—U.S. silver prices

(Dollars per troy ounce)

Period	Low		High		Average
	Price	Date	Price	Date	
1983	8.34	Nov. 17	14.74	Feb. 16	11.44
1984	6.26	Dec. 20	10.04	Mar. 5	8.14
1985	5.57	Mar. 12	6.74	Mar. 27	6.14
1986	4.87	May 20	6.20	Jan. 27	5.47
1987:					
January	5.36	Jan. 7	5.68	Jan. 27	5.53
February	5.39	Feb. 18	5.57	Feb. 2,9	5.49
March	5.45	Mar. 2,3	6.31	Mar. 31	5.68
April	6.28	Apr. 1	10.20	Apr. 27	7.43
May	7.41	May 26	9.37	May 18	8.44
June	6.84	June 25	7.86	June 11	7.41
July	7.24	July 1	8.26	July 31	7.68
August	7.39	Aug. 28	8.80	Aug. 4	7.85
September	7.28	Sept. 1	7.72	Sept. 4	7.59
October	6.91	Oct. 29	8.20	Oct. 19	7.56
November	6.36	Nov. 5,10	7.07	Nov. 30	6.66
December	6.60	Dec. 4	7.00	Dec. 14	6.79
Year	5.36	Jan. 7	10.20	Apr. 27	7.01

Source: Handy & Harman daily quotation.

Table 12.—U.S. exports of silver, by country

(Thousand troy ounces and thousand dollars)

Year and country	Ores and concentrates		Wastes and sweepings		Doré and precipitates		Refined bullion		Total[1]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1983	67	554	17,231	197,996	996	9,516	13,658	169,383	31,952	377,449
1984	1,048	8,335	12,059	102,452	1,001	9,178	10,340	86,339	24,447	206,306
1985	270	1,651	10,325	67,884	1,550	9,551	12,611	81,746	24,756	160,832
1986	284	1,630	12,913	72,729	1,805	11,436	10,109	56,785	25,114	142,581
1987:										
Belgium-Luxembourg	7	52	1,459	11,700	--	--	9	56	1,475	11,809
Brazil	--	--	--	--	10	73	600	3,845	610	3,917
Canada	7	60	1,069	8,124	93	650	2,086	16,623	3,254	25,456
France	--	--	5,683	39,155	99	647	134	691	5,916	40,492
Germany, Federal Republic of	--	--	218	1,680	317	2,112	261	1,914	796	5,706
Japan	--	--	54	354	163	1,216	5,426	36,359	5,642	37,930
Sweden	--	--	1,172	7,767	--	--	--	--	1,172	7,767
Switzerland	--	--	--	--	156	1,468	4	20	160	1,488
Taiwan	--	--	3	46	268	1,962	11	73	283	2,081
United Kingdom	--	--	3,981	27,667	1,050	8,104	2,568	18,427	7,599	54,198
Other	2	38	35	246	7	63	142	1,115	186	1,462
Total[1]	15	150	13,675	96,738	2,163	16,294	11,240	79,123	27,093	192,305

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

Source: Bureau of the Census.

Table 13.—U.S. imports for consumption of silver, by country

(Thousand troy ounces and thousand dollars)

Year and country	Ores and concentrates[1]		Wastes and scrap		Doré and precipitates		Refined bullion		Total[2]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1983	13,911	145,419	1,241	13,010	3,540	39,038	161,199	1,926,102	179,891	2,123,569
1984	13,018	105,587	903	7,871	7,499	64,901	93,546	784,838	114,966	963,198
1985	3,533	20,180	1,771	10,854	9,900	65,364	137,398	855,550	152,601	951,947
1986	5,516	30,926	1,867	10,372	12,141	68,590	125,365	688,296	144,890	798,183
1987:										
Belgium-Luxembourg	--	--	--	--	7	37	2,385	14,194	2,392	14,230
Brazil	85	655	--	--	--	--	201	1,349	287	2,004
Canada	650	3,665	2,303	14,951	1,055	6,603	16,665	115,631	20,673	140,850
Chile	17	177	22	154	5,224	37,617	113	621	5,375	38,568
Dominican Republic	--	--	11	33	893	5,797	--	--	903	5,830
France	--	--	--	--	--	--	102	841	102	841
Mexico	1,561	10,974	122	831	17	92	40,779	275,843	42,479	287,740
Netherlands	--	--	--	--	163	1,123	--	--	163	1,123
Panama	--	--	232	1,580	--	--	243	1,379	476	2,959
Peru	27	172	278	2,002	361	2,147	6,535	43,707	7,201	48,028
South Africa, Republic of	163	1,032	--	--	--	--	--	--	163	1,032
Singapore	106	610	108	756	--	--	--	--	214	1,365
United Kingdom	13	107	22	157	21	197	97	722	153	1,183
Yugoslavia	--	--	42	361	--	--	768	5,427	810	5,788
Other	59	628	265	1,688	41	246	71	521	436	3,086
Total[2]	2,681	18,019	3,404	22,514	7,781	53,858	67,959	460,235	81,826	554,627

[1]Includes silver content of base metal ores, concentrates, and matte imported for refining.
[2]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

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

(Thousand troy ounces)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Algeria[e]	120	120	120	120	120
Argentina	2,500	1,984	2,170	2,134	2,000
Australia	33,208	31,260	34,914	32,882	32,762
Bolivia	6,025	4,560	3,580	3,058	3,800
Brazil[3]	486	829	[e]1,013	[e]1,490	1,610
Bulgaria[e]	930	930	930	910	910
Burma	558	455	568	527	[4]839
Canada	35,559	42,655	38,484	34,979	40,180
Chile	15,055	15,766	16,633	16,078	15,800
China[e]	2,500	2,500	2,500	3,000	3,000
Colombia[5]	99	130	153	[r e]168	144
Costa Rica[e]	2	2	2	2	2
Czechoslovakia	964	1,029	[e]1,000	[e]1,000	1,000
Dominican Republic	1,329	1,207	1,581	1,356	1,150
Ecuador	3	2	[e]2	[e]2	2
El Salvador	22	22	--	--	--
Fiji	13	15	14	17	16
Finland	980	[r]1,101	998	1,193	[4]1,421
France	696	770	849	832	[4]810
German Democratic Republic	1,380	1,290	1,320	1,320	1,200
Germany, Federal Republic of	1,167	1,225	1,090	884	[4]1,736
Ghana[e]	14	14	14	14	14
Greece[e]	[4]1,797	1,800	1,700	1,700	1,700
Greenland	492	334	[e]300	385	[4]418
Honduras	2,587	2,697	2,765	1,745	2,000
India[5]	469	862	816	1,048	1,200
Indonesia	1,135	1,121	1,175	1,369	1,560
Ireland	[r]319	279	276	262	[4]231
Italy[5 6]	2,361	1,554	2,301	1,813	[4]2,668
Japan	9,877	10,403	10,915	11,294	[4]9,040
Korea, North[e]	1,600	1,600	1,600	1,600	1,600
Korea, Republic of	3,366	3,759	3,990	5,034	5,000
Malaysia (Sabah)	[r]485	470	522	455	500
Mexico	63,607	75,340	73,167	[e]75,200	75,000
Morocco	2,850	2,410	2,733	1,566	1,410
Namibia	3,535	3,255	3,404	3,472	3,300
New Zealand	(7)	--	--	--	--
Nicaragua	63	[e]50	30	[e]25	25
Papua New Guinea	1,524	1,427	1,483	[r e]1,787	[4]1,963
Peru	50,477	53,080	58,230	61,916	66,000
Philippines	1,823	1,574	1,685	1,688	[4]1,654
Poland	21,798	23,920	26,717	26,653	26,500
Portugal	20	22	33	17	20
Romania[e]	820	810	810	800	750
Solomon Islands	(7)	--	--	--	--
South Africa, Republic of	6,513	6,997	6,700	7,145	[4]6,691
Spain	1,496	4,999	9,482	5,697	[4]5,709
Sweden	[r]6,655	[r]7,676	7,442	[r e]9,000	9,000
Taiwan	345	364	366	[e]406	315
Tunisia	90	[e]85	26	50	50
Turkey[e]	220	220	220	220	220
U.S.S.R.[e 5]	47,200	47,400	47,900	48,200	48,200
United States	43,431	44,592	39,433	34,524	[4]39,790
Yugoslavia[5]	3,987	4,051	5,015	5,690	4,850
Zaire	1,288	1,225	1,516	[e]1,500	1,400
Zambia	933	795	607	861	[4]961
Zimbabwe	938	893	799	841	850
Total	[r]387,711	[r]413,930	422,093	415,929	429,091

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

[1]Recoverable content of ores and concentrates produced unless otherwise specified. Table includes data available through July 1, 1988.

[2]In addition to the countries listed, Austria and Thailand may produce silver, but information is inadequate to make reliable estimates of output levels.

[3]Of total production, the following quantities, in thousand troy ounces, are identified as placer silver (the balance being silver content of other ores and concentrates): 1983—247; 1984—250 (estimated); 1985—434 (estimated); 1986—640 (estimated); and 1987—650 (estimated).

[4]Reported figure.

[5]Smelter and/or refinery production.

[6]Includes production from imported ores.

[7]Less than 1/2 unit.

Slag—Iron and Steel

By Judith F. Owens[1]

Iron and steel slag sales were essentially unchanged from those of 1986. A significant decrease in sales and use of steel slag was offset by an increase in sales of iron-blast-furnace slag. Air-cooled iron-blast-furnace slag continued to comprise the largest portion of total blast furnace slag sold or used.

The construction industry continued to be the major user of iron and steel slag products. Air-cooled iron-blast-furnace slag was used mainly for asphaltic concrete aggregate, concrete aggregate, fill, railroad ballast, and road base. The use of air-cooled slag as a road base decreased slightly from that of 1986. Sales and uses of granulated and expanded iron-blast-furnace slags increased significantly over that of 1986 and, were primarily used for fill, lightweight concrete aggregate, road base, soil conditioning, and the production of slag cement. Steel slag was typically used as road base and fill. The average unit values of both iron slag and steel slag remained essentially unchanged from those of 1986.

Domestic Data Coverage.—Sales, use, and transportation data for iron and steel slag are developed by the Bureau of Mines from a voluntary annual survey of U.S. processors. Of the 95 operations canvassed, 80 responded, representing 84% of the total sales or use data shown in table 1. Data for the nonrespondents were estimated based on prior year slag sales data. Of the 80 respondents, 4 reported their operations as idle and 3 reported their plants as closed.

DOMESTIC PRODUCTION

Domestic iron and steel slag production, which is not reported to the Bureau of Mines, apparently increased owing to a significant increase in U.S. iron and steel production. However, sales and consumption of iron and steel slag, as reported by processors, remained essentially unchanged from those of 1986, when combined. Steel slag consumption decreased significantly, but was offset by a slight increase in the sales and use of iron-blast-furnace slag. According to the U.S. Department of Commerce, private nonresidential and highway and bridge construction decreased 8% and 3%, respectively, and public construction increased 2%. Federal funding for highway construction was interrupted during 1987 as a result of an impasse in Congress over the renewal of spending authority under the Federal-aid-Highways Programs. In effect, this impasse most likely decreased slag consumption for road construction from October 1986 to April 1987.[2] Sales of slag products generally reflect demand from the construction industry.

Iron-blast-furnace slag sold or used increased slightly, totaling 15.8 million short tons valued at $96.1 million. Approximately two-thirds of this, in decreasing order, was produced in Indiana, Pennsylvania, Ohio, and Michigan.

Table 1.—Iron and steel slags sold or used[1] in the United States

(Thousand short tons and thousand dollars)

Year	Iron-blast-furnace slag: Air-cooled		Granulated		Expanded		Total iron slag[2]		Steel slag		Total slag[2]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1983	12,380	50,999	(3)	(3)	1,175	13,736	13,554	64,735	4,832	14,546	18,386	79,280
1984	15,325	66,289	(3)	(3)	1,452	19,142	16,776	85,432	5,287	17,327	22,063	102,758
1985	13,363	62,588	(3)	(3)	1,742	24,290	15,106	86,878	5,972	17,472	21,078	104,351
1986	13,501	58,899	(3)	(3)	1,879	33,851	15,380	92,750	5,689	17,883	21,068	110,633
1987	13,448	61,092	(3)	(3)	2,389	35,003	15,837	96,096	4,935	15,354	20,772	111,449

[1]Value based on selling price at plant.
[2]Data may not add to totals shown because of independent rounding.
[3]Included with "Expanded" to avoid disclosing company proprietary data.

Of all the iron and steel slag products sold, 86% traveled by truck with an average marketing range of 32 miles; 7% traveled by waterway with an average range of 559 miles; and 7% traveled by rail with an average range of 156 miles. The remaining 1% was used at the plant where it was processed.

CONSUMPTION AND USES

Iron and steel slags were consumed mainly by the construction industry as substitutes for natural aggregates and other construction materials. Historically, iron and steel slags have been used in place of other materials because of their lower costs, superior performance for many applications, or shortages of natural aggregates.

Practically all of the iron-blast-furnace slag products are eventually utilized. Of the air-cooled iron-blast-furnace slag sold or used in 1987, 53% was used as road base, 13% as concrete aggregate, 10% as fill, 8% as asphaltic concrete aggregate, and 5% as railroad ballast. The remaining 11% was used in concrete products, glass manufacture, mineral wool, soil conditioning, sewage treatment, and other miscellaneous uses. Expanded blast furnace slag was mainly used as a lightweight concrete aggregate. Granulated blast furnace slag was mainly utilized in cement manufacture. The largest growth area for iron slag appears to be in the replacement of cement in concrete construction and in fill.

Based on raw steel production, an estimated 3.1 million tons of steel slag was recycled to blast furnaces in 1987. However, the bulk of the steel slag produced was used in aggregate applications. Steel slag processed and sold primarily as road base comprised 44%; as fill, 25%; as asphaltic concrete aggregate, 13%; and as railroad ballast, 3%. The remaining 15% was used for ice control, soil conditioning, and miscellaneous uses. The major growth areas for steel slag usage would appear to be as fill and road base.

PRICES

The average price, f.o.b. plant, for all iron-blast-furnace slag sold remained essentially unchanged at $6.07 per ton. The price of air-cooled iron slag increased 4% over that of 1986 to $4.54 per ton. The average price of granulated iron slag showed a significant decrease from that of 1986, reflecting a significant increase of lower priced granulated slag entering the marketplace. Expanded slag price information was withheld to avoid disclosing company proprietary data. The unit value of steel slag remained stable.

FOREIGN TRADE

U.S. foreign trade data for iron and other steel slag cannot be determined because slag is classified in categories with other materials and cannot be separated. U.S. exports of slag are classified under the headings "Metal Bearing Ores and Metal Bearing Materials" or "Waste and Scrap Not Specifically Provided For."

Basic slag, a byproduct of basic steelmaking processes, is imported for use as a fertilizer because of its high lime and phosphorus content. Statistics developed by the U.S. Department of Commerce, Bureau of the Census, indicated that 82,394 tons of basic slag valued at $786,000 was imported from Canada, and 38,524 tons valued at $310,058 was imported from Japan. Basic slag was also imported from the Federal Republic of Germany, 11,539 tons valued at $89,148, followed by Mexico with 395 tons valued at $6,716, and the United Kingdom with 313 tons valued at $5,318.

WORLD REVIEW

Estimated world production of iron-blast-furnace slag and steel slag was 130 million tons and 58 million tons, respectively. These estimates are based on iron and steel production estimates for 1987. Reported production of iron and steel slag by country is incomplete owing to late reporting, incompleteness of data, and lack of reporting by some countries. Some countries do not report slag production because slag is thought of as a waste product rather than as a resource.

Production estimates for major world producers of iron-blast-furnace slag and steel slag, respectively, are as follows: European Economic Community, 21 million tons and 10 million tons; Japan, 27 million tons and 14 million tons; and U.S.S.R., 27.8 million tons and 8.8 million tons. These production estimates, based on estimated production of iron and steel, have remained essentially unchanged from those of 1986.

TECHNOLOGY

Pretoria Portland Cement Ltd.'s Newcastle portland blast furnace cement plant in the Republic of South Africa made use of new technology in the processing of granulated iron-blast-furnace slag. For the first time in the country, tubular conveyors were used that operated at steeper angles than did standard conveyors, and they could turn corners horizontally. Another first was the use of a fluidized bed for drying of the slag. Owing to the efficient design of the facility, it occupies a smaller area than do most slag processors and has encountered fewer problems with spillage. This facility, which produces a finished product called slagment, offers the Republic of South Africa's construction industry a new source for concrete products and a new market for blast furnace slag processors.[3]

The American Concrete Institute reported that, owing to rising costs of portland cement, recent attention has focused on the use of ground, granulated blast furnace slag as a separate constituent in concrete. Advantages to the cement industry include reduced costs, improved workability, and increased ultimate compressive and flexural strength. Advantages to the slag industry would be a higher valued product per ton, greatly surpassing the value of other end uses.[4]

A process for stabilizing steelmaking slag was granted a U.S. patent in 1987. In this process, a boron-containing mineral such as borax or kernite is added to the slag prior to cooling. This prevents the slag from powdering during the cooling stage. This would be advantageous to the steel slag industry because the slag would be easier to handle and the process would produce a homogenous product.[5]

Researchers in Japan have discovered that certain types of iron-blast-furnace slags are an effective deterrent in the liberation of phosphate from sediments in shallow or coastal waters. It was determined that the most effective type of iron slag was soft granulated iron slag, which suppressed the phosphate liberation by as much as 98.8% when mixed with or laid upon the sediments. This discovery may be important to marine biology in helping to control eutrophication or the oversaturation of water with nutrients that can lead to oxygen deficiencies in closed water areas.[6]

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[1]Physical scientist, Branch of Ferrous Metals.

[2]U.S. Department of Commerce. Construction Review. V. 33, No. 6, Nov.-Dec. 1987, pp. 2, 11.

[3]Venter, P. W. Construction of a New Slag Processing Factory at Newcastle. South Afr. Mech. Eng., v. 37, May 1987, pp. 207-211.

[4]ACI Committee 226. Ground Granulated Blast-Furnace Slag as a Cementitious Constituent in Concrete. ACI Mater. J., v. 84, No. 4, Jul.-Aug. 1987, pp. 327-342.

[5]Ishizaka, K., F. Sudo, A. Seki, and Y. Aso. Method of Stabilizing a Steel Making Slag. U.S. Pat. 4,655,831, Apr. 7, 1987.

[6]Yamada, H., K. Mitsu, S. Kazuo, and H. Masakazu. Suppression of Phosphate Liberation From Sediment Using Iron Slag. J. Int. Assoc. on Water Pollu. Res. & Control, v. 21, No. 3, Mar. 1987, pp. 325-333.

Table 2.—Iron-blast-furnace slags sold or used[1] in the United States, by region and State

(Thousand short tons and thousand dollars)

Region and State	1986				1987			
	Air-cooled, screened and unscreened		Total, all types		Air-cooled, screened and unscreened		Total, all types	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
North Central:								
Illinois, Indiana, Michigan	5,079	16,235	W	W	5,322	17,246	W	W
Ohio	2,202	12,744	W	W	2,282	14,293	W	W
Total	7,281	28,979	7,998	34,229	7,604	31,539	8,273	36,250
Middle Atlantic:								
Maryland, New York, West Virginia	1,225	5,774	W	W	W	W	W	W
Pennsylvania	2,460	13,805	2,887	20,335	2,109	12,351	W	W
Total	3,685	19,579	W	W	W	W	5,174	50,028
West: Colorado, Texas, Utah	1,193	4,645	1,193	4,645	W	W	W	W
South: Alabama and Kentucky	612	3,363	612	3,363	W	W	W	W
Pacific: California	730	2,336	730	2,336	808	2,776	808	2,776
Grand total[2]	13,501	58,899	15,380	92,750	13,448	61,094	15,837	96,096

W Withheld to avoid disclosing company proprietary data; included in "Total" and "Grand total."
[1]Value based on selling price at plant.
[2]Data may not add to totals shown because of independent rounding.

Table 3.—Locations and processing methods of iron slag and sources of steel slag[1] in 1987

State, city, and company	Processing method of iron slag: Air-cooled	Ex-panded	Granu-lated	Steel slag	Sources of steel slag: Open hearth	Basic oxygen process	Elec-tric
Alabama:							
Alabama City:							
Vulcan Materials Co	1	--	--	1	--	1	--
Fairfield:							
Vulcan Materials Co	1	--	--	1	--	1	--
Total	2	--	--	2	--	2	--
Arkansas: Fort Smith:							
International Mill Service Co	--	--	--	1	--	--	1
California: Fontana:							
Heckett Co	1	--	--	--	--	--	--
Colorado: Pueblo:							
Fountain Sand and Gravel Co	1	--	--	--	--	--	--
International Mill Service Co	--	--	--	1	--	1	--
Total	1	--	--	1	--	1	--
Delaware: Claymont:							
International Mill Service Co	--	--	--	1	--	1	--
Florida: Tampa:							
International Mill Service Co	--	--	--	1	--	--	1
Georgia:							
Atlanta:							
International Mill Service Co	--	--	--	1	--	--	1
Cartersville:							
International Mill Service Co	--	--	--	1	--	--	1
Total	--	--	--	2	--	--	2
Illinois:							
Alton:							
International Mill Service Co	--	--	--	1	--	--	1
Chicago:							
Heckett Co	1	--	--	--	--	--	--
International Mill Service Co	--	--	--	1	--	1	--
Granite City:							
International Mill Service Co	--	--	--	1	--	1	--
St. Louis Slag Products Co. Inc	1	--	--	--	--	--	--
Total	2	--	--	3	--	2	1
Indiana:							
Burns Harbor:							
The Levy Co. Inc	1	1	--	1	--	1	--
East Chicago:							
Heckett Co	--	--	--	1	--	1	--
The Levy Co. Inc	1	--	--	--	--	--	--
Gary:							
International Mill Service Co	--	--	--	1	--	1	1
Total	2	1	--	3	--	3	1
Iowa: Keokuk:							
International Mill Service Co	--	--	--	1	--	--	1
Kentucky: Ashland							
Heckett Co	1	--	--	--	--	--	--
Louisiana: LaPlace:							
International Mill Service Co	--	--	--	1	--	--	1

See footnote at end of table.

Table 3.—Locations and processing methods of iron slag and sources of steel slag[1] in 1987 —Continued

State, city, and company	Processing method of iron slag: Air-cooled	Processing method of iron slag: Ex-panded	Processing method of iron slag: Granu-lated	Steel slag	Sources of steel slag: Open hearth	Sources of steel slag: Basic oxygen process	Sources of steel slag: Elec-tric
Maryland:							
Baltimore:							
Maryland Slag Co	1	--	--	--	--	--	--
Sparrows Point:							
Blue Circle Atlantic	--	--	1	--	--	--	--
C. J. Langenfelder & Sons Inc	--	--	--	1	1	1	--
Total	1	--	1	1	1	1	--
Michigan:							
Detroit:							
Edward C. Levy Co	1	1	--	1	--	1	1
Monroe:							
International Mill Service Co	--	--	--	1	--	--	1
Total	1	1	--	2	--	1	2
Minnesota: Newport:							
International Mill Service Co	--	--	--	1	--	--	1
Mississippi: Jackson:							
Heckett Co	--	--	--	1	--	--	1
Missouri: Kansas City:							
International Mill Service Co	--	--	--	1	--	--	1
New Jersey:							
Perth Amboy:							
International Mill Service Co	--	--	--	1	--	--	1
Riverton:							
International Mill Service Co	--	--	--	1	--	--	1
Total	--	--	--	2	--	--	2
New York: Buffalo:							
Buffalo Crushed Stone Corp	1	--	--	--	--	--	--
North Carolina: Charlotte:							
Heckett Co	--	--	--	1	--	--	1
Ohio:							
Canton:							
Heckett Co	--	--	--	1	--	--	1
Cleveland:							
Standard Slag Co	1	--	--	--	--	--	--
Do	1	--	--	--	--	--	--
Stein Inc	--	--	--	1	--	1	1
Hamilton:							
American Materials Corp	1	--	--	--	--	--	--
Lorain:							
Fritz Enterprises Inc	1	--	--	--	--	--	--
Stein Inc	--	--	--	1	--	1	--
Lordstown:							
Standard Slag Co	--	--	1	--	--	--	--
Mansfield:							
Heckett Co	--	--	--	1	--	--	1
Marion:							
International Mill Service Co	--	--	--	1	--	--	1
Middletown:							
American Materials Corp	1	--	--	--	--	--	--
International Mill Service Co	--	--	--	1	--	1	--
Mingo Junction:							
International Mill Service Co	--	--	--	1	--	1	--
Standard Slag Co	1	--	--	--	--	--	--
Warren:							
Heckett Co	--	--	--	1	--	1	1
Standard Slag Co	1	--	--	--	--	--	--
Total	7	--	1	8	--	5	5
Oklahoma: Sand Springs:							
International Mill Service Co	--	--	--	1	--	--	1

See footnote at end of table.

Table 3.—Locations and processing methods of iron slag and sources of steel slag[1] in 1987—Continued

State, city, and company	Processing method of iron slag: Air-cooled	Processing method of iron slag: Expanded	Processing method of iron slag: Granulated	Steel slag	Sources of steel slag: Open hearth	Sources of steel slag: Basic oxygen process	Sources of steel slag: Electric
Pennsylvania:							
Bala-Cynwyd:							
Warner Co	1	1	--	--	--	--	--
Beaver Falls:							
International Mill Service Co	--	--	--	1	--	--	1
Belle Vernon:							
Duquesne Slag Products Co	1	--	--	--	--	--	--
Bethlehem:							
Sheridan Slag Corp	--	1	--	--	--	--	--
Burgettstown:							
Duquesne Slag Products Co	--	--	1	--	--	--	--
Butler:							
Heckett Co	--	--	--	1	--	--	1
Coatesville:							
International Mill Service Co	--	--	--	1	--	--	1
Johnstown:							
Heckett Co	--	--	--	1	--	--	1
Lebanon:							
Sheridan Slag Corp	1	--	--	--	--	--	--
Midland:							
International Mill Service Co	--	--	--	1	--	--	1
Monessen:							
International Mill Service Co	--	--	--	1	--	1	--
Morrisville:							
Heckett Co	--	--	--	1	1	--	--
Patton:							
International Mill Service Co	--	--	--	1	--	1	--
Penn Hills:							
Gascola Slag Co	--	--	--	1	1	--	--
Phoenixville:							
International Mill Service Co	--	--	--	1	--	--	1
Riddlesburg:							
New Enterprise Stone & Lime Co. Inc	1	--	--	--	--	--	--
Steelton:							
Hempt Bros. Inc	--	--	--	1	--	--	1
West Aliquippa:							
Duquesne Slag Products Co	1	--	--	1	--	1	--
West Mifflin:							
Duquesne Slag Products Co	1	--	--	--	--	--	--
Do	1	--	--	1	--	1	--
Wheatland:							
Dunbar Slag Co. Inc	1	--	--	1	1	1	--
Total	8	2	1	14	3	5	7
South Carolina: Georgetown:							
Heckett Co	--	--	--	1	--	--	1

See footnote at end of table.

Table 3.—Locations and processing methods of iron slag and sources of steel slag[1] in 1987 —Continued

State, city, and company	Processing method of iron slag			Steel slag	Sources of steel slag		
	Air-cooled	Ex-panded	Granu-lated		Open hearth	Basic oxygen process	Elec-tric
Texas:							
Beaumont:							
International Mill Service Co	--	--	--	1	--	--	1
El Paso:							
International Mill Service Co	--	--	--	1	--	--	1
Lone Star:							
Gifford-Hill & Co. Inc	1	--	--	--	--	--	--
Longview:							
International Mill Service Co	--	--	--	1	--	--	1
Midlothian:							
International Mill Service Co	--	--	--	1	--	--	1
Seguin:							
International Mill Service Co	--	--	--	1	--	--	1
Total	1	--	--	5	--	--	5
Utah:							
Plymouth:							
International Mill Service Co	--	--	--	1	--	--	1
Provo:							
Heckett Co	1	--	--	1	1	--	--
Total	1	--	--	2	1	--	1
Washington: Seattle:							
Heckett Co	--	--	--	1	--	--	1
West Virginia: Weirton:							
International Mill Service Co	--	--	--	1	--	1	--
Standard Slag Co	1	--	--	--	--	--	--
Total	1	--	--	1	--	1	--
Grand total	30	4	3	58	5	22	37

[1]Number indicates the existence of an active plant shown by processing method or furnace source; previous years showed the number of active processing lines for some plants.

Table 4.—Shipments of iron and steel slag in the United States in 1987, by method of transportation

Method of transportation	Quantity (thousand short tons)
Truck	17,807
Waterway	1,419
Rail	1,327
Not transported (used at plant site)	219
Total	20,772

Table 5.—Air-cooled iron-blast-furnace slag sold or used[1] in the United States, by use

(Thousand short tons and thousand dollars)

Use	1986 Quantity	1986 Value	1987 Quantity	1987 Value
Asphaltic concrete aggregate	977	5,089	1,094	6,351
Concrete aggregate	1,753	8,799	1,717	8,759
Concrete products	513	2,474	317	1,930
Fill	779	3,257	1,358	4,058
Glass manufacture	107	W	W	W
Mineral wool	519	2,862	488	2,614
Railroad ballast	875	3,826	675	3,141
Road base	7,453	28,165	7,157	30,050
Roofing, built-up and shingles	74	660	82	744
Sewage treatment	W	W	W	W
Soil conditioning	W	W	W	W
Other[2]	452	[3]3,767	560	[3]3,446
Total[4]	13,501	58,899	13,448	61,092

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Value based on selling price at plant.
[2]Includes ice control, miscellaneous uses, and data indicated by symbol W.
[3]Includes glass manufacture.
[4]Data may not add to totals shown because of independent rounding.

Table 6.—Granulated and expanded iron-blast-furnace slags sold or used[1] in the United States, by use

(Thousand short tons and thousand dollars)

Uses	1986 Granulated Quantity	1986 Granulated Value	1986 Expanded Quantity	1986 Expanded Value	1987 Granulated Quantity	1987 Granulated Value	1987 Expanded Quantity	1987 Expanded Value
Cement manufacture	(2)	(2)	W	W	(2)	(2)	W	W
Concrete products	--	--	W	W	--	--	--	--
Fill	(2)	(2)	W	W	(2)	(2)	W	W
Lightweight concrete aggregate	--	--	W	W	--	--	W	W
Road base	(2)	(2)	W	W	(2)	(2)	W	W
Soil conditioning	(2)	(2)	W	W	(2)	(2)	W	W
Other[3]	(2)	(2)	1,879	33,851	(2)	(2)	2,389	35,003
Total	(2)	(2)	1,879	33,851	(2)	(2)	2,389	35,003

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Value based on selling price at plant.
[2]Included with "Expanded" to avoid disclosing company proprietary data.
[3]Includes miscellaneous uses and data indicated by symbol W.

Table 7.—Steel slag sold or used[1] in the United States, by use

(Thousand short tons and thousand dollars)

Use	1986 Quantity	1986 Value	1987 Quantity	1987 Value
Asphaltic concrete aggregate	632	2,613	624	2,810
Fill	1,318	3,861	1,215	3,410
Railroad ballast	W	W	164	513
Road base	2,549	7,879	2,179	6,546
Other[2]	1,190	3,531	753	2,075
Total[3]	5,689	17,883	4,935	15,354

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Excludes tonnage returned to furnace for charge material. Value based on selling price at plant.
[2]Includes ice control, soil conditioning, miscellaneous uses, and data indicated by symbol W.
[3]Data may not add to totals shown because of independent rounding.

Table 8.—Average value at the plant for iron and steel slags sold or used in the United States

(Dollars per short ton)

Year	Iron-blast-furnace slag				Steel slag	Total slag
	Air-cooled	Granu-lated	Expanded	Total iron slag		
1983	4.12	W	9.67	4.78	3.01	4.31
1984	4.33	W	11.49	5.09	3.28	4.66
1985	4.68	W	11.00	5.75	2.93	4.95
1986	4.36	21.26	12.57	6.03	3.14	5.25
1987	4.54	11.14	W	6.07	3.11	5.36

W Withheld to avoid disclosing company proprietary data.

Table 9.—Average selling price and range of selling prices at the plant for iron and steel slags in the United States in 1987, by use

(Dollars per short ton)

Use	Iron-blast-furnace slag						Steel slag	
	Air-cooled		Granulated		Expanded			
	Average	Range	Average	Range	Average	Range	Average	Range
Asphaltic concrete aggregate	5.81	2.44- 9.33	--	--	--	--	4.51	2.30-5.29
Cement manufacture	--	--	W	W	--	--	--	--
Concrete aggregate	5.10	2.55- 9.09	W	W	--	--	--	--
Concrete products	6.10	1.84- 9.09	--	--	--	--	--	--
Fill	2.99	1.50- 7.12	W	W	--	--	2.81	1.00-6.75
Glass manufacture	W	W	--	--	--	--	--	--
Lightweight concrete aggregate	--	--	--	--	W	W	--	--
Mineral wool	5.36	3.43-10.54	--	--	--	--	--	--
Railroad ballast	4.66	3.71- 8.00	--	--	--	--	3.13	2.65-3.75
Road base	4.20	2.17- 9.09	W	W	--	--	3.00	1.69-5.80
Roofing, built-up and shingles	9.03	5.16-11.55	--	--	--	--	--	--
Sewage treatment	W	W	--	--	--	--	--	--
Soil conditioning	W	W	W	W	--	--	--	--
Other	4.25	3.37- 6.30	11.14	1.62-34.20	W	W	2.69	2.19-4.03

W Withheld to avoid disclosing company proprietary data; included with "Other."

Sodium Compounds

By Dennis S. Kostick[1]

U.S. soda ash production rebounded because of an increase in domestic and export soda ash demand. These increases began in the third quarter as market conditions improved in the chemical, fiberglass, and flue gas desulfurization sectors. Exports to Asia remained strong, primarily to China, which accounted for about one-fourth of total U.S. exports. Production of natural and synthetic sodium sulfate was unchanged; however, exports increased as imports for consumption and ending inventories decreased, indicating stagnant domestic growth in consumption.

Table 1.—Salient sodium compound statistics

(Thousand short tons and thousand dollars)

	Soda ash		Sodium sulfate[1]	
	1986	1987	1986	1987
United States:				
Production	[1]8,438	[2]8,891	[r]812	805
Value[3]	[e]$553,517	$593,685	[r]$69,923	$69,769
Exports	[4]2,049	[4]2,224	111	122
Value	[4]$241,238	[4]$253,200	$10,183	$10,554
Imports for consumption	106	150	188	138
Value	$15,023	$18,334	$13,829	$10,363
Stocks, Dec. 31: Producers'	[5]294	259	[6]72	[6]55
Consumption, apparent	6,590	6,853	834	838
World: Production	[p]31,179	[e]32,395	[p]4,974	[e]5,007

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

[1]Includes natural and synthetic except where noted. Total production data for sodium sulfate obtained from the Bureau of the Census.

[2]Includes some soda liquors, converted to soad ash equivalent.

[3]The value for soda ash includes synthetic soda ash, for 1986 only. The value for synthetic sodium sulfate is based upon the average value for natural sodium sulfate.

[4]Export data were adjusted by the Bureau of Mines to reconcile data discrepancies among the Bureau of the Census, the American Natural Soda Ash Corp., and Statistics Canada.

[5]Includes synthetic soda ash.

[6]Natural only.

Domestic Data Coverage.—Domestic production data for soda ash and natural sodium sulfate are developed by the Bureau of Mines from monthly and annual voluntary surveys of U.S. operations. Of the seven soda ash operations and four natural sodium sulfate operations to which a survey request was sent, all responded, representing 100% of the total production data shown in table 1.

DOMESTIC PRODUCTION

Soda Ash.—The domestic soda ash industry operated at 84% of total nameplate capacity as production rose more than 5% compared with the previous year. The increase in output was necessary to meet the rise in demand created by favorable market conditions.

The 51% share of Stauffer Chemical Co. of Wyoming was sold to Imperial Chemical Industries (ICI) and later to Rhône-Poulenc S.A., both European synthetic soda ash producers. Including other French and Australian investments in Texasgulf Chemical Co. and General Chemical Co., respectively, the total foreign ownership in the U.S. soda ash industry represented about 30% of nameplate capacity.

T. G. Soda Ash Inc. obtained environmental permits from the Wyoming Department of Environmental Quality to increase capacity to 1.3 million tons; however, an operational capacity of 1.1 million tons was still being maintained by the plant.

Denison Resources NL, an Australian mineral company, signed a letter of intent near yearend to acquire the Owens Lake sodium carbonate deposit in California from Lake Minerals Corp., a subsidiary of Cominco American Incorporated. Dennison planned to construct an $85 million facility to produce 500,000 tons of soda ash annually and a similar amount of sodium sulfate.[2]

Sodium Sulfate.—Production of natural sodium sulfate decreased slightly, but recovery of synthetic sodium sulfate increased slightly. At midyear, the natural sodium sulfate industry operated at 72% of total nameplate capacity. Based on second-half production data, the industry operated at about 90% of total nameplate capacity, which was reduced by 70,000 tons to 440,000 tons per year with the temporary closure of Ozark-Mahoning Co.'s Brownfield, TX, facility. Extensive rainfall that diluted the brinefield, which caused production problems, was the reason for the action.

The synthetic sodium sulfate industry operated at about 81% of total annual nameplate capacity, which was 524,000 tons. J. M. Huber Co., Etowah, TN, increased synthetic sodium sulfate capacity by 5,000 tons per year because the company expanded its silica pigment operation.

Table 2.—Producers of soda ash and natural sodium sulfate in 1987

Product and company	Plant nameplate capacity (thousand short tons)	Plant location	Source of sodium
Soda ash, natural:			
FMC Wyoming Corp	2,850	Green River, WY.	Underground trona.
General Chemical Corp.[1]	2,200	do	Do.
Kerr-McGee Chemical Corp	1,300	Argus, CA	Dry lake brine.
Do[2]	150	Westend, CA	Do.
Stauffer Chemical Co. of Wyoming[3]	1,960	Green River, WY.	Underground trona.
Tenneco Minerals Co	1,000	do	Do.
T. G. Soda Ash Inc.[4]	1,100	Granger, WY	Do.
Total	10,560		
Sodium sulfate, natural:			
Great Salt Lake Minerals & Chemicals Corp.[5]	50	Ogden, UT	Salt lake brine.
Kerr-McGee Chemical Corp	240	Westend, CA	Dry lake brine.
Ozark-Mahoning Co.[5]	70	Brownfield, TX.	Subterranean brine.
Do	150	Seagraves, TX	Do.
Total	[6]510		

[1]General Chemical Corp. formed a joint venture with Australian Consolidated Industries International, which acquired 49% of the soda ash operation.
[2]Scheduled to terminate soda ash production in Jan. 1988.
[3]Bought by Rhône-Poulenc S.A. in Sept. 1987.
[4]Owned by Société Nationale Elf Aquitaine.
[5]Placed on standby Aug. 1987.
[6]Capacity reduced to 440,000 tons effective Aug. 1987 because Ozark's Brownfield plant was placed on standby.

Table 3.—Synthetic and natural sodium sulfate[1] produced in the United States

(Thousand short tons and thousand dollars)

Year	Synthetic and natural[2] (quantity)			Natural	
	Lower purity[3] (99% or less)	High purity	Total[4]	Quantity	Value
1983	r461	r453	r914	423	39,425
1984	r426	r475	r901	435	40,125
1985	r375	r436	r811	389	35,860
1986	r342	r471	r812	396	34,102
1987	347	458	805	382	33,086

rRevised.
[1]All quantities converted to 100% Na_2SO_4 basis.
[2]Current Industrial Reports, Inorganic Chemicals, Bureau of the Census. Revisions for 1983-86 from 1986 Annual, MA28A, p. 6.
[3]Includes Glauber's salt.
[4]Data may not add to totals shown because of independent rounding.

Table 4.—Estimated consumption of soda ash in the United States, by end use

(Thousand short tons)

End use	1986	1987
Glass:		
Bottle and container	2,150	2,100
Flat	750	725
Fiber	300	325
Other	275	275
Total	3,475	3,425
Chemicals	1,300	1,450
Soaps and detergents	650	625
Pulp and paper	200	200
Water treatment	250	250
Flue gas desulfurization	200	300
Other[1]	515	603
Total	3,115	3,428
Grand total	6,590	6,853

[1]Includes soda ash used in petroleum and metal refining, leather tanning, enamels, etc.

CONSUMPTION AND USES

Soda ash consumption increased 4% and reversed its downward trend from the previous 3 years.

Beginning in the third quarter, the domestic demand for chemicals increased significantly. High chlorine and caustic soda operating rates created tight supplies, which resulted in an increase in the spot price for these chlor-alkalis. The trend continued and some caustic-soda-based consumers began converting to soda ash on a limited scale by yearend.

The use of soda ash and sodium sulfate in glass manufacture increased slightly, primarily in the fiberglass and specialty glass sectors. Demand for flat glass was down because of the downturn in residential and commercial construction starts. Soda ash consumed in glass container manufacture stabilized despite continued competition from plastic containers.

Liquid detergents represented nearly 40% of the domestic detergent market. Consumer preference for convenience and environmental concerns regarding phosphates continued to reduce the amount of soda ash and sodium sulfate used in detergent formulations. One powdered laundry detergent producer, however, did announce it will change its powder formulation to require more sodium sulfate beginning in 1988.

STOCKS

Soda Ash.—Yearend stocks of dense soda ash in plant silos, warehouses, terminals, and on teamtracks amounted to 259,000 tons, or 12% less than the 1986 yearend inventories. The drawdowns were attributed to higher fourth-quarter sales, which reduced the amount of onhand stocks.

Sodium Sulfate.—Inventories of natural sodium sulfate decreased 24%.

PRICES

Soda Ash.—At midyear, a list price increase of $4 per ton and an off-schedule price increase of $6 per ton, both f.o.b. mine or plant, Wyoming, were announced, bringing the list and spot prices up to $87 and $89, respectively. Excess production capacity and strong consumer resistance prevented the producers from achieving the full realization of the price increases. Market prices remained well below these published prices. The average annual value of natural soda ash, f.o.b. Green River, WY, and Searles Valley, CA, was $66.78 per ton.

Sodium Sulfate.—Prices of natural and synthetic high-purity sodium sulfate reportedly were at the list levels, ranging from $105 to $115 per ton, depending on location and grade. Saltcake listed at about $60 per ton, f.o.b. plant.[3] The average annual value of bulk natural product, f.o.b. mine or plant, was $86.72 per ton.

Table 5.—Sodium compounds yearend prices

		1986	1987
Sodium carbonate (soda ash):			
Light, paper bags, carlots, works	per ton	$150.00	$150.00
Light, bulk, carlots, works	do	123.00	123.00
Dense, paper bags, carlots, works	do	120.00	131.00
Dense, bulk, carlots, works	do	83.00	83.00
Sodium sulfate (100% Na_2SO_4):			
Technical detergent, rayon grade, bags, carlots	do	$90.00- 96.00	$90.00- 96.00
Sodium sulfate, bulk, carlots, works[1]	do	113.00- 114.00	113.00- 114.00
Domestic salt cake, bulk, works[1]	do	65.00- 98.00	65.00- 98.00
National Formulary (NF XII), drums	per pound	.235	.235

[1]East of Mississippi River.

Sources: Chemical Marketing Reporter. Current Prices of Chemicals and Related Materials. V. 230, No. 26, Dec. 29, 1986, p. 31; and v. 232, No. 26, Dec. 28, 1987. p. 35.

FOREIGN TRADE

Soda Ash.—Bureau of the Census data for exports to Canada were under reported, according to industry sources. With the cooperation of Statistics Canada, International Trade Division, total exports were adjusted by the Bureau of Mines.

Although China continued to be the largest importer of U.S. soda ash, its share of imports decreased from 32% in 1986 to 23% in 1987. The decline was attributed to reduced soda ash consumption because of intentional slowdowns in housing and commercial construction starts, which required significant quantities of flat glass. The construction pace was progressing faster than the seventh 5-year plan stipulated. A surplus of glass containers manufactured the previous year also contributed to fewer glass bottles made and less soda ash consumed in 1987.

Certain countries maintained trade barriers to limit entry of U.S. soda ash. Early in the year, a commitment was obtained from the Japanese to investigate U.S. soda ash access in Japan. At yearend, the Japanese Fair Trade Commission found that although the four Japanese soda ash producers did not violate Japan's antimonopoly act, they did engage in restrictive trade practices.[4]

Table 6.—U.S. exports of sodium carbonate and sodium sulfate

(Thousand short tons and thousand dollars)

Year	Sodium carbonate		Sodium sulfate	
	Quantity	Value[1]	Quantity	Value[1]
1984	1,648	160,774	76	9,587
1985	[2]1,747	[2]173,937	119	11,899
1986	[2]2,049	[2]241,238	111	10,183
1987	[2]2,224	[2]253,200	122	10,554

[1]Free alongside ship (f.a.s.) value at U.S. port.
[2]Adjusted by the Bureau of Mines to account for discrepancies in data.

Source: Bureau of the Census.

Table 7.—Regional distribution of U.S. soda ash exports in 1987, by customs districts

(Short tons)

Customs districts	North America	Central America	South America	Caribbean	Europe	Middle East	Africa	Asia	Oceania	Total
Atlantic:										
Baltimore, MD	--	--	14	--	--	--	--	3	--	17
Charleston, SC	--	2	--	--	--	--	--	--	--	2
Miami, FL	--	32	5	288	--	--	--	--	--	325
New York, NY	--	94	7,840	39	12	1	--	1,544	--	9,530
Philadelphia, PA	--	--	10	--	--	--	--	--	--	10
Portland, MA	298	--	--	--	--	--	--	--	--	298
Gulf:										
Galveston, TX	--	--	24	--	--	--	8,806	--	--	8,830
Mobile, AL	--	25	--	--	--	--	--	--	350	375
New Orleans, LA	--	1	1,171	--	--	154	2,322	--	--	3,648
Port Arthur, TX	--	8,726	345,385	19,687	47,725	--	74,878	--	--	496,401
Tampa, FL	--	6	--	--	--	--	--	--	--	6
Pacific:										
Anchorage, AK	1,988	--	--	--	--	--	--	--	--	1,988
Los Angeles, CA	--	7,071	151,145	--	2	--	22,704	155,154	--	336,076
Portland, OR	--	--	13,615	--	36,070	--	39,132	892,349	75,769	1,056,935
San Diego, CA	1,822	--	--	--	--	--	--	--	--	1,822
San Francisco, CA	--	--	3,168	--	--	--	--	43	--	3,211
Seattle, WA	4,050	--	--	--	--	--	--	5	--	4,055
North Central:										
Detroit, MI	102,958	--	--	--	9	--	--	--	--	102,967
Duluth, MN	38	--	--	--	--	--	--	--	--	38
Great Falls, MT	16,205	--	--	--	--	--	--	--	--	16,205
Pembina, ND	14,130	--	--	--	--	--	--	--	--	14,130
Northeast:										
Buffalo, NY	198	--	--	--	--	--	--	--	--	198
Ogdensburg, NY	121	--	--	--	--	--	--	--	--	121
St. Albans, VT	117	--	--	--	--	--	--	--	--	117
Southwest:										
El Paso, TX	72	--	--	--	--	--	--	--	--	72
Laredo, TX	140,574	--	--	--	--	--	--	--	--	140,574
Nogales, AZ	6	--	--	--	--	--	--	--	--	6
Total[1]	282,577	15,957	522,377	20,014	83,818	155	147,842	1,049,098	76,119	2,197,957
Adjusted total	[2]308,422	15,957	522,377	20,014	83,818	155	147,842	1,049,098	76,119	[2]2,223,802

[1]Bureau of the Census.
[2]Adjusted by the Bureau of Mines to reconcile discrepancies between Bureau of the Census data and Statistics Canada data, which industry sources report were closer to actual transactions in Canada. The discrepancy probably occurred in the North Central customs districts.

Table 8.—U.S. imports for consumption of sodium sulfate

(Thousand short tons and thousand dollars)

Year	Crude (salt cake)[1]		Anhydrous		Total[1]	
	Quantity	Value[2]	Quantity	Value[2]	Quantity	Value[2]
1984	61	4,223	204	16,975	265	21,198
1985	40	2,549	155	11,943	195	14,492
1986	32	1,885	156	11,944	188	13,829
1987	37	2,189	101	8,173	138	[3]10,363

[1]Includes Glauber's salt as follows: 1984—12 tons ($4,997); 1985—none; 1986—38 tons ($9,175); and 1987—666 tons ($38,318).

[2]Customs, insurance, and freight (c.i.f.) value at U.S. port.

[3]Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

Table 9.—U.S. imports for consumption of sodium carbonate

	1986		1987	
	Quantity (short tons)	Value[1] (thousands)	Quantity (short tons)	Value[1] (thousands)
Sodium carbonate, calcined	105,917	$14,991	149,603	$18,211
Sodium carbonate, hydrated and sesquicarbonate	48	32	500	123
Total	105,965	15,023	150,103	18,334

[1]Customs, insurance, and freight (c.i.f.) value at U.S. port.

Source: Bureau of the Census.

WORLD REVIEW

Botswana.—Soda Ash Botswana (Pty.) Ltd., a subsidiary of British Petroleum Minerals International, withdrew plans to construct a soda ash refinery in the Makgadikgadi Pan. A South African industrial group, African Explosives and Chemicals Industries, in which Anglo American Corp. and ICI each own a 30% share, decided to continue with the project. The American Natural Soda Ash Corp. protested the project on the grounds that Botswana was a politically risky source of supply and that the soda ash would prove to be more expensive and less pure than U.S. soda ash.[5]

Egypt.—A natural sodium sulfate operation was proposed for construction at Lake Qarun near Fayyoum. The project should begin construction by 1989. A synthetic soda ash plant, with an annual capacity of 200,000 tons, was also proposed for construction at El Arish in the Sinai.[6]

Korea, North.—Plans were announced to remodel and expand many chemical plants, including the Sunchon synthetic soda ash facility. The goal is to increase soda ash output by 4.5 times in the next 7-year plan.

Tanzania.—A plant was constructed at Mikocheni that will use natural sodium carbonate from Lake Natron to produce caustic soda for use by local soap manufacturers, textile mills, and vegetable oil refineries. The project will help offset the level of imports, which had been about 15,000 tons per year of soda ash.[7]

U.S.S.R.—Sodium sulfate production resumed from Kara-Bogaz-Gol after an 8-year hiatus due to environmental problems.[8] The facility was reconstructed and modernized, which should reestablish the U.S.S.R. as the largest producer of natural sodium sulfate in the world.

[1]Physical scientist, Branch of Industrial Minerals.

[2]Chemical Marketing Reporter. U.S. May See Aussie Entry in Soda Ash. V. 232, No. 14, Oct. 5, 1987, p. 7.

[3]———. Sodium Sulfate Slump, Some Hope in Sight. V. 232, No. 26, Dec. 28, 1987, pp. 3, 18.

[4]———. Japan Soda Ash Barriers Lower. V. 232, No. 24, Dec. 14, 1987, pp. 3, 11.

[5]Mining Journal (London). Botswana Soda Ash. V. 309, No. 7940, 1987, p. 327.

[6]Mining Annual Review. Egypt. 1987, p. 436.

[7]Industrial Minerals (London). Mineral Notes. No. 244, 1988, p. 63.

[8]Mining Annual Review. U.S.S.R. 1987, p. 464.

Table 10.—Sodium carbonate: World production, by country[1]

(Short tons)

Country	1983	1984	1985	1986[p]	1987[e]
Albania[e]	30,900	33,100	34,200	35,300	34,000
Australia[e]	330,000	330,000	330,000	330,000	330,000
Austria[e]	190,000	165,000	165,000	[r]165,000	165,000
Belgium	286,341	451,224	492,164	507,000	500,000
Brazil[e]	[2]231,485	210,000	210,000	220,000	231,000
Bulgaria	1,400,918	1,336,292	1,142,695	[e]1,210,000	1,320,000
Canada[e]	470,000	400,000	385,000	385,000	385,000
China[e]	[2]1,976,442	2,070,000	2,220,000	2,310,000	2,610,000
Colombia	130,392	142,683	124,791	124,473	138,000
Czechoslovakia	104,694	111,711	123,459	124,561	121,000
Denmark[3]	159	139	126	129	130
Egypt	47,399	53,072	54,132	[e]55,000	55,000
France[e]	1,100,000	990,000	990,000	825,000	880,000
German Democratic Republic	977,749	981,056	974,442	975,544	978,000
Germany, Federal Republic of	1,342,614	1,503,551	1,556,462	1,589,531	1,554,000
Greece[e]	1,100	1,100	1,100	1,100	1,100
India	820,481	915,869	896,839	962,978	1,003,000
Italy[e]	95,000	100,000	100,000	90,000	95,000
Japan	1,216,265	1,142,140	1,165,254	1,125,292	1,157,000
Kenya[4]	213,506	249,177	251,062	261,964	275,000
Korea, Republic of	254,193	273,292	276,559	291,245	309,000
Mexico[5]	438,279	466,277	504,197	[e]500,000	500,000
Netherlands[e]	460,000	440,000	420,000	420,000	420,000
Pakistan	113,932	131,376	130,169	144,286	145,500
Poland	909,406	1,011,921	[e]940,000	[e]940,000	990,000
Portugal[e]	180,000	165,000	165,000	170,000	180,000
Romania	868,620	1,005,307	921,531	[e]940,000	950,000
Spain[e]	550,000	610,000	610,000	580,000	610,000
Switzerland[e]	50,000	49,000	50,000	[r]48,000	25,000
Taiwan	103,419	118,179	123,479	147,002	110,000
Turkey[e]	132,000	220,000	331,000	386,000	410,000
U.S.S.R.[6]	5,620,679	5,639,418	5,418,956	5,546,824	5,700,000
United Kingdom[e]	1,430,000	1,100,000	1,100,000	1,100,000	1,100,000
United States[7]	8,467,118	8,511,359	8,511,055	8,438,192	[2]8,890,746
Yugoslavia	202,135	207,555	220,053	229,245	[2 3]222,158
Total	30,745,226	31,134,798	30,938,725	31,178,666	32,394,634

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through May 6, 1988. Synthetic unless otherwise specified.
[2]Reported figure.
[3]Production for sale only; excludes output consumed by producers.
[4]Natural only.
[5]Includes natural and synthetic; in 1985, Mexico produced 200,000 tons of natural soda ash.
[6]Excludes potash for 1985-87.
[7]Includes natural and synthetic.

Table 11.—Sodium sulfate: World production, by country[1]

(Thousand short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Natural:					
Argentina	50	36	34	[e]39	35
Canada	500	427	403	[e]409	413
Chile[3]	1	1	1	[e]1	1
Egypt[e]	[4]2	2	[r]2	[r]2	2
Iran[e]	13	13	13	[r]136	136
Mexico[5]	436	456	440	505	496
South Africa, Republic of	1	1	([6])	1	1
Spain	345	405	530	497	496
Turkey	68	92	120	161	165
U.S.S.R.[e 7]	[r]395	[r]390	[r]385	[r]380	400
United States	423	435	389	396	[4]382
Total	[r]2,234	[r]2,258	2,317	2,527	2,527
Synthetic:					
Austria[e]	61	55	55	61	61
Belgium[e]	276	276	287	292	287
Chile[8]	57	63	58	76	72
Finland[e]	39	39	39	39	39
France[e]	165	132	138	121	127

See footnotes at end of table.

Table 11.—Sodium sulfate: World production, by country[1] —Continued

(Thousand short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Synthetic—Continued					
German Democratic Republic	168	181	190	200	193
Germany, Federal Republic of	138	141	153	180	182
Greece[e]	[4]8	8	8	8	8
Hungary[e]	11	11	11	[r]10	10
Italy[e]	99	88	[r]88	83	88
Japan	287	307	305	279	287
Netherlands[e]	55	50	50	50	50
Portugal[e]	62	55	55	57	61
Spain[e 9]	187	187	165	165	182
Sweden[e]	110	110	110	110	110
U.S.S.R.[e 7]	[r]300	[r]300	[r]300	[r]300	300
United States[10]	[r]491	[r]466	422	416	[4]423
Total	[r]2,514	[r]2,469	2,434	2,447	2,480
Grand total	[r]4,748	[r]4,727	4,751	4,974	5,007

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through May 6, 1988.
[2]In addition to the countries listed, China, Norway, Poland, Romania, Switzerland, and the United Kingdom are known to or are assumed to have produced synthetic sodium sulfate, and other unlisted countries may have produced this commodity, output is not reported, and available information is inadequate to make reliable estimates of output levels.
[3]Natural mine output, excluding byproduct output from the nitrate industry, which is reported separately under "Synthetic" in this table.
[4]Reported figure.
[5]Series reflects output reported by Industrias Peñoles S.A. de C.V., Mexico's principal producer, plus an additional 33,000 short tons (revised, estimated) by a smaller producer.
[6]Less than 1/2 unit.
[7]Conjectural estimates based on 1968 information on natural sodium sulfate and general economic conditions.
[8]Byproduct of nitrate industry.
[9]Quantities of synthetic sodium sulfate credited to Spain are reported in official sources in a way such 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.
[10]Derived approximate figures; data presented are the difference between reported total sodium sulfate production (natural and synthetic not differentiated) and reported natural sodium sulfate sold by producers (reported under "Natural" in this table).

Crushed Stone

By Valentin V. Tepordei[1]

A total of 1.2 billion short tons of crushed stone was reportedly produced in the United States in 1987, an increase of 17.3% over that of 1986. It is the highest production ever recorded in the United States, 9.2% more than the previous record-high production of 1.1 billion tons reported in 1979. About 70% of the crushed stone production continued to be limestone and dolomite, followed by granite, traprock, sandstone and quartzite, shell, marble, calcareous marl, volcanic cinder and scoria, and slate, in order of volume.

Foreign trade in crushed stone remained relatively minor. Exports and imports increased 10.3% and 25.5%, respectively. Ninety-seven percent of the exported and 37% of the imported crushed stone was limestone. Apparent consumption of crushed stone was 1.2 billion tons.

Table 1.—Salient U.S. crushed stone statistics

(Thousand short tons and thousand dollars)

	1983	1984	1985	1986	1987
Sold or used by producers:					
Quantity[1]	861,600	e956,000	1,000,800	e1,023,200	1,200,100
Value[1]	$3,327,000	e$3,755,600	$4,053,000	e$4,255,000	$5,248,600
Exports (value)	$23,021	$23,970	$29,347	$36,957	$26,063
Imports for consumption (value)[2]	$12,610	$17,543	$11,640	$12,451	$14,024

eEstimated.
[1]Does not include American Samoa, Guam, Puerto Rico, and the Virgin Islands.
[2]Excludes precipitated calcium carbonate.

Domestic Data Coverage.—Domestic production data for crushed stone are developed by the Bureau of Mines from voluntary surveys of U.S. producers. Full surveys of crushed stone producers are conducted for odd-numbered years only. For even-numbered years, preliminary surveys, which collect production information on a sample basis, are conducted to generate only annual preliminary estimates at the State level.

Of the 5,634 crushed stone operations surveyed, 3,473 were active. Of these, 2,677 or 77.1% reported to the Bureau of Mines. Their total production represented 80.2% of the total U.S. crushed stone output. The nonrespondents' production was estimated using adjusted prior years' production reports and/or employment data. Of the 2,677 reporting operations, 569 did not indicate a breakdown by end use. Their production, as well as estimates of 828 nonrespondents, representing 30.6% of the U.S. total, is included in tables 11, 13, and 15-18 under "Other unspecified uses." A total of 1,330 quarries were either idle or presumed to be idle, because no information was available to estimate their production.

Legislation and Government Programs.—On April 2, the U.S. Congress enacted the 1987 Surface Transportation Assistance Act (STAA), which extended the Federal-Aid Highway Program for 5 more years. The total funding was $68 billion, with annual authorizations ranging between $13.6 and $13.9 billion. On December 31, the Airport Improvement Program (AIP) legislation was enacted, which appropriated $1.7 billion for fiscal years 1988-90 and $1.8 billion for fiscal years 1991 and 1992. The $8.7 billion total represented a 65% increase in funding over the previous AIP.

Funding for the fiscal year 1988 program was later reduced by the Continuing Resolution (Public Law 100-202) by $0.57 billion for the STAA program and by $0.43 billion for the AIP.

Responding to requests made by the industry, the Occupational Safety and Health Administration (OSHA) extended a partial stay to July 21, 1988, for implementation of the new provisions of its revised asbestos standards for nonasbestiform varieties of actinolite, anthophyllite, and tremolite minerals. The stay was issued to allow OSHA time to review additional data regarding the feasibility of regulating these nonasbestiform minerals. The extension was needed because of the range of the affected industries and the lack of mineralogic and exposure data in these industries. The former asbestos standards remain in effect for the extent of the stay.

The introduction of the revised OSHA regulations regarding the airborne asbestos standards, which include nonasbestiform varieties of actinolite, anthophyllite, and tremolite, would have a very significant impact on the aggregates industries, consequently affecting the construction industries. The resulting costs to society, in the form of increased construction costs and disruption of the supply of aggregates, were considered potentially enormous according to industry estimates.

DOMESTIC PRODUCTION

Of the total 1.2 billion tons of crushed stone produced in the United States, 841 million tons or 70% was limestone and dolomite, 180 million tons or 15% was granite, and 103 million tons or 8.6% was traprock. The remaining 6.4% was shared by marble, calcareous marl, shell, sandstone and quartzite, slate, volcanic cinder and scoria, and miscellaneous stone.

A comparison of the four major geographic regions indicated that in 1987 the South continued to lead the Nation in the production of crushed stone with 47.7% of the total, followed by the Midwest with 26.2%, and the Northeast with 15.7%. Approximately 74% of the total U.S. crushed stone output was produced in two major geographic regions, the South and the Midwest. Of the nine geographic regions, the South Atlantic led the Nation in the production of crushed stone with 316 million tons or 26.3% of the U.S. total. Next was the East North Central region with 196 million tons or 16.3% of the total, followed by the Middle Atlantic with 154 million tons or 12.8%.

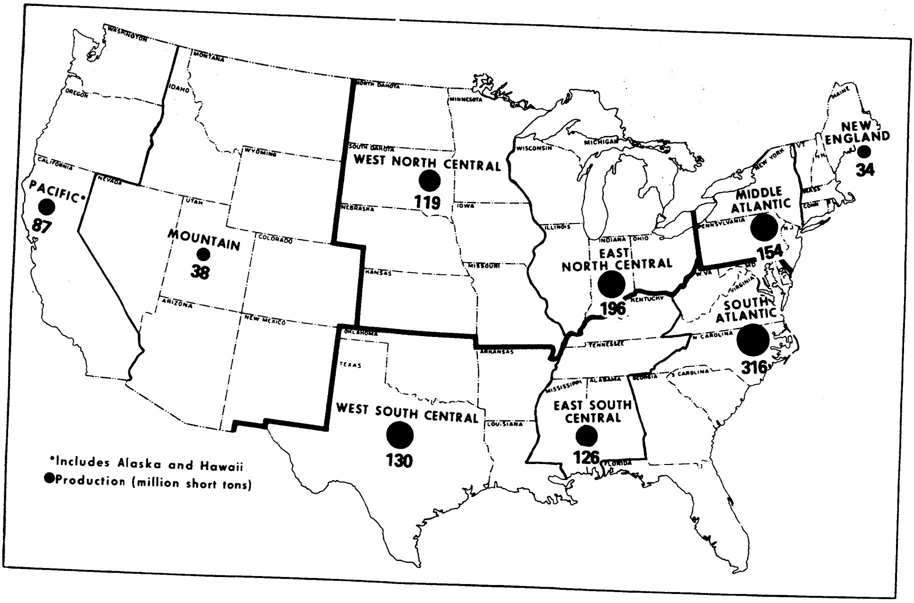

Figure 1.—Production of crushed stone in the United States in 1987, by geographic region.

A comparison of the estimated 1986 and reported 1987 production data by regions indicated that the output of crushed stone increased in all regions except the West South Central, which includes Texas. The largest increases were recorded in New England, 45.6%; the Middle Atlantic, 28.6%; and the East North Central, 28.2%.

Based on the 1985 Bureau of the Census population estimates, 1987 U.S. per capita crushed stone production was 5.0 tons. Per capita production by major geographic region was 7.0 tons in the South, followed by the Midwest with 5.3 tons, the Northeast with 3.8 tons, and the West with 2.6 tons.

Crushed stone was produced in every State except Delaware. The 10 leading States in the production of crushed stone, in order of volume, were Pennsylvania, Texas, Florida, Georgia, Virginia, Missouri, Illinois, Ohio, Tennessee, and North Carolina. Their combined production represented 53.4% of the national total.

ARC America Corp. of Newport Beach, CA, a subsidiary of Consolidated Gold Fields PLC of the United Kingdom, acquired American Aggregates Corp. of Greenville, OH, one of the largest aggregates producers in Ohio. American Aggregates owned a significant amount of reserves in the State and operated 10 crushed stone quarries and 12 sand and gravel pits.

Blue Circle Industries PLC of London, United Kingdom, acquired Raia Industries Inc. of Hackensack, NJ. Raia Industries operated a crushed stone quarry and ready-mixed cement operations in Sussex County, NJ.

Vulcan Materials Co. of Birmingham, AL, acquired White Mines Co. of San Antonio, TX. The purchase included a rock asphalt quarry at Uvalde, TX; a basalt quarry at Knippa, TX; and three limestone quarries at Brownwood, Abilene, and Weatherford, TX. The newly acquired operations were combined with Vulcan's existing Texas operation to form a new division with headquarters in San Antonio, TX.

Florida Rock Industries Inc. of Jacksonville, FL, acquired Arundel Corp. of Baltimore, MD, a large construction aggregates producer with operations in Delaware, Maryland, North Carolina, and Virginia. Prior to the acquisition, Florida Rock's 14 quarries were in Florida and Georgia.

Dravo Basic Materials Co. of Kenner, LA, acquired from Florida Crushed Stone Co. of Leesburg, FL, a limestone quarry at Perry, FL, that will allow Dravo to supply aggregates to the Tallahassee market. Dravo already has operations in Chattahoochee, Pensacola, and Tampa, FL.

USX Corp. of Pittsburgh, PA, sold its two Michigan limestone quarries, Calcite Quarry and Cedarville Quarry, to Michigan Limestone Operations Ltd., a newly formed company.

Limestone.—Beginning with the 1983 survey, a new canvassing procedure was implemented that is designed to collect separate information on the amount of limestone and dolomite produced in the United States. In 1987, 153 quarries reported producing only dolomite, while 35 additional quarries reported producing both limestone and dolomite, without making a distinction between the two kinds of stone. Therefore, the limestone totals shown in this chapter include an undetermined amount of dolomite, in addition to the dolomite reported separately. Compared with that of 1985, the 1987 output of crushed limestone, including some dolomite, increased 15.7% to 792 million tons valued at $3.2 billion. Limestone was produced by 1,130 companies at 2,496 quarries in 46 States. Leading States, in order of tonnage, were Texas, Pennsylvania, Florida, Missouri, and Illinois; these five States accounted for 39.6% of the total U.S. output. Leading U.S. producers were, in order of volume, Vulcan, Martin Marietta Aggregates, Koppers Co. Inc., Florida Rock, and the Rogers Group. These five companies accounted for about 16% of total U.S. output of limestone.

Dolomite.—Production of dolomite increased 55% to 49 million tons valued at $207 million. Crushed dolomite was reportedly produced by 86 companies in 24 States. An additional undetermined amount of dolomite is included in the total crushed limestone data. Leading States in the production of dolomite, in order of tonnage, were Pennsylvania, Michigan, Alabama, New York, and Ohio; these five States accounted for 67% of the total U.S. output. Leading U.S. producers were Glasgow Inc., Stabler Co., Bethlehem Steel Corp., Vulcan, and Michigan Minerals Associates; their combined production represented 44% of the total U.S. dolomite production.

Marble.—Production of crushed marble increased 129% to 5.6 million tons valued at $62 million. Crushed marble was produced by 18 companies at 47 quarries in 11 States. Leading States, in order of tonnage, were Virginia, California, Alabama, Georgia, and Vermont; these five States accounted for 93% of the total U.S. output. Leading producers of crushed marble, in order of tonnage, were Koppers, CalMat Co., and Georgia Marble Co.; their combined production represented 65% of the total U.S. output.

Calcareous Marl.—Output of marl increased 5% to 4.2 million tons valued at $7.7 million. Marl was produced by 15 companies at 16 quarries in 7 States. South Carolina accounted for 81% of total U.S. output. Leading producers, in order of tonnage, were Dundee Cement Co., Giant Portland & Masonry Cement Co., and Gifford-Hill & Co.; their combined production represented 80% of the total U.S. output.

Shell.—Shell is mainly derived from fossil reefs or oyster shell. The output of crushed shell decreased 8% to 8.4 million tons valued at $51 million. The decrease is mostly due to the restrictions imposed on the industry in Louisiana as a result of concerns that shell dredging produces irreversible damage to the environment. Crushed shell was produced by 15 companies from 19 operations in 7 States. The major producing States were Louisiana and Florida and the leading producers, in order of tonnage, were Dravo, Ashland Oil Inc., Leisey Shell Corp., Pontchartrain Dredging Corp., and Quality Aggregates Inc.; their combined production represented 77% of the U.S. output.

Granite.—Compared with that of 1985, the 1987 output of crushed granite increased 24% to 180 million tons valued at $901 million. Crushed granite was produced by 136 companies at 735 quarries in 31 States. Leading States, in order of tonnage, were Georgia, North Carolina, Virginia, South Carolina, and California; these five States accounted for 76% of the U.S. output. Leading U.S. producers, in order of tonnage, were Vulcan, Martin Marietta, Koppers, Georgia Marble, and Tarmac America; their combined production represented 54% of the U.S. total.

Traprock.—Production of crushed traprock increased 24% to 103 million tons valued at $505 million. Traprock was produced by 257 companies at 813 quarries in 23 States. Leading States, in order of tonnage, were Oregon, New Jersey, Washington, Connecticut, and Massachusetts; these five States accounted for 58% of U.S. output. Leading U.S. producers, in order of tonnage, were Tilcon Inc., U.S. Forest Service Region 3, Traprock Industries Inc., Koppers, and Chantilly Crushed Stone Inc.; their combined production accounted for 25% of the total U.S. output.

Sandstone and Quartzite.—The combined output of crushed sandstone and quartzite increased 40% to 32 million tons valued at $158 million. Crushed sandstone was produced by 121 companies at 181 quarries in 27 States, while crushed quartzite was produced by 28 companies at 28 quarries in 17 States. Leading States in the production of sandstone were Pennsylvania, Arkansas, and California and for quartzite Georgia, South Dakota, and Virginia; the three States accounted for 55% of the U.S. output of sandstone and 61% of the U.S. output of quartzite. Leading producers, in order of tonnage, were Arkhola Sand and Gravel Co., Commercial Stone Corp., and Dutra Construction Co. for crushed sandstone, and Martin Marietta, Salem Stone Corp., and Concrete Material Co., for crushed quartzite.

Slate.—Compared with that of 1985, the 1987 output of crushed slate increased 201% to 2.3 million tons valued at $14.3 million. Crushed slate was produced by 8 companies at 10 quarries in 6 States. Leading States, in order of tonnage, were North Carolina and Georgia. Leading producers, in order of tonnage, were Martin Marietta, Big River Industries, and Lesuer-Richmond Slate Corp. The top three producers accounted for most of the U.S. output of crushed slate.

Volcanic Cinder and Scoria.—Production of volcanic cinder and scoria increased 23% to 3.7 million tons valued at $15 million. Volcanic cinder and scoria were produced by 39 companies from 359 operations in 13 States. Leading States, in order of volume were, Oregon, Arizona, California, North Carolina, and Hawaii; their combined production accounted for 78% of the total U.S. output. Leading producers, in order of tonnage, were the U.S. Forest Service, Martin Marietta, and U.S. Industries Inc.; their combined production accounted for 44% of U.S. output.

Miscellaneous Stone.—Output of other kinds of crushed stone increased 43% to 19 million tons valued at $78 million. Miscellaneous stone was produced by 59 companies from 304 quarries in 22 States. Leading States, in order of volume, were Pennsylvania, Maryland, and Florida; their combined production accounted for 70% of the total U.S. output. Leading producers, in order of tonnage, were Rockville Crushed Stone, Capeletti Inc., and Gill Quarries Inc.

Table 2.—Crushed stone sold or used in the United States, by kind

Kind	1985 Number of quarries	1985 Quantity (thousand short tons)	1985 Value (thousands)	1985 Unit value	1987 Number of quarries	1987 Quantity (thousand short tons)	1987 Value (thousands)	1987 Unit value
Limestone	2,316	685,002	$2,618,621	$3.82	2,496	792,448	$3,249,713	$4.10
Dolomite	87	31,348	133,271	4.25	119	48,656	206,904	4.25
Marble	22	2,437	20,439	8.39	51	5,576	62,335	11.18
Calcareous marl	14	3,959	8,083	2.04	16	4,154	7,650	1.84
Shell	17	9,106	37,951	4.16	19	8,402	51,028	6.07
Granite	580	145,254	669,807	4.61	735	179,972	900,682	5.00
Traprock	644	83,548	388,027	4.64	813	103,413	505,187	4.89
Sandstone and quartzite	378	23,148	103,483	4.47	523	32,495	157,934	4.86
Slate	7	773	3,758	4.86	10	2,330	14,258	6.12
Volcanic cinder and scoria	256	2,953	12,504	4.23	359	3,657	14,952	4.09
Miscellaneous stone	81	13,269	56,875	4.29	304	19,027	77,954	4.10
Total[1]	XX	1,000,800	4,053,000	4.05	XX	1,200,100	5,248,600	4.37

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

Table 3.—Crushed stone[1] sold or used in the United States, by region

(Thousand short tons and thousand dollars)

Region	1986[e] Quantity	1986[e] Value	1987 Quantity	1987 Value
Northeast:				
New England	23,700	119,500	34,500	203,581
Middle Atlantic	119,600	609,100	153,782	767,445
Midwest:				
East North Central	152,600	544,900	195,622	804,954
West North Central	107,200	385,700	118,759	431,975
South:				
South Atlantic	275,600	1,252,700	315,991	1,510,541
East South Central	104,700	438,000	126,245	556,353
West South Central	136,400	488,700	129,613	465,909
West:				
Mountain	31,700	119,000	38,121	147,323
Pacific	71,700	297,400	87,497	360,517
Total[2]	1,023,200	4,255,000	1,200,100	5,248,600

[e]Estimated.
[1]Includes volcanic cinder and scoria.
[2]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 State[1]

(Thousand short tons and thousand dollars)

State	1986[e] Quantity	1986[e] Value	1987 Quantity	1987 Value
Alabama	24,000	120,500	30,018	146,247
Alaska	2,000	8,500	2,033	8,945
Arizona	5,600	25,100	7,712	33,999
Arkansas	15,500	58,500	15,234	63,847
California	38,500	159,300	44,315	186,504
Colorado	8,000	30,700	8,045	33,465
Connecticut	7,700	45,800	11,412	76,668
Florida	69,000	288,200	[2]78,992	[2]350,537
Georgia	56,700	293,100	60,834	318,903
Hawaii	7,100	42,100	5,732	41,548
Idaho	3,700	12,700	3,852	15,346
Illinois	44,200	179,600	52,102	216,212
Indiana	[2]22,600	[2]76,500	31,067	106,770
Iowa	23,400	98,000	25,991	110,106
Kansas	16,600	60,300	19,319	69,628
Kentucky	[3]38,400	[3]137,000	43,330	173,222

See footnotes at end of table.

Table 4.—Crushed stone sold or used by producers in the United States, by State[1] —Continued

(Thousand short tons and thousand dollars)

State	1986[e] Quantity	1986[e] Value	1987 Quantity	1987 Value
Louisiana[4]	5,400	25,300	4,390	36,514
Maine	1,600	4,400	2,010	7,532
Maryland	26,400	126,000	30,136	151,579
Massachusetts	10,000	50,000	14,907	78,969
Michigan	27,800	83,900	37,909	109,514
Minnesota	8,300	26,300	8,995	29,246
Mississippi	1,600	4,400	1,492	9,621
Missouri	51,200	170,500	54,910	184,824
Montana	[5]2,200	[5]6,200	1,463	3,585
Nebraska	4,000	17,900	4,316	19,461
Nevada	1,500	7,000	[6]1,264	[6]5,700
New Hampshire	1,800	5,900	2,479	10,386
New Jersey	15,300	95,400	[7]17,576	[7]111,951
New Mexico	3,900	15,300	4,503	15,919
New York	40,600	196,600	38,103	188,694
North Carolina	43,500	206,500	48,847	237,181
North Dakota	W	W	W	W
Ohio	39,300	147,300	51,590	300,096
Oklahoma	30,900	102,100	[6]25,155	[6]83,732
Oregon	15,100	53,400	20,663	73,902
Pennsylvania	63,700	317,100	97,213	458,676
Rhode Island	[4]1,000	[4]5,700	1,228	7,797
South Carolina	18,200	76,700	[8]24,278	[8]105,387
South Dakota	3,600	12,600	5,070	18,515
Tennessee	[9]40,700	[9]175,600	51,406	227,263
Texas	84,200	301,500	84,347	276,477
Utah	4,500	14,100	7,989	23,606
Vermont	1,600	7,600	[9]2,159	[9]20,400
Virginia	52,000	224,700	60,376	295,903
Washington	9,000	34,100	14,754	49,618
West Virginia	9,800	37,500	12,458	50,947
Wisconsin	18,700	57,600	[5]22,757	[5]71,776
Wyoming	[9]1,700	[9]5,900	3,171	15,049
Other	1,100	4,000	2,230	16,831
Total[10]	1,023,200	4,255,000	1,200,100	5,248,600

[e]Estimated. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]To avoid disclosing company proprietary data, certain State totals do not include all kinds of stone produced within the State; the portion not shown has been included with "Other."
[2]Excludes marl.
[3]Excludes sandstone.
[4]Excludes other stone.
[5]Excludes traprock.
[6]Excludes dolomite.
[7]Excludes limestone.
[8]Excludes shell.
[9]Excludes granite.
[10]Data may not add to totals shown because of independent rounding.

Table 5.—U.S. crushed stone sold or used by producers in 1987, by size of operation

Size range (Thousand short tons)	Number of operations	Quantity (thousand short tons)	Percent
0 to 25	764	7,262	0.6
25 to 50	331	12,110	1.0
50 to 75	248	15,561	1.3
75 to 100	197	17,323	1.5
100 to 200	525	77,276	6.4
200 to 300	332	81,583	6.8
300 to 400	192	67,500	5.6
400 to 500	168	75,341	6.3
500 to 600	111	61,700	5.1
600 to 700	116	74,990	6.3
700 to 800	78	58,926	4.9
800 to 900	76	65,177	5.4
900 to 999	44	41,522	3.5
1,000 to 1,999	207	277,373	23.1
2,000 and over	84	266,485	22.2
Total	3,473	[1]1,200,100	100

[1]Data do not add to total shown because of independent rounding.

Table 6.—Crushed limestone and dolomite sold or used in the United States in 1987, by State

(Thousand short tons and thousand dollars)

State	Limestone		Dolomite	
	Quantity	Value	Quantity	Value
Alabama	24,155	100,413	4,753	21,705
Alaska	W	W	--	--
Arizona	3,748	15,977	--	--
Arkansas	3,726	14,349	1,483	W
California	20,226	77,126	396	6,011
Colorado	2,565	10,701	--	--
Connecticut	377	2,350	--	--
Florida	72,184	329,011	1,128	7,481
Georgia	W	W	W	W
Hawaii	1,337	9,093	--	--
Idaho	373	1,034	(1)	(1)
Illinois	49,883	207,185	2,154	8,539
Indiana	29,549	101,000	1,486	5,658
Iowa	25,991	110,106	--	--
Kansas	18,788	66,306	--	--
Kentucky	W	W	W	W
Maine	1,509	4,395	--	--
Maryland	18,793	94,102	--	--
Massachusetts	1,739	10,019	--	--
Michigan	32,180	91,508	5,588	17,578
Minnesota	W	W	W	W
Mississippi	1,492	9,621	--	--
Missouri	51,680	174,925	1,151	4,505
Montana	1,244	2,803	--	--
Nebraska	4,316	19,461	--	--
Nevada	W	W	W	W
New Jersey	W	W	--	--
New Mexico	3,150	10,263	--	--
New York	26,052	113,576	3,723	18,602
North Carolina	4,242	22,414	--	--
Ohio	48,181	286,479	3,243	13,183
Oklahoma	W	W	W	W
Oregon	W	W	--	--
Pennsylvania	58,274	288,608	15,455	59,103
Rhode Island	678	4,866	--	--
South Carolina	5,980	24,670	--	--
South Dakota	3,872	11,408	--	--
Tennessee	W	W	W	W
Texas	79,684	251,792	1,328	3,678
Utah	W	W	W	W
Vermont	1,807	8,065	--	--
Virginia	19,622	87,616	2,112	16,255
Washington	689	2,400	415	1,093
West Virginia	10,737	39,586	--	--
Wisconsin	18,175	58,477	1,075	2,420
Wyoming	W	W	W	W
Other	145,452	588,009	3,165	21,093
Total[2]	792,450	3,249,700	48,650	206,900

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Less than 1/2 unit.
[2]Data may not add to totals shown because of independent rounding.

Table 7.—Crushed calcareous marl sold or used by producers in the United States in 1987, by State

(Thousand short tons and thousand dollars)

State	Quantity	Value
Florida	W	W
Indiana	W	W
Maine	W	W
Michigan	20	67
North Carolina	31	156
South Carolina	3,355	6,089
Texas	W	W
Other	748	1,338
Total	4,154	7,650

W Withheld to avoid disclosing company proprietary data; included with "Other."

Table 8.—Crushed granite, traprock, and sandstone and quartzite sold or used by producers in the United States in 1987, by State

(Thousand short tons and thousand dollars)

State	Granite		Traprock		Sandstone and quartzite	
	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	W	W	--	--	--	--
Alaska	511	1,966	635	2,718	W	W
Arizona	3,014	13,636	--	--	W	W
Arkansas	5,826	26,784	--	--	4,038	16,432
California	9,890	40,362	8,017	40,403	2,736	9,755
Colorado	4,505	19,126	--	--	153	628
Connecticut	W	W	10,958	73,607	--	--
Georgia	47,204	247,555	--	--	2,082	11,383
Hawaii	--	--	4,139	31,160	--	--
Idaho	172	814	2,684	9,151	623	4,347
Illinois	--	--	--	--	66	488
Indiana	--	--	--	--	W	W
Kansas	--	--	--	--	531	3,322
Kentucky	--	--	--	--	W	W
Louisiana	--	--	--	--	14	97
Maine	--	--	W	W	W	W
Maryland	3,104	16,504	3,188	11,986	267	1,690
Massachusetts	2,198	16,838	9,960	45,681	W	W
Michigan	--	--	W	1	W	W
Minnesota	W	W	W	W	W	W
Missouri	W	W	--	--	--	--
Montana	--	--	W	W	132	534
Nevada	33	48	--	--	--	--
New Hampshire	1,002	4,938	1,477	5,448	--	--
New Jersey	5,964	42,510	11,612	69,441	--	--
New Mexico	W	W	223	W	W	W
New York	W	W	3,178	23,331	1,050	6,042
North Carolina	38,665	183,868	3,058	15,931	W	W
Ohio	--	--	--	--	165	434
Oklahoma	1,176	4,804	--	--	353	1,261
Oregon	351	1,179	16,331	57,784	1,166	4,704
Pennsylvania	W	W	7,669	35,714	8,438	44,289
Rhode Island	534	W	W	W	--	--
South Carolina	14,943	74,629	--	--	--	--
South Dakota	W	W	--	--	1,195	6,451
Texas	--	--	W	W	1,614	9,853
Utah	W	W	--	--	544	1,647
Vermont	W	W	--	--	--	--
Virginia	26,824	137,584	7,833	39,852	1,185	4,974
Washington	633	2,655	11,401	37,675	984	3,451
West Virginia	--	--	--	--	1,721	11,361
Wisconsin	1,874	6,266	W	W	1,634	4,614
Wyoming	W	W	--	--	--	--
Other	11,548	58,612	1,050	5,304	1,805	10,178
Total[1]	180,000	900,700	103,400	505,200	32,500	157,900

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Data may not add to totals shown because of independent rounding.

Table 9.—Volcanic cinder and scoria and miscellaneous crushed stone sold or used by producers in the United States in 1987, by State

(Thousand short tons and thousand dollars)

State	Volcanic cinder and scoria		Miscellaneous stone	
	Quantity	Value	Quantity	Value
Alaska	--	--	111	610
Arizona	845	3,217	43	W
Arkansas	--	--	153	956
California	490	2,137	1,095	3,361
Colorado	93	665	729	2,345
Florida	--	--	2,266	3,815
Hawaii	255	1,294	1	1
Louisiana	--	--	W	W
Maryland	--	--	W	W
Massachusetts	--	--	W	W
Montana	18	18	--	--
Nevada	222	1,046	12	12
New Mexico	113	310	W	W
Oregon	860	2,833	766	2,328

See footnote at end of table.

Table 9.—Volcanic cinder and scoria and miscellaneous crushed stone sold or used by producers in the United States in 1987, by State —Continued

(Thousand short tons and thousand dollars)

State	Volcanic cinder and scoria		Miscellaneous stone	
	Quantity	Value	Quantity	Value
Pennsylvania	--	--	6,749	27,953
Tennessee	--	--	W	W
Texas	--	--	269	1,942
Utah	100	412	(1)	2
Virginia	--	--	W	W
Washington	80	411	554	1,933
Other[2]	581	2,610	6,280	32,697
Total[3]	3,700	15,000	19,000	78,000

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Less than 1/2 unit.
[2]Includes data for North Carolina, North Dakota, and Wyoming.
[3]Data may not add to totals shown because of independent rounding.

Table 10.—Kind of crushed stone produced in the United States in 1987, by State

State	Limestone	Dolomite	Marble	Marl	Shell	Granite	Traprock	Sandstone	Quartzite	Slate	Volcanic cinder and scoria	Miscellaneous
Alabama	X	X	X			X						
Alaska	X				X	X	X	X				X
Arizona	X		X			X		X			X	X
Arkansas	X	X				X		X		X		X
California	X	X	X		X	X	X	X	X	X	X	X
Colorado	X					X		X			X	X
Connecticut	X					X	X					
Florida	X	X		X	X							X
Georgia	X	X	X			X			X	X		
Hawaii	X						X				X	X
Idaho	X	X				X	X	X	X			
Illinois	X	X						X				
Indiana	X	X		X				X				
Iowa	X											
Kansas	X							X	X			
Kentucky	X	X						X				
Louisiana					X			X				X
Maine	X			X			X		X			
Maryland	X				X	X	X	X	X			X
Massachusetts	X					X	X	X				X
Michigan	X	X		X			X		X			
Minnesota	X	X				X	X	X	X			
Mississippi	X											
Missouri	X	X				X						
Montana	X						X	X	X		X	
Nebraska	X											
Nevada	X	X	X			X					X	X
New Hampshire						X	X					
New Jersey	X					X	X					
New Mexico	X		X			X	X		X		X	X
New York	X	X	X			X	X	X		X		
North Carolina	X			X		X	X		X	X	X	X
North Dakota											X	X
Ohio	X	X						X				
Oklahoma	X	X				X		X				
Oregon	X					X	X	X	X		X	X
Pennsylvania	X	X				X	X	X	X			
Rhode Island	X					X	X					
South Carolina	X			X	X	X						
South Dakota	X					X		X	X			

Tennessee	X	X										X
Texas	X	X	X	X	X		X	X				X
Utah	X	X				X		X	X		X	X
Vermont	X		X			X						
Virginia	X	X	X			X	X	X	X	X		X
Washington	X	X				X	X	X	X		X	X
West Virginia	X							X				
Wisconsin	X	X				X	X	X				
Wyoming	X	X	X			X					X	X
American Samoa							X					
Guam	X											
Puerto Rico	X		X			X	X	X				X
Virgin Islands							X					X

CONSUMPTION AND USES

Crushed stone production reported to the Bureau of Mines is actually material that was either sold or used by the producers. Stockpiled production is not reported. Therefore, the sold or used tonnage represented the amount of production released for domestic consumption or export in a given year. Because some of the crushed stone producers did not report a breakdown by end use, their total production, as well as the estimated production of nonrespondents, was included in the tables under "Other unspecified uses" starting with the 1983 survey. This change in the processing procedures should be taken into account when 1983 through 1987 use patterns are compared with prior years.

In 1987, U.S. consumption of crushed stone was 1.2 billion tons valued at $5.2 billion, a 17.3% increase over the estimated consumption of 1986, and a 19.9% increase over the reported consumption of 1985. About 55% of this tonnage was used as construction aggregates, mostly for highway and road construction and maintenance, 9% for cement and lime manufacturing, 2% for agricultural purposes, 2% for a variety of industrial uses, and 32% for other unspecified uses. No significant changes occurred in the use patterns of crushed stone at the national level except for the large increase in the amount included under "Other unspecified uses."

Limestone.—Of the 792 million tons of crushed limestone consumed, 50% was used as construction aggregates, 13% for cement and lime manufacturing, and 3% for agricultural purposes. Owing to the significant increase in the amount of limestone included under "Other unspecified uses," from 138 million tons in 1985 to 261 million tons in 1987, a meaningful comparison of changes in the consumption of limestone by uses between 1985 and 1987 cannot be made. It is recommended that with any such comparison, the quantities and values included with "Other unspecified uses" be distributed among the reported uses being analyzed based on the following calculation: The percentage for each reported use should be calculated as a percentage of the U.S. total minus "Other unspecified uses"; the resulting percentages then should be applied to "Other unspecified uses" and the resulting quantities and values added to the reported uses published in the table.

Dolomite.—Of the 49 million tons of crushed dolomite consumed, 66% was used as construction aggregates, 3% as agricultural lime, 3% as flux stone, 1% for lime manufacturing, and 25% for other unspecified uses. An additional undefined amount of dolomite consumed in a variety of uses is reported with the limestone.

Marble.—Of the 5.6 million tons of crushed marble consumed, 25% was used as fillers and extenders, 9% was used for construction purposes, and 42% was used for other unspecified uses.

Calcareous Marl.—Of the 4.2 million tons of marl consumed, 98% was used for cement manufacturing and 1% was used for agricultural purposes.

Shell.—Of the 8.4 million tons of crushed shell consumed, 37% was used as construction aggregates and 62% for other unspecified uses.

Granite.—Of the 180 million tons of crushed granite consumed, 76% was used as construction aggregates, 5% was used as railroad ballast, and 19% was used for other unspecified uses.

Traprock.—Of the 103 million tons of crushed traprock consumed, 50% was used as construction aggregates, less than 2% was used as railroad ballast, and 48% was used for other unspecified uses.

Sandstone and Quartzite.—Of the 32 million tons of combined crushed sandstone and quartzite consumed, 60% was used as construction aggregates, 2% as railroad ballast, 1% for cement manufacturing, and 36% for other unspecified uses.

Slate.—Of the 2.3 million tons of crushed slate consumed, 63% was used for a variety of industrial applications and 37% was used as construction aggregates.

Volcanic Cinder and Scoria.—Of the 3.7 million tons of volcanic cinder and scoria consumed, 43% was used as construction aggregates, mainly for road construction and maintenance, and 52% was used for other unspecified uses.

Miscellaneous Stone.—Of the 19 million tons of miscellaneous crushed stone consumed, 71% was used as construction aggregates and 29% for other unspecified uses.

Table 11.—Crushed stone sold or used by producers in the United States in 1987, by use

(Thousand short tons and thousand dollars)

Use	Quantity	Value
Coarse aggregate (+1-1/2 inch):		
Macadam	10,688	44,007
Riprap and jetty stone	24,353	108,056
Filter stone	6,497	27,579
Other coarse aggregate	2,367	9,641
Coarse aggregate, graded:		
Concrete aggregate, coarse	109,699	504,936
Bituminous aggregate, coarse	72,626	339,956
Bituminous surface-treatment aggregate	25,148	116,471
Railroad ballast	16,471	67,761
Other graded coarse aggregate	7,138	31,841
Fine aggregate (-3/8 inch):		
Stone sand, concrete	19,540	100,339
Stone sand, bituminous mix or seal	19,037	85,858
Screening, undesignated	25,328	101,448
Other fine aggregate	1,194	6,300
Coarse and fine aggregates:		
Graded road base or subbase	194,872	717,359
Unpaved road surfacing	30,451	117,108
Terrazzo and exposed aggregate	2,438	11,956
Crusher run or fill or waste	63,670	263,986
Other coarse and fine aggregates	5,477	16,610
Other construction materials[1]	28,279	149,892
Agricultural:		
Agricultural limestone	20,602	93,869
Poultry grit and mineral food	2,047	20,511
Other agricultural uses	391	2,553
Chemical and metallurgical:		
Cement manufacture	93,233	270,317
Lime manufacture	13,047	64,466
Dead-burned dolomite manufacture	650	5,429
Flux stone	5,998	28,438
Chemical stone	207	1,365
Glass manufacture	755	6,642
Sulfur oxide removal	1,550	7,458
Special:		
Mine dusting or acid water treatment	774	7,185
Asphalt fillers or extenders	1,634	11,827
Whiting or whiting substitute	403	12,234
Other fillers or extenders	5,182	88,149
Roofing granules	1,672	8,717
Other miscellaneous uses[2]	4,742	31,078
Other unspecified uses[3]	381,969	1,767,256
Total[4]	1,200,100	5,248,600

[1]Includes dam construction and drain fields.
[2]Includes stone used in chemicals, disinfectant and animal sanitation, and refractory stone (including ganister).
[3]Includes production reported without a breakdown by use and estimates for nonrespondents.
[4]Data may not add to totals shown because of independent rounding.

Table 12.—Crushed limestone and dolomite sold or used by

(Thousand short tons)

State	Concrete aggregate		Bituminous aggregate		Roadstone and coverings		Riprap and railroad ballast	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	5,054	21,577	4,633	16,868	2,863	10,773	1,079	4,030
Alaska	--	--	--	--	W	W	--	--
Arizona	W	W	W	W	W	W	--	--
Arkansas	188	787	364	W	929	3,401	488	1,839
California	W	W	W	W	525	1,123	W	W
Colorado	--	--	W	W	W	W	--	--
Connecticut	--	--	--	--	--	--	--	--
Florida	21,136	114,768	8,262	43,101	13,394	40,212	257	1,210
Georgia	1,220	6,741	1,511	7,478	2,525	13,242	79	382
Hawaii	259	2,524	--	--	215	1,658	--	--
Idaho	--	--	--	--	50	125	--	--
Illinois	4,969	19,765	6,025	27,874	16,196	58,860	1,252	6,167
Indiana	3,704	10,774	3,423	11,141	3,789	13,516	1,684	6,217
Iowa	1,942	9,338	3,873	17,871	4,905	18,256	116	505
Kansas	1,435	6,387	1,457	6,382	3,904	13,257	390	1,794
Kentucky	3,670	13,377	5,772	22,406	8,510	32,326	1,843	7,150
Maine	W	W	--	--	--	--	--	--
Maryland	1,175	4,996	527	2,694	700	3,124	177	792
Massachusetts	W	W	W	W	--	--	--	--
Michigan	1,604	4,423	609	1,540	4,130	12,389	265	1,251
Minnesota	365	1,042	504	1,721	3,667	11,545	156	611
Mississippi	W	W	W	W	W	W	W	W
Missouri	4,502	17,304	3,463	13,508	10,288	36,208	3,604	11,540
Montana	--	--	--	--	--	--	--	--
Nebraska	1,516	6,877	W	W	696	3,362	78	417
Nevada	--	--	--	--	--	--	--	--
New Jersey	W	W	W	W	W	W	--	--
New Mexico	256	529	74	220	736	2,696	290	1,555
New York	2,150	11,317	5,572	26,782	3,583	16,846	999	5,038
North Carolina	523	2,887	W	W	912	4,749	W	W
Ohio	2,912	10,349	2,213	8,883	13,112	45,217	1,049	4,034
Oklahoma	1,826	6,496	784	3,184	956	2,465	167	604
Oregon	--	--	--	--	--	--	--	--
Pennsylvania	5,411	25,703	11,600	48,902	11,493	49,484	425	2,011
Rhode Island	--	--	--	--	--	--	--	--
South Carolina	719	3,696	482	2,197	1,788	4,506	W	W
South Dakota	W	W	139	533	W	W	125	559
Tennessee	5,346	24,630	8,723	37,101	8,899	36,306	453	1,889
Texas	11,561	45,334	8,201	36,820	27,177	60,964	863	4,374
Utah	--	--	--	--	20	40	3,230	W
Vermont	--	--	--	--	W	W	--	--
Virginia	3,393	15,670	2,222	10,623	3,947	15,103	814	3,595
Washington	--	--	22	104	1	3	4	18
West Virginia	641	2,289	455	1,897	330	1,340	63	281
Wisconsin	1,139	3,856	1,195	3,404	7,229	20,903	243	1,857
Wyoming	313	951	540	1,976	199	660	303	1,119
Total (excluding withheld)	88,930	394,386	82,645	355,212	157,667	534,658	543,084	70,837
Total withheld	1,703	6,578	1,271	8,193	2,273	8,426	W	8,277
Grand total[1]	90,633	400,964	83,916	363,405	159,940	543,084	20,494	79,114
Guam	W	620	--	--	W	W	W	10
Puerto Rico	941	4,753	75	411	W	W	W	W

W Withheld to avoid disclosing company proprietary data; included with "Total withheld" and "Other uses."
[1]Data may not add to totals shown because of independent rounding.
[2]Less than 1/2 unit.

producers in the United States in 1987, by State and use

and thousand dollars)

Other construction uses		Cement manufacture		Agricultural uses		Lime manufacture		Other uses		Total[1]	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
4,054	15,813	3,795	11,088	733	4,658	1,535	5,742	5,163	31,569	28,908	122,119
(2)	1	--	--	--	--	--	--	W	W	W	W
W	W	2,116	7,819	--	--	--	--	1,632	8,158	3,748	15,977
177	538	W	W	169	1,181	W	W	2,896	11,698	5,210	19,443
W	W	17,076	51,368	W	W	W	W	3,021	30,647	20,622	83,137
W	W	W	W	W	W	W	W	2,565	10,701	2,565	10,701
W	44	--	--	W	247	--	--	377	2,060	377	2,350
10,609	35,548	1,985	8,002	1,091	7,351	--	--	16,577	86,300	73,312	336,492
822	4,590	W	W	W	W	--	--	4,444	19,946	10,600	52,377
W	W	746	4,252	W	W	--	--	117	659	1,337	9,093
--	--	W	W	25	74	--	--	298	835	373	1,034
1,947	7,027	1,762	4,999	4,639	16,367	W	W	15,246	74,665	52,036	215,724
2,267	8,169	3,584	10,092	2,059	8,103	--	--	10,524	38,646	31,035	106,658
1,814	7,803	2,811	7,385	2,546	15,931	W	W	7,985	33,017	25,991	110,106
1,927	7,146	3,001	8,056	291	795	--	--	6,385	22,489	18,788	66,306
2,924	10,195	W	W	1,686	6,267	W	W	18,834	81,196	43,239	172,916
--	--	W	W	W	W	--	--	1,509	4,395	1,509	4,395
1,472	6,660	2,660	7,914	--	--	W	W	12,082	67,923	18,793	94,102
320	2,020	--	--	W	W	W	W	1,419	7,999	1,739	10,019
347	1,100	5,386	9,053	212	1,084	3,528	W	21,687	78,246	37,769	109,086
356	1,470	--	--	250	851	--	--	2,084	6,816	7,381	24,057
W	W	--	--	124	662	--	--	1,368	8,960	1,492	9,621
2,956	12,217	3,103	7,552	1,881	6,063	W	W	23,033	75,037	52,832	179,430
--	--	W	W	--	--	--	--	1,244	2,803	1,244	2,803
762	4,154	W	W	329	2,069	--	--	936	2,582	4,316	19,461
--	--	W	W	W	W	W	W	1,121	5,247	1,121	5,247
W	W	--	--	W	W	--	--	W	W	W	W
1,060	3,189	W	W	--	--	--	--	733	2,073	3,150	10,263
2,905	11,773	4,019	9,802	123	948	--	--	10,425	49,672	29,776	132,178
2,341	13,147	--	--	W	W	--	--	466	1,631	4,242	22,414
2,053	6,793	1,538	3,913	1,437	6,464	W	1,423	27,110	212,587	51,424	299,662
1,986	4,136	2,525	4,696	79	224	--	--	15,587	59,513	23,911	81,318
W	W	W	W	--	--	--	--	W	W	W	W
7,785	26,758	7,427	31,590	1,144	11,124	1,620	11,972	26,824	140,168	73,729	347,711
--	--	--	--	16	W	--	--	662	4,866	678	4,866
1,844	8,029	--	--	W	W	--	--	1,147	6,242	5,980	24,670
74	300	W	W	--	--	W	W	3,533	10,016	3,872	11,408
10,484	42,475	W	W	1,265	4,910	W	W	16,196	79,779	51,366	227,090
2,636	5,930	9,247	20,595	326	949	724	2,995	20,276	77,509	81,012	255,470
--	--	1,438	4,352	6	98	W	W	1,758	14,011	6,453	18,501
W	W	--	--	--	--	--	--	1,807	8,065	1,807	8,065
3,876	14,083	1,114	6,798	713	6,605	W	W	5,656	31,395	21,734	103,871
5	71	--	--	7	32	--	--	1,066	3,265	1,103	3,493
1,143	5,129	W	W	33	318	--	--	8,073	28,331	10,737	39,586
513	1,123	W	W	879	4,472	W	W	8,052	25,281	19,249	60,896
119	458	W	W	--	--	--	--	226	525	1,698	5,689
71,573	267,889	75,331	219,325	22,064	107,846	7,408	22,132	312,144	1,467,523	838,258	3,439,806
1,350	6,616	11,456	33,752	819	7,742	6,284	47,671	2,848	16,811	2,848	16,812
72,923	274,505	86,787	253,077	22,883	115,588	13,692	69,803	XX	XX	841,100	3,456,600
W	W	--	--	--	--	--	--	--	W	355	2,289
W	W	W	5,902	--	--	--	--	--	13,154	5,377	24,221

XX Not applicable.

Table 13.—Crushed limestone and dolomite sold or used by producers in the United States in 1987, by use

(Thousand short tons and thousand dollars)

Use	Limestone		Dolomite	
	Quantity	Value	Quantity	Value
Coarse aggregate (+1-1/2 inch):				
Macadam	8,041	30,428	169	745
Riprap and jetty stone	14,945	55,614	487	2,014
Filter stone	4,526	17,886	171	651
Other coarse aggregate	1,191	4,742	697	2,415
Coarse aggregate, graded:				
Concrete aggregate, coarse	71,095	306,531	4,290	20,093
Bituminous aggregate, coarse	45,749	198,658	3,750	17,551
Bituminous surface-treatment aggregate	16,992	73,756	1,075	4,262
Railroad ballast	4,232	16,550	1,099	4,936
Other graded coarse aggregate	568	2,299	3,400	10,838
Fine aggregate (-3/8 inch):				
Stone sand, concrete	13,569	65,116	1,073	6,358
Stone sand, bituminous mix or seal	9,581	39,950	1,302	5,150
Screening, undesignated	16,866	64,427	430	1,102
Other fine aggregate	607	2,867	--	--
Coarse and fine aggregates:				
Graded road base or subbase	117,348	385,981	7,676	27,615
Unpaved road surfacing	24,200	88,732	616	2,426
Terrazzo and exposed aggregate	590	1,938	(1)	(1)
Crusher run, fill or waste	33,638	126,501	2,112	8,264
Other coarse and fine aggregates	1,304	4,472	3,016	7,418
Other construction materials[2]	9,265	36,722	339	1,553
Agricultural:				
Agricultural limestone	19,081	82,679	1,521	11,190
Poultry grit and mineral food	1,958	19,993	--	--
Other agricultural uses	218	1,493	29	159
Chemical and metallurgical:				
Cement manufacture	87,792	255,467	--	--
Lime manufacture	12,499	62,071	542	2,303
Dead-burned dolomite manufacture	67	716	W	W
Flux stone	4,498	20,887	1,237	5,102
Chemical stone	189	1,287	W	W
Glass manufacture	755	6,642	--	--
Sulfur oxide removal	1,550	7,458	--	--
Special:				
Mine dusting or acid water treatment	691	6,273	W	W
Asphalt fillers or extenders	1,495	10,921	W	19
Whiting or whiting substitute	213	7,221	W	114
Other fillers or extenders	3,513	53,727	147	1,683
Roofing granules	206	1,744	8	23
Paper manufacture	W	W	--	--
Other miscellaneous uses[3]	2,463	15,962	1,208	8,021
Other unspecified uses[4]	260,953	1,172,003	12,259	54,901
Total[5]	792,450	3,249,700	48,650	206,900

W Withheld to avoid disclosing company proprietary data; included with "Other miscellaneous uses."
[1]Included with "Other construction materials."
[2]Includes stone used in dam construction and drain fields.
[3]Includes stone used in chemicals, disinfectant and animal sanitation, waste material, and data indicated by symbol W.
[4]Includes production reported without a breakdown by use and estimates for nonrespondents.
[5]Data may not add to totals shown because of independent rounding.

Table 14.—Crushed marble sold or used by producers in the United States in 1987, by use

(Thousand short tons and thousand dollars)

Use	Quantity	Value
Coarse aggregate, graded	12	100
Fine aggregate (-3/8 inch):		
Screenings, undesignated	2	36
Other fine aggregate	3	25
Coarse and fine aggregates:		
Graded road base or subbase	373	W
Terrazzo and exposed aggregate	80	1,594
Crusher run or fill or waste	15	73
Other construction materials[1]	27	2,110
Chemical and metallurgical: Lime manufacture	5	92
Special: Whiting or whiting substitute and fillers	1,530	37,031
Other miscellaneous uses[2]	1,195	7,050
Other unspecified uses[3]	2,335	14,304
Total[4]	5,600	62,300

W Withheld to avoid disclosing company proprietary data; included with "Other unspecified uses."
[1]Includes other coarse and fine aggregates, riprap and jetty stone, and stone sand.
[2]Includes agricultural stone, cement manufacture, and roofing granules.
[3]Includes production reported without a breakdown by use, estimates for nonrespondents, and data indicated by symbol W.
[4]Data may not add to totals shown because of independent rounding.

Table 15.—Crushed granite and traprock sold or used by producers in the United States in 1987, by use

(Thousand short tons and thousand dollars)

Use	Granite		Traprock	
	Quantity	Value	Quantity	Value
Coarse aggregate (+1-1/2 inch):				
Macadam	1,185	6,115	456	2,701
Riprap and jetty stone	5,008	30,641	2,293	10,765
Filter stone	1,180	5,522	254	1,512
Other coarse aggregate	--	--	326	2,087
Coarse aggregate, graded:				
Concrete aggregate, coarse	23,589	123,805	6,561	34,235
Bituminous aggregate, coarse	15,722	85,549	4,941	25,870
Bituminous surface-treatment aggregate	3,609	19,995	1,962	10,108
Railroad ballast	8,692	34,502	1,682	7,290
Other graded coarse aggregate	40	126	2,746	17,543
Fine aggregate (-3/8 inch):				
Stone sand, concrete	2,990	13,788	613	8,129
Stone sand, bituminous mix or seal	5,447	26,366	1,300	6,499
Screening, undesignated	6,717	30,781	231	1,025
Other fine aggregate	267	1,408	298	1,920
Coarse and fine aggregates:				
Graded road base or subbase	34,814	159,063	21,016	84,777
Unpaved road surfacing	1,555	7,533	2,605	10,319
Terrazzo and exposed aggregate	859	3,560	62	358
Crusher run or fill or waste	20,471	98,868	3,156	13,270
Other coarse and fine aggregates	48	126	736	3,538
Other construction materials	13,236	83,122	2,225	14,201
Other miscellaneous uses[1]	1,144	5,235	650	3,341
Other unspecified uses[2]	33,398	164,577	49,298	245,699
Total[3]	180,000	900,700	103,400	505,200

[1]Includes roofing granules, granite used in poultry grit and mineral food, and traprock.
[2]Includes production reported without a breakdown by end use and estimates for nonrespondents.
[3]Data may not add to totals shown because of independent rounding.

Table 16.—Crushed sandstone and quartzite sold or used by producers in the United States in 1987, by use

(Thousand short tons and thousand dollars)

Use	Sandstone Quantity	Sandstone Value	Quartzite Quantity	Quartzite Value
Coarse aggregate (+1-1/2 inch):				
Macadam	325	1,186	--	--
Riprap and jetty stone	1,086	5,736	125	619
Filter stone	227	1,417	14	104
Other coarse aggregate	6	114	--	--
Coarse aggregate, graded:				
Concrete aggregate, coarse	1,716	9,665	1,123	5,306
Bituminous aggregate, coarse	1,952	9,834	256	1,183
Bituminous surface-treatment aggregate	673	3,923	186	775
Railroad ballast	292	1,837	400	2,181
Other graded coarse aggregate	72	306	--	--
Fine aggregate (-3/8 inch):				
Stone sand, bituminous mix or seal	1,126	6,111	357	1,636
Screening, undesignated	938	5,832	20	64
Other fine aggregate	704	2,229	--	--
Coarse and fine aggregates:				
Graded road base or subbase	5,430	23,584	911	4,399
Unpaved road surfacing	346	1,647	69	295
Terrazzo and exposed aggregate	82	625	--	--
Crusher run or fill or waste	1,311	4,939	3	11
Other construction materials	424	2,265	534	2,882
Chemical and metallurgical:				
Cement manufacture	197	842	139	971
Flux stone	--	--	262	2,449
Special:				
Asphalt fillers or extenders	20	W	--	--
Refractory stone	--	--	25	70
Other fillers or extenders	--	--	3	15
Other miscellaneous uses[1]	69	836	--	--
Other unspecified uses[2]	10,101	46,204	970	5,841
Total[3]	27,100	129,100	5,400	28,800

W Withheld to avoid disclosing company proprietary data; included with "Other miscellaneous uses."
[1]Includes stone used in poultry grit and mineral food and data indicated by symbol W.
[2]Includes production reported without a breakdown by end use and estimates for nonrespondents.
[3]Data may not add to totals shown because of independent rounding.

Table 17.—Crushed volcanic cinder and scoria sold or used by producers in the United States in 1987, by use

(Thousand short tons and thousand dollars)

Use	Quantity	Value
Coarse aggregate (+1-1/2 inch): Riprap and jetty stone	8	40
Concrete aggregate, graded: Concrete aggregate, coarse	396	927
Coarse and fine aggregates:		
Graded road base or subbase	426	1,951
Unpaved road surfacing	212	1,083
Terrazzo and exposed aggregate	207	1,567
Crusher run or fill or waste	65	670
Other construction materials[1]	278	954
Other miscellaneous uses[2]	157	599
Other unspecified uses[3]	1,908	7,161
Total[4]	3,700	15,000

[1]Includes railroad ballast, bituminous aggregate (coarse), fine aggregate, stone sand, and screening.
[2]Includes roofing granules and a minor amount of stone used for agricultural purposes.
[3]Includes production reported without a breakdown by use and estimates for nonrespondents.
[4]Data may not add to totals shown because of independent rounding.

Table 18.—Crushed miscellaneous stone[1] sold or used by producers in the United States in 1987, by use

(Thousand short tons and thousand dollars)

Use	Quantity	Value
Coarse aggregate (+1-1/2 inch):		
Macadam	511	2,832
Riprap and jetty stone	396	2,259
Other coarse aggregate	83	217
Coarse aggregate, graded:		
Concrete aggregate, coarse	929	4,375
Bituminous aggregate, coarse	231	1,118
Bituminous surface-treatment aggregate	630	3,551
Other graded coarse aggregate	300	628
Fine aggregate (-3/8 inch):		
Stone sand, concrete	134	536
Stone sand, bituminous mix or seal	112	425
Coarse and fine aggregates:		
Graded road base or subbase	6,878	28,650
Unpaved road surfacing	846	5,073
Terrazzo and exposed aggregate	105	510
Crusher run or fill	2,898	11,389
Other coarse and fine aggregates	358	797
Other construction materials[2]	3,098	16,243
Agricultural: Other agricultural purposes	75	409
Chemical and metallurgical: Cement manufacture	4,051	7,238
Other miscellaneous uses[3]	1,553	8,524
Other unspecified uses[4]	10,724	56,116
Total[5]	33,900	150,900

[1]Includes marl, other stone, shell, and slate.
[2]Includes filter stone, lightweight aggregate, railroad ballast, and undesignated screenings.
[3]Includes fillers or extenders and roofing granules.
[4]Includes production reported without a breakdown by end use and estimates for nonrespondents.
[5]Data may not add to totals shown because of independent rounding.

PRICES

Compared with that of 1985, the 1987 average unit price of crushed stone increased 8% to $4.37. By kind of stone, the average unit prices showed increases of 46% for shell, 33% for marble, 26% for slate, 9% for granite and sandstone and quartzite, 7% for limestone, and 5% for traprock. At the same time, the average unit prices decreased by 10% for marl, 4% for miscellaneous stone, and 3% for volcanic cinder and scoria. Despite the increase in the reported output of crushed dolomite in 1987, the average unit price remained unchanged at $4.25.

TRANSPORTATION

Of the total crushed stone produced, 51% was transported by truck from the processing plant or quarry to the first point of sale or use, 4% was transported by rail, and 3% by waterway. For about 40% of the total crushed stone produced in 1987 no means of transportation was reported by the producers or the production was used on-site.

Table 19.—Crushed stone sold or used by producers in the United States in 1987, by method of transportation

Method of transportation	Quantity (thousand short tons)	Percent
Truck	613,760	51
Rail	50,435	4
Water	29,271	3
Other	26,968	2
Not transported	479,696	40
Total	[1]1,200,100	100

[1]Data do not add to total shown because of independent rounding.

FOREIGN TRADE

Exports.—Compared with those of 1986, exports of crushed stone increased 10.3% to 3.2 million tons, while the value decreased 29.5%. About 97% of the exported crushed stone was limestone, of which more than 99% was exported to Canada.

Imports.—Imports of crushed stone increased 25.5% to 3.6 million tons, and 14.7% in value to $12.5 million. About 37% of this tonnage was limestone, 84% of which came from Canada, 8% from the Bahamas, and 5% from Mexico.

Imports of calcium carbonate fines decreased 25% to 263,000 tons, and 2% in value to $1.5 million. Eighty-six percent of the natural chalk came from the Bahamas, while most of the processed calcium carbonate was imported from France, 84%; the United Kingdom, 7%; and Japan, 5%.

Shipments of crushed stone from Scotland, the United Kingdom, and Nova Scotia, Canada, into the United States continued in 1987 and were mostly responsible for the increase in total imports. The imported crushed stone, used mostly as construction aggregates, was distributed in North Carolina, South Carolina, Florida, Louisiana, and Texas. This trend was expected to increase significantly as a result of recent developments in Canada and Mexico. The Newfoundland Resources & Mining Co. Ltd. of Mississauga, Ontario, Canada, a subsidiary of Explaura Holdings PLC of London, United Kingdom, is developing a crushed stone quarry in Lower Cove, Newfoundland, Canada. The company plans to market its high-quality crushed limestone to end users in the construction, chemical, metallurgical, and mining industries on the east coast of Canada and the United States. The quarry is expected to become operational in 1989. Vulcan of Birmingham, AL, formed a joint venture with Mexico's Calizas Industries del Carmen S.A. to develop a limestone quarry on the Yucatan Peninsula that will produce construction aggregates to be marketed in Florida, Louisiana, and Texas. The shipments of crushed stone are expected to begin in late 1988 or early 1989.

Table 20.—U.S. exports of crushed stone in 1987, by destination

(Thousand short tons unless otherwise specified)

Destination	Quartzite	Limestone[1]	Other	Total
North America:				
Bahamas	--	--	182	182
Bermuda	--	893	--	893
Canada	815	3,105,138	67,772	3,173,725
Dominican Republic	--	--	413	413
Leeward and Windward Islands	--	--	1,719	1,719
Mexico	908	321	4,578	5,807
Other	148	55	24	227
Total	1,871	3,106,407	74,688	3,182,966
South America:				
Chile	--	751	21	772
Ecuador	--	--	113	113
Venezuela	59	63	1,164	1,286

See footnote at end of table.

Table 20.—U.S. exports of crushed stone in 1987, by destination —Continued

(Thousand short tons unless otherwise specified)

Destination	Quartzite	Limestone[1]	Other	Total
South America —Continued				
Other	--	13	85	98
Total	59	827	1,383	2,269
Europe:				
France	366	--	18,253	18,619
Germany, Federal Republic of	1,171	--	253	1,424
Netherlands	591	--	1	592
United Kingdom	469	55	1,514	2,038
Other	392	15	425	832
Total	2,989	70	20,446	23,505
Asia:				
Japan	3,064	64	2,223	5,351
Korea, Republic of	1,499	--	54	1,553
Taiwan	54	38	298	390
Other	84	--	273	357
Total	4,701	102	2,848	7,651
Oceania	231	1,434	2,655	4,320
Middle East and Africa	20	--	121	141
Grand total	9,871	3,108,840	102,141	3,220,852
Total value thousands	$6,337	$15,412	$4,313	$26,063

[1]Includes ground limestone.

Source: Bureau of the Census.

Table 21.—U.S. imports for consumption of crushed stone and calcium carbonate fines, by type

(Thousand short tons and thousand dollars)

Type	1986		1987	
	Quantity	Customs value	Quantity	Customs value
Crushed stone and chips:				
Limestone	1,454	6,466	1,330	4,775
Marble, breccia	3	190	3	333
Quartzite	6	335	67	1,234
Slate	5	76	1	66
Other	1,396	3,836	2,193	6,092
Total[1]	2,864	10,902	3,595	12,500
Calcium carbonate fines:[2]				
Natural aragonite[3]	345	948	257	856
Chalk, whiting	5	600	5	668
Total[1]	351	1,548	263	1,524
Grand total[1]	3,215	12,451	3,858	14,024

[1]Data may not add to totals shown because of independent rounding.
[2]Excludes precipitated calcium carbonate.
[3]Includes some chalk and other calcareous materials.

Source: Bureau of the Census.

WORLD REVIEW

Canada.—The 1986 production of stone in Canada was 107.6 million tons valued at $489 million; about 95% of this output was crushed stone. The Province of Ontario continued to be the largest producer of stone with 45 million tons valued at $226 million, followed by Quebec with 36 million tons valued at $172 million. Preliminary estimates for 1987 stone production indicate an increase of about 11% to 117 million tons valued at $547 million, with the Province of Ontario accounting for about 48% of the total output.

United Kingdom.—The 1986 production of crushed stone for construction purposes was 137 million tons, as reported by the British Aggregate Construction Materials Industries Association. About 79% of this output was limestone and dolomite. The Southwest was the largest producing region with 40.0 million tons, followed by East Midlands with 38.3 million tons, and Wales with 26.2 million tons. About 64% of the total crushed stone production was limestone and 28% was igneous rock. Preliminary production figures for 1987 indicated an increase of about 16% compared with those of 1986.

TECHNOLOGY

The introduction of sophisticated electronic equipment and computer systems used to improve the efficiency of mining and processing operations continued in the crushed stone industry. On the increase was the use of computer programs that formulate plant design, including selection of types and sizes of crushers and screens, complete with blueprints and flow diagrams. The use of computerized systems that provide a high degree of automation in the day-to-day operation of the plant, quality control, and computerized truck dispatch systems was also on the upswing in crushed stone quarries. Operations such as blasting, excavation, crushing and screening, and loading and hauling, have advanced into highly technical disciplines that use a wide range of automated equipment. In addition to investing in larger equipment, most producers can significantly improve the efficiency of their operations through automation.

In August, Genstar Stone Products Co. of Hunt Valley, MD, a subsidiary of Redland PLC of Groby, United Kingdom, dedicated a $10 million crushed stone plant at its Texas, MD, quarry. The plant is controlled by a sophisticated central computer system that allows the simultaneous production of as many as eight different products, ranging from riprap to manufactured sand. The entire plant is run by three operators, one in the central computer control room, one in the primary crusher control room, and one on the ground. Twelve closed-circuit TV monitors and two computer screens in the central control room provide a continuous visual display of the operating status of each of the main plant sections. They also provide the operator with information about production rate, cumulative production figures, plant running times and down times, as well as a daily log of events. Genstar's Texas quarry is considered to be one of the most technologically advanced automated quarries in the world.[2]

Construction of a pilot plant that will convert phosphogypsum, a waste product of the phosphate industry, into aggregates for road and building construction was started in August 1987. The pilot plant is being built in Convent, LA, by Freeport-McMoRan Inc. to test a new proprietary technology developed by Davy McKee Corp. and the Florida Institute of Phosphate Research. In the process, a mixture of phosphogypsum, petroleum coke, waste phosphoric clays, and pyrites is fed onto a circular grate and is processed in a series of sealed zones on the grate. The raw gas, high in SO_2, is collected and fed to a metallurgical-type sulfuric acid plant, and the sintered, clinker-like byproduct is discharged from the grate in dry form. The pilot plant is designed to convert 35 tons per day of phosphogypsum into 29 tons per day of sulfuric acid and 25 tons per day of aggregates. The pilot plant will cost $2 million to construct and another $1 million to operate for 6 months. The breakthrough in developing an economical process to convert phosphogypsum into useful products comes at a time when disposal of the byproduct waste had become an environmental issue in Louisiana.[3]

Hillhead '87 Review, the fourth biennial quarry exhibition featuring actual equipment working at the show site, was held at Tarmac's Hillhead Quarry, near Buxton, Derbyshire, United Kingdom. A wide range of loaders, crawlers, trucks, specialized railroad cars, mobile and stationary crushers, rock breakers, screening plants, and heavy construction equipment were put to work in the quarry during the show. In addition, more than 100 exhibitors displayed static equipment and accessories in a large pavilion at the center of the quarry. This international exhibition is becoming one of the most important quarrying and heavy construction equipment shows in the world.[4]

Results of various techniques that were tested over the years indicate that high calcium carbonate limestone is the product of choice for reducing the acidity of contaminated lakes and streams in Canada, Finland, Norway, Sweden, and the United States. Limestone is relatively inexpensive, noncaustic, dissolves easily, and is easy to handle. The limestone used for liming surface waters comes in three forms: dry powder that is used in lakes, preslurried material used in streams, and granular limestone used in rivers. Sweden was the first country to use limestone for treatment of acidic surface waters. Between 1977 and 1982, 1,500 lakes and streams were treated in Sweden as part of an experimental program. Later the program was extended to one-half of the country's surface waters. In the United States, 81 projects were initiated to assess the adverse effects of acid deposition on lakes and streams, while experimental liming projects were conducted in Maryland, Massachusetts, Minnesota, Tennessee, and West Virginia.[5]

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[1]Physical scientist, Branch of Industrial Minerals.

[2]Hill, B. Automation Repays Investment at U.S. Quarry. Quarry Mgmt. (Nottingham), May 1988, pp. 9-22.

[3]Rukavina, M. Phosphate Industry Hopes To Turn Phosphogypsum Waste Into Aggregates. Rock Prod., v. 90, No. 9, Sept. 1987, pp. 17, 78.

[4]Huhta, R. S. Highlights of Hillhead. Rock Prod., v. 90, No. 9, Sept. 1987, pp. 53-59.

Hillhead '87 Review. Quarry Mgmt., July 1987, pp. 9-20.

[5]Roehlkepartain, J. L. Limestone: Key to Renovating Acidic Lakes and Streams. Rock Prod., v. 90, No. 2, Feb. 1987, pp. 21-24.

Dimension Stone

By Harold A. Taylor, Jr.[1]

Production of dimension stone increased slightly to 1.18 million short tons valued at $190 million. More than one-half of the dimension stone produced was granite. Limestone, marble, sandstone, and slate were also produced.

Exports of dimension stone increased 40% in value to $20 million. The value of dimension stone imports for consumption increased 16% to $439 million, equivalent to 231% of the value of domestic production.

Domestic Data Coverage.—Domestic production data for dimension stone are developed by the Bureau of Mines from voluntary surveys of U.S. producers of rough and finished dimension stone. Of the 442 dimension stone operations surveyed, including those that were idle, 415, or 94%, responded, representing 97% of the total value sold or used by producers, as shown in table 1. Production data for nonrespondents were estimated using preliminary production reports, adjusted prior years production levels, and employment data.

Table 1.—Salient U.S. dimension stone statistics

(Thousand short tons and thousand dollars)

	1983	1984	1985	1986	1987
Sold or used by producers[1]	1,090	[e]1,141	1,104	[e]1,163	1,184
Value[1]	$147,843	[e]$161,912	$172,435	[e]173,269	$190,153
Exports (value)	19,126	$23,007	$13,835	$14,623	$20,470
Imports for consumption (value)[r]	$191,663	$222,596	$291,246	$379,724	$439,278

[e]Estimated. [r]Revised.
[1]Excludes Puerto Rico.

DOMESTIC PRODUCTION

In 1987, dimension stone was produced by 185 companies at 271 quarries in 35 States. Leading States, in order of tonnage, were Indiana, Georgia, and Vermont, producing together 39% of the Nation's total. Georgia's output was down 10% from the year before, and Indiana's down 4%. Of the total 1987 production, 52% was granite, 28% was limestone, 10% was sandstone, 3% was slate and 2% was marble. The remaining 5% was miscellaneous stone, including argillite, schist, soapstone, and traprock (basalt). Leading producing companies in terms of tonnage were Cold Spring Granite Co. principally in California, Minnesota, South Dakota, and Texas; Rock of Ages Corp. in New Hampshire and Vermont; and Coggins Granite Industries Inc. in Georgia.

Granite.—Dimension granite includes all coarse-grained igneous rocks. Production increased slightly to 629,000 tons and increased 10% in value to $107 million. Granite was produced by 64 companies at 103 quarries in 22 States. Georgia continued to be the leading State, producing 26% of the U.S. total, followed by Vermont and Massachusetts. These three States together produced more than 51% of the U.S. total. Cold Spring Granite, Rock of Ages Corp., and Coggins Granite Industries were the leading producers and accounted for 31% of U.S. production.

In December, the International Trade Administration, U.S. Department of Commerce, made a preliminary positive countervailing duty determination on granite products from Spain. A number of Spanish manufacturers had received subsidies such as short-term Government loans to exporters, and rebates of interest, grants, and preferential access to Government credit under a regional development program to encourage employment in the Province of Galicia. Furthermore, Basque-area authorities provided subsidies through cash grants for making investments in capital goods. This action was preliminarily determined not to be countervailable. Several other subsidy programs were not used and several are still being investigated. Except for two firms with different rates, the net subsidy was determined to be 2.51%. Barring difficulties, the final determination was to be made by March 3, 1988. If the determination is positive, the U.S. International Trade Commission (ITC) will determine whether these imports injure the U.S. industry.

Also in December, the International Trade Administration made a preliminary negative countervailing duty determination on granite products from Italy. This determination of no benefit is based on a net subsidy of zero for almost all responding firms and a de minimis subsidy of 0.36% for all other firms, including those firms that did not respond to requests for information. The countervailable programs identified were a reduction in social security payments for firms in the Mezzogiorno, a regional loan program, and local tax concessions. Although one firm was found to have a de minimis benefit from a local tax concession. Some programs did not confer a subsidy. Those included an accelerated depreciation and tax exemptions for reinvested capital gains. Others, such as a rebate of customs duties, export credit financing, and preferential rates on Italian railroads, were not used. A final negative determination would end the case, but a positive finding would move it to the ITC for an injury determination.

Limestone.—Dimension limestone includes bituminous, dolomitic, and siliceous limestones. It was produced by 38 companies at 45 quarries in 13 States. Indiana, the leading State, was followed by Wisconsin and Texas. Leading producers were Indiana Limestone Co. Inc., Elliott Stone Co. Inc., and Independent Limestone Co. The top three companies accounted for 28% of U.S. output.

Marble.—Dimension marble includes certain hard limestones, travertines, and any other calcareous stones that can be polished. Dimension marble was produced by 7 companies at 10 quarries in 6 States. Georgia, Vermont, and New Mexico, in order of tonnage, were the leading States, accounting for approximately 85% of U.S. output. Leading producers were Georgia Marble Co., Vermont Marble Co., and Rocky Mountain Stone Co. The top three companies accounted for 85% of U.S. output.

Sandstone.—Dimension sandstone includes calcareous- and siliceous-cemented sandstones or conglomerates. Quartzite, which is also included, may be described as siliceous-cemented sandstone. It was produced by 35 companies at 40 quarries in 17 States. Leading States were, in order of volume, Ohio, New York, and Pennsylvania. These three States accounted for almost two-thirds of U.S. output. Delaware Quarries Inc., Waller Bros. Stone Co., and Standard Slag Co. were the leading producers, accounting for 39% of U.S. production. In addition to the quantities shown in table 6, dimension quartzite totaled 19,451 tons worth $1,465,315.

Slate.—Dimension slate was produced by 19 companies at 29 quarries in 5 States. The two leading producing States, in order of volume, Pennsylvania and Vermont, accounted for 75% of U.S. output. The top three producers, A. Dally and Sons Inc., Hilltop Slate Co., and Le Sueur-Richmond Slate Co. Inc., accounted for an estimated 54% of U.S. output by value.

Miscellaneous Stone.—Miscellaneous dimension stone, including traprock, was produced by 10 companies from 10 quarries in 4 States, and totaled 17,961 tons valued at $1,232,624.

Table 2.—Dimension stone sold or used by producers in the United States, by State

State	1986[e] Quantity (short tons)	1986[e] Value (thousands)	1987 Quantity (short tons)	1987 Value (thousands)
Alabama	7,797	$968	W	W
Arkansas	5,145	305	10,541	$629
California	22,794	2,582	33,335	4,554
Colorado	3,600	255	3,000	133
Connecticut	24,425	1,653	18,140	1,646
Georgia	198,905	20,678	179,207	21,683
Illinois	1,750	107	W	W
Indiana	190,995	20,252	183,609	23,115
Kansas	W	W	11,423	445
Maine	W	W	7,512	5,924
Maryland	20,505	1,286	22,843	1,516
Massachusetts	78,728	14,928	76,579	12,747
Michigan	5,836	148	W	W
Minnesota	27,973	10,507	41,354	12,967
Missouri	W	W	3,212	454
New Hampshire	82,294	6,451	67,479	10,684
New Mexico	21,615	378	21,893	626
New York	15,637	3,002	38,553	5,822
North Carolina	41,418	6,633	32,669	5,128
Ohio	35,698	2,708	47,816	2,427
Oklahoma	18,503	913	8,311	861
Pennsylvania	72,352	8,100	60,118	10,177
South Carolina	7,550	533	2,319	312
South Dakota	54,934	18,399	50,718	18,209
Tennessee	5,598	1,553	3,360	573
Texas	49,457	15,407	75,426	10,030
Utah	W	W	2,004	95
Vermont	104,610	27,075	103,923	30,074
Virginia	9,542	3,128	9,077	2,720
Washington	1,223	69	297	42
Wisconsin	22,912	2,878	36,903	3,697
Other[1]	31,551	2,371	32,228	2,865
Total[2]	1,163,347	[2]173,269	1,183,849	190,153

[e]Estimated. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Includes data for Arizona, Idaho, Iowa, Montana, Oregon (1986), and data indicated by symbol W.
[2]Data may not add to totals shown because of independent rounding.

Table 3.—Dimension granite sold or used by producers in the United States, by State

State	1986[e] Quantity (short tons)	1986[e] Value (thousands)	1987[p] Quantity (short tons)	1987[p] Cubic feet (thousands)	1987[p] Value (thousands)
California	15,075	$1,257	16,525	202	$3,410
Connecticut	11,742	826	W	W	W
Georgia	166,504	9,504	166,108	1,652	11,054
Maine	W	W	7,512	91	5,924
Massachusetts	W	W	74,079	866	12,372
New Hampshire	81,647	6,423	67,479	818	10,684
North Carolina	28,813	4,675	28,526	346	4,786
Oklahoma	6,346	762	5,950	70	796
Pennsylvania	9,132	1,898	12,516	149	2,566
South Carolina	8,052	568	2,319	28	312
South Dakota	53,402	18,236	50,718	541	18,209
Texas	W	W	46,717	545	6,935
Vermont	97,267	14,661	83,660	1,012	15,400
Wisconsin	3,253	1,956	2,730	31	2,241
Other[1]	144,009	36,239	64,526	756	12,367
Total[2]	625,242	97,005	629,365	7,106	107,056

[e]Estimated. [p]Preliminary. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Includes data for Colorado, Maryland, Minnesota, Missouri, New York, South Carolina, Virginia, Washington, and data indicated by symbol W.
[2]Data may not add to totals shown because of independent rounding.

CONSUMPTION AND USES

Dimension stone was marketed over wide areas. Industry stockpiles were not monitored, and production during 1987 was assumed to equal consumption.

Consumption of domestic dimension stone decreased slightly to 1.18 million tons valued at $190.2 million. Dressed ashlars and partially squared pieces made up 24% of the total value of consumption, followed by dressed monumental, 14%; rough stone used for monumental purposes, 14%; curbing, 12%; rough blocks for building and construction, 10%; and other uses, 26%.

Of the total consumption of domestic granite, 24% by value was of rough monumental, 23% was of ashlars and partially squared pieces, and 22% was curbing.

Consumption of domestic limestone totaled 329,800 tons valued at $35.0 million, of which 33% by value was of ashlars and partially squared pieces and 28% was of rough blocks for building and construction.

Table 4.—Dimension limestone sold or used by producers in the United States in 1987, by State

State	Quantity (short tons)	Cubic feet (thousands)	Value (thousands)
Indiana	179,809	2,480	$22,890
Kansas	11,423	149	445
Texas	28,707	370	3,095
Wisconsin	31,584	373	1,297
Other[1]	78,318	989	7,240
Total[2]	329,843	4,361	34,968

[1]Includes Alabama, California, Iowa, Minnesota, Montana, New York, Ohio, and Virginia.
[2]Data may not add to totals shown because of independent rounding.

Table 5.—Dimension marble sold or used by producers in the United States in 1987, by State

State	Quantity (short tons)	Cubic feet (thousands)	Value (thousands)
Massachusetts	2,500	25	$375
Other[1]	21,871	258	20,038
Total	24,371	[2]282	20,413

[1]Includes Georgia, New Mexico, Tennessee, and Vermont.
[2]Data do not add to total shown because of independent rounding.

Table 6.—Dimension sandstone sold or used by producers in the United States in 1987, by State

State	Quantity (short tons)	Cubic feet (thousands)	Value (thousands)
Arkansas	10,541	132	$629
California	6	(1)	1
Indiana	3,800	49	225
New York	24,288	311	2,117
Ohio	28,597	391	2,336
Pennsylvania	24,003	308	922
Wisconsin	12	(1)	1
Other[2]	25,039	316	1,067
Total	116,286	[3]1,506	7,298

[1]Less than 1/2 unit.
[2]Includes Alabama, Arizona, Colorado, Georgia, Maryland, Michigan, Missouri, North Carolina, Oklahoma, and Tennessee.
[3]Data do not add to total shown because of independent rounding.

Table 7.—Dimension stone sold or used by producers in the United States in 1987, by use

Use	Quantity (short tons)	Cubic feet (thousands)	Value (thousands)
Rough stone:			
Rough blocks for building and construction	240,329	3,072	$19,919
Irregular-shaped stone[1]	148,888	1,853	5,193
Flagging	2,700	27	165
Monumental	225,492	2,450	26,214
Other[2]	20,221	242	1,837
Dressed stone:			
Ashlars and partially squared pieces	210,034	2,611	45,729
Slabs and blocks for building and construction	52,671	672	18,101
Monumental	49,965	553	27,137
Curbing	129,294	1,532	23,339
Flagging	34,510	436	2,392
Flagging (slate)	9,086	--	1,785
Roofing slate	14,892	--	7,626
Structural and sanitary	5,636	--	3,200
Flooring slate	7,077	--	2,963
Other[3]	33,054	377	4,556
Total[4]	1,183,849	13,826	190,153

[1]Includes rubble.
[2]Includes unspecified uses.
[3] Includes a minor amount of slate used for billiard tabletops, miscellaneous, and unspecified uses.
[4]Data may not add to totals shown because of independent rounding.

Table 8.—Dimension granite sold or used in the United States in 1987, by use

Use	Quantity (short tons)	Cubic feet (thousands)	Value (thousands)
Rough stone:			
Rough blocks for building and construction	85,052	961	$8,621
Irregular-shaped stone[1]	27,767	325	1,108
Flagging	2,700	27	165
Monumental	220,084	2,385	26,003
Other[2]	8,891	90	383
Dressed stone:			
Ashlars and partially squared pieces	106,132	1,231	25,275
Slabs and blocks for building and construction	11,308	134	1,405
Flagging	2,633	32	468
Monumental	37,813	425	20,311
Curbing	119,543	1,410	23,082
Other[3]	7,442	86	236
Total	629,365	7,106	[4]107,056

[1]Includes rubble.
[2]Includes rough stone used for flagging and unspecified uses.
[3]Includes flagging and unspecified uses.
[4]Data do not add to total shown because of independent rounding.

Table 9.—Dimension limestone sold or used by producers in the United States in 1987, by use

Use	Quantity (short tons)	Cubic feet (thousands)	Value (thousands)
Rough stone:			
Rough blocks for building and construction	137,837	1,890	$9,964
Irregular-shaped stone[1]	70,082	880	1,266
Other[2]	10,623	143	1,300
Dressed stone:			
Ashlars and partially squared pieces	57,030	750	11,562
Slabs and blocks for building and construction	34,068	450	9,616
Monumental	3,061	22	264
Curbing	1,295	16	68
Flagging	12,735	168	434
Other[3]	3,112	42	493
Total	329,843	4,361	[4]34,968

[1]Includes rubble.
[2]Includes monumental and unspecified uses.
[3]Includes unspecified uses.
[4]Data do not add to total shown because of independent rounding.

Table 10.—Dimension marble sold or used by producers in the United States in 1987, by use

Use	Quantity (short tons)	Cubic feet (thousands)	Value (thousands)
Rough stone:			
Rough blocks for building and construction	3,571	38	$734
Irregular shaped stone[1]	4,752	56	350
Dressed stone:			
Monumental[2]	16,048	188	19,330
Total	24,371	282	[3]20,413

[1]Includes rubble and a minor amount of stone used for monumental purposes.
[2]Includes dressed ashlars and partially squared pieces, slabs, blocks, a small amount used in flagging, and unspecified uses.
[3]Data do not add to total shown because of independent rounding.

Table 11.—Dimension sandstone sold or used by producers in the United States in 1987, by use

Use	Quantity (short tons)	Cubic feet (thousands)	Value (thousands)
Rough stone:			
Rough blocks for building and construction	11,705	156	$501
Irregular-shaped stone[1]	32,485	415	1,527
Other[2]	1,846	23	95
Dressed stone:			
Ashlars and partially squared pieces	36,869	486	1,637
Slabs and blocks for building and construction	621	8	27
Flagging	6,695	86	505
Other[3]	26,065	332	3,007
Total	116,286	1,506	[4]7,298

[1]Includes rubble.
[2]Includes monumental and unspecified uses.
[3]Includes curbing and unspecified uses.
[4]Data do not add to total shown because of independent rounding.

Table 12.—Dimension slate sold or used by producers in the United States in 1987, by use

Use	Quantity (short tons)	Value (thousands)
Flagging (slate)	9,086	1,785
Roofing (slate)	14,892	7,626
Structural and sanitary	5,636	3,200
Flooring (slate)	7,077	2,963
Other[1]	2,990	873
Total	39,681	[2]16,446

[1]Includes a minor amount of slate used for billiard tabletops, blackboards, and unspecified uses.
[2]Data do not add to total shown because of independent rounding.

PRICES

The average price for dimension stone rose to $161 per ton, up 8% from $149 in 1986.

FOREIGN TRADE

Exports.—Exports of dimension stone, about one-half of which was granite, increased 40% in value.

Imports.—Imports for consumption of dimension stone increased 16% in value to $439 million, mostly because of an increase in imports of polished slabs of marble, partly offset by a decrease in imports of dressed granite. Imports of polished marble slabs, mostly from Italy, increased 45% to

$179 million. Imports of dressed granite decreased 10%. On a value basis, marble accounted for 54% of imports, followed by granite, 33%; travertine, 6%; and slate, 4%.

Table 13.—U.S. exports of dimension stone, by type

(Thousand short tons and thousand dollars unless otherwise specified)

Type	1986 Quantity	1986 Value	1987 Quantity	1987 Value	Major destination in 1987 (percent[1])
Granite articles	NA	1,530	NA	2,608	Canada 44%
Granite, rough	53.3	6,046	54.2	7,800	Japan 58%.
Limestone, dressed, for building or monumental	25.9	113	2.4	257	United Kingdom 24%.
Limestone articles	4.8	178	18.0	1,000	Italy 80%.
Marble, breccia, and onyx, rough or squared	14.2	290	20.9	514	Canada 63%.
Marble, breccia, and onyx articles	NA	1,727	NA	2,694	Japan 24%.
Slate building articles	NA	118	NA	213	Canada 49%.
Slate building articles, other	NA	967	NA	905	Canada 25%.
Stone, rough, for building or monumental	15.6	1,735	19.0	2,280	Canada 48%.
Stone, other, including alabaster or jet	NA	1,919	NA	2,199	Canada 60%.
Total	NA	14,623	NA	20,470	

NA Not available.
[1]By value.

Source: Bureau of the Census.

Table 14.—U.S. imports for consumption of dimension granite, by country

(Thousand cubic feet and thousand dollars)

Country	Rough[1] Quantity	Rough[1] Value	Dressed[1] Quantity	Dressed[1] Value	Other n.s.p.f. undecorated[2] (value)
1985	3,020	6,097	7,928	103,680	11,064
1986:					
Brazil	167	166	253	3,603	459
Canada	1,078	3,757	199	12,365	2,486
India	14	287	268	1,290	16
Italy	665	218	7,596	104,467	4,052
Japan	r(3)	10	10	167	363
Portugal	--	--	341	1,773	5
Saudi Arabia	(3)	25	7	373	--
South Africa, Republic of	382	1,695	(3)	19	--
Spain	13	57	646	10,985	50
Other	377	492	320	7,143	1,211
Total[4]	2,699	6,707	9,635	142,185	8,642
1987:					
Brazil	575	152	315	3,294	199
Canada	5,329	5,125	249	12,621	507
India	9	165	120	2,446	26
Italy	37	587	4,626	89,655	4,606
Japan	--	--	15	188	64
Portugal	593	1,224	20	977	54
Saudi Arabia	1	11	19	303	--
South Africa, Republic of	80	2,435	1	44	--
Spain	1	3	355	10,527	76
Other	708	938	342	7,540	546
Total[4]	7,333	10,641	6,063	127,594	6,078

[1]Excludes unmanufactured, nonmonumental granite.
[2]Quantity not reported. Excludes granite n.s.p.f. decorated.
[3]Less than 1/2 unit.
[4]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

Table 15.—U.S. imports for consumption of major categories of dimension marble, travertine, and other calcareous stones, by country

Country	Marble, breccia, or onyx, polished slabs		Marble, breccia, or onyx, other n.s.p.f.[1] [2]	Travertine dressed[3]	
	Quantity (thousand square feet)	Value (thousands)	Value (thousands)	Quantity (short tons)	Value (thousands)
1985	56,137	$88,579	$39,521	180,311	$18,654
1986:					
France	976	2,975	671	23	20
Germany, Federal Republic of	362	493	832	13	9
Greece	2,883	6,124	535	15	12
Italy	51,184	83,785	29,810	172,430	15,066
Mexico	1,176	2,032	2,719	425	231
Pakistan	71	103	523	--	--
Philippines	198	342	102	--	--
Portugal	3,049	5,936	961	43	14
Spain	10,832	15,620	2,824	739	69
Taiwan	1,665	2,749	6,367	--	--
Other	1,672	3,479	2,383	124	75
Total	74,069	123,637	47,728	173,812	15,496
1987:					
France	1,307	6,657	464	59	23
Germany, Federal Republic of	320	597	866	--	--
Greece	3,569	9,155	1,042	55	66
Italy	53,338	120,692	29,686	104,508	14,285
Mexico	1,894	3,201	2,567	776	364
Pakistan	26	8	528	--	--
Philippines	365	763	315	--	--
Portugal	3,240	7,513	1,278	--	--
Spain	15,925	20,161	2,868	1,437	127
Taiwan	4,382	4,813	9,407	--	--
Other	2,279	5,469	4,088	165	261
Total[4]	86,645	179,030	53,109	107,000	15,128

[1]Excludes special kinds of rough marble, breccia, or onyx.
[2]Quantity not reported.
[3]Suitable for use as monumental, paving, or building stone. Excludes travertine articles.
[4]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

Table 16.—U.S. imports for consumption of other dimension stone, by type

Type	1986		1987		Major source in 1987 (percent[1])
	Quantity	Value (thousands)	Quantity	Value (thousands)	
Granite, n.s.p.f., decorated	--	$933	--	$1,344	Italy 57%.
Limestone, dressed, hewn short tons	34,553	2,288	25,545	6,184	France 63%.
Marble and breccia, rough cubic feet	87,002	515	86,538	840	Italy 61%.
Marble, breccia, onyx, slab and tiles, unpolished square feet	914,748	2,593	1,441,111	4,428	Italy 50%.
Slate, roofing do	2,152,986	927	4,053,425	1,863	Spain 51%.
Slate, other, n.s.p.f	--	8,876	--	13,404	Italy 63%.
Travertine articles, undecorated	--	6,222	--	8,250	Italy 94%.
Travertine articles, decorated	--	1,532	--	1,573	Italy 92%.
Stone, unmanufactured short tons	30,940	966	5,765	658	Mexico 50%.
Stone, dressed, building do	2,483	825	24,589	2,094	Mexico 35%.
Stone, other n.s.p.f., undecorated	--	2,034	--	2,574	Italy 16%.
Stone, other n.s.p.f., decorated	--	3,723	--	4,486	Mexico 21%.

[1]By value.

Source: Bureau of the Census.

WORLD REVIEW

Dimension stone is quarried in most countries of the world. As usual, Italy produced about one-half of the world's total. Other significant producers were Brazil, Finland, India, Norway, Portugal, Spain, Sweden, Turkey, and the United States.

Bulgaria.—Bulgaria, a sizable producer of dimension stone, usually produces about 240,000 tons of rough block, of which marble comprises 120,000 tons. Significant amounts of other kinds of stone are also produced. Exports to destinations outside Eastern Europe are quite small, usually averaging 1,000 to 2,000 tons per year, and almost all marble.

The first description of the dimension stone industry in Bulgaria in a long time appeared this year. The deposits are scattered fairly evenly throughout the country except for the north. Domestic use of stone has increased dramatically in the last few decades. The quarries used a mix of modern equipment, such as chain saws, and older equipment, such as helicoidal wire saws. A number of finishing plants were situated around the country, most of which used Italian, West German, and Bulgarian equipment. Most marble slab produced is 2 centimeters thick and much of the marble tile produced is 1 centimeter thick. The marble produced is almost all gray or white with various colored streaks or marks. Travertine and breccia also are produced.[2]

Germany, Federal Republic of.—According to the most recent estimates of the Government of the Federal Republic of Germany, dimension stone production is usually 1.1 to 1.3 million tons per year, with 70% to 75% of the total coming from Bavaria. This number includes many firms with fewer than 10 employees, companies usually that are missed by the statistical surveys. Bavarian production is mostly of granite, marble, and Solenhofen limestone. Production of rough blocks in 1982 was estimated at a minimum of 104,600 tons of marble and 20,600 tons of granite.

The industry uses some innovative extraction techniques. For Jura marble, large pieces of stone are divided by drilling a series of holes to which an automatic wedger is applied. Resembling a jackhammer in appearance, the hydraulic device drives a wedge down between the feather parts of the machine, forcing the stone apart. Slate is cut from the face with a self-propelled, circular, diamond saw machine along a rectangular grid. Blows from a self-propelled hydraulic hammer split off the material from the face.

The market for roofing slate has increased greatly in the last decade, mostly at the expense of asbestos tiles once asbestos-related health problems became known. Domestic production of roofing slate grew from around 16,500 tons in 1975 to 55,000 tons in 1986.

The major West German marble is the light yellow Jura marble, of which about $90 million is produced each year. The marble is quarried mostly in Bavaria in conjunction with the Solenhofen limestone. It is usually used in polished form as window and door sills and flooring. Exports constitute about 25% of production, almost all destined to other Western European nations.

Japan.—Production of dimension granite in 1987 was estimated to be 500,000 tons from about 1,000 quarries. Production of dimension marble was about 300 tons in 1987. The granite, almost all standard gray, was quarried in Aichi, Ehime, Fukushima, Ibaragi, and Yamaguchi Prefectures.

The principal use of dimension granite is for monuments. Typical monumental products include grave plot stones, stone lanterns, torji gates, and cemetery fences.

Customers are conservative and buy gray granite monuments exclusively in most of Japan although some black granite is used north of Tokyo. Based on industry sources and a small sample of plants, the more a plant is involved in producing monuments the more likely it is to be labor intensive, have a small staff and use older types of equipment. No plants are known to use robots.

The next largest uses of dimension granite stone are for buildings, curbing, embankments, and paving. Almost all tile is imported. Customers prefer gray, pink, black, and red granite for building purposes, plus minor amounts of other colors. The granite is sold usually as 2.5-centimeter slabs, sometimes as 3-centimeter slabs. A plant producing primarily architectural products is likely to be less labor intensive, larger, and have more modern equipment such as automatic polishers.

Other stones are used in much smaller volumes. Marble is almost exclusively used in buildings; virtually none goes to monuments. Customers prefer colored, multicolored, and veined marbles over white. Growth in marble use has tended to be offset by the use of increasingly thinner marble. Relatively small amounts of slate are used, including roofing slate, but the use of it seems to be increasing rapidly. However, roofing slate encounters severe competition from traditional curved gray tile, since tile lasts nearly as long, costs the same, and is more culturally acceptable to the Japanese.

Japanese culture strongly influences the purchases of dimension stone. Dimension stone used outdoors must be in harmony with the environment and become part of an overall design; this means that requests for color and pattern are very specific. Stone required for the interior or exterior of buildings must be of a very uniform color and pattern, as close to matching as possible, without any surficial cracks or scars. This requirement sometimes extends beyond the limits imposed by the variability of a natural product. There may be other stringent requirements, such as low water absorption or tight physical and chemical standards for stone in outdoor use. This is particularly true for granite monuments.

Korea, Republic of.—Dong-in Stone Industrial Co. Ltd. scheduled the opening of a huge new granite processing and finishing complex at Chongju City. The complex will cost about $20 million and employ 600 people, including those working in its associated diamond tool and machinery plant. It ultimately will include 38 gang saws, each producing 20,000 square feet of granite slab per month.

U.S.S.R.—The Soviet Union is a sizable producer of dimension stone but not as large as might be expected from its immense land area. Production totaled about 350,000 tons, mostly of granite but with significant amounts of other kinds produced. Exports, composed of mostly granite, to destinations other than its allied countries are quite small, usually averaging 5,000 to 10,000 tons per year.

A description of the Soviet dimension stone industry, with an emphasis on its products, appeared in a Western stone publication this year, the first such description in many years. The more important or better known stones described included the reddish-brown granite with coarse ovoid feldspar grains from Kuzrechenskoye, the black gabbro-norite (black granite) with blue or rose plagioclase from Chernaya Salma, the deep crimson quartzite from Petrozavodsk that was used to make Napoleon's tomb in Paris, and the black coarse-grained labradorite from Golovino, Zhitomir region. Many techniques employed in other countries are not yet in use in the U.S.S.R. For example, the installation of diamond wire saws in marble quarries is just beginning, as is the automation of saws and the introduction of diamond tools in the finishing plants.[3]

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[1]Physical scientist, Branch of Industrial Minerals.
[2]Stoev, S. The Decorative Stone Industry in Bulgaria. Stone Industries, v. 22, No. 5, June 1987, pp. 27-30.
[3]Oskolkov, V. A. Growth of U.S.S.R. Stone Industry. Stone Ind., v. 22, No. 1, Jan.-Feb. 1987, pp. 22-24.

Sulfur

By David E. Morse[1]

The United States retained its position as the world's foremost producer and consumer of sulfur. Production and shipments from U.S. Frasch mines, the Nation's major source of discretionary sulfur, decreased because low international prices reduced export opportunities. Although the industry operated well below capacity, shipments by Frasch producers to their major consumer, the domestic phosphate fertilizer industry, increased because exports of fertilizers by U.S. producers were substantially higher than those in 1986.

Production of recovered elemental sulfur, a nondiscretionary byproduct of petroleum refining and natural gas processing, continued to increase, setting an alltime record high; domestic output from this source exceeded the quantity of elemental sulfur produced by any other nation in the world. Shipments of recovered elemental sulfur to domestic consumers were greater than Frasch shipments. For the first time, recovered sulfur exports, primarily from California where sulfur supplies exceed local demands, were higher than Frasch sulfur exports.

Table 1.—Salient sulfur statistics

(Thousand metric tons, sulfur content, and thousand dollars unless otherwise specified)

	1983	1984	1985	1986	1987
United States:					
Production:					
Frasch	3,202	4,193	5,011	4,043	3,202
Recovered[1]	4,955	5,214	5,313	5,816	6,161
Other forms	1,133	1,245	1,285	1,228	1,176
Total	9,290	10,652	11,609	11,087	10,539
Shipments:					
Frasch	4,111	5,001	4,678	4,108	3,610
Recovered[1]	5,041	5,210	5,266	5,798	6,180
Other forms	1,133	1,245	1,285	1,228	1,176
Total	10,285	11,456	11,229	11,134	10,966
Exports, elemental[2]	992	1,334	1,365	1,895	1,242
Imports, elemental	1,695	2,557	2,104	1,347	1,599
Consumption, all forms	10,988	12,679	11,968	10,586	11,323
Stocks, Dec. 31: Producer, Frasch and recovered	3,223	2,419	2,799	2,748	2,316
Value:					
Shipments, f.o.b. mine or plant:					
Frasch	$414,210	$546,106	$573,570	$508,512	$386,834
Recovered[1]	384,214	416,878	485,084	533,752	492,136
Other forms	116,255	121,692	123,937	105,639	90,707
Total	914,679	1,084,676	1,182,591	1,147,903	969,677
Exports, elemental[3]	$109,298	$156,067	$189,248	$251,664	$139,431
Imports, elemental[4]	$129,110	$200,189	$199,240	$142,220	$152,096
Price, elemental, dollars per metric ton, f.o.b. mine or plant	$87.24	$94.31	$106.46	$105.22	$89.78
World: Production, all forms (including pyrites)	[r]49,770	[r]51,859	54,331	[p]54,074	[e]54,221

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Includes Puerto Rico and the Virgin Islands.
[2]Includes exports from the Virgin Islands to foreign countries.
[3]Includes value of exports from the Virgin Islands to foreign countries.
[4]Declared customs valuation.

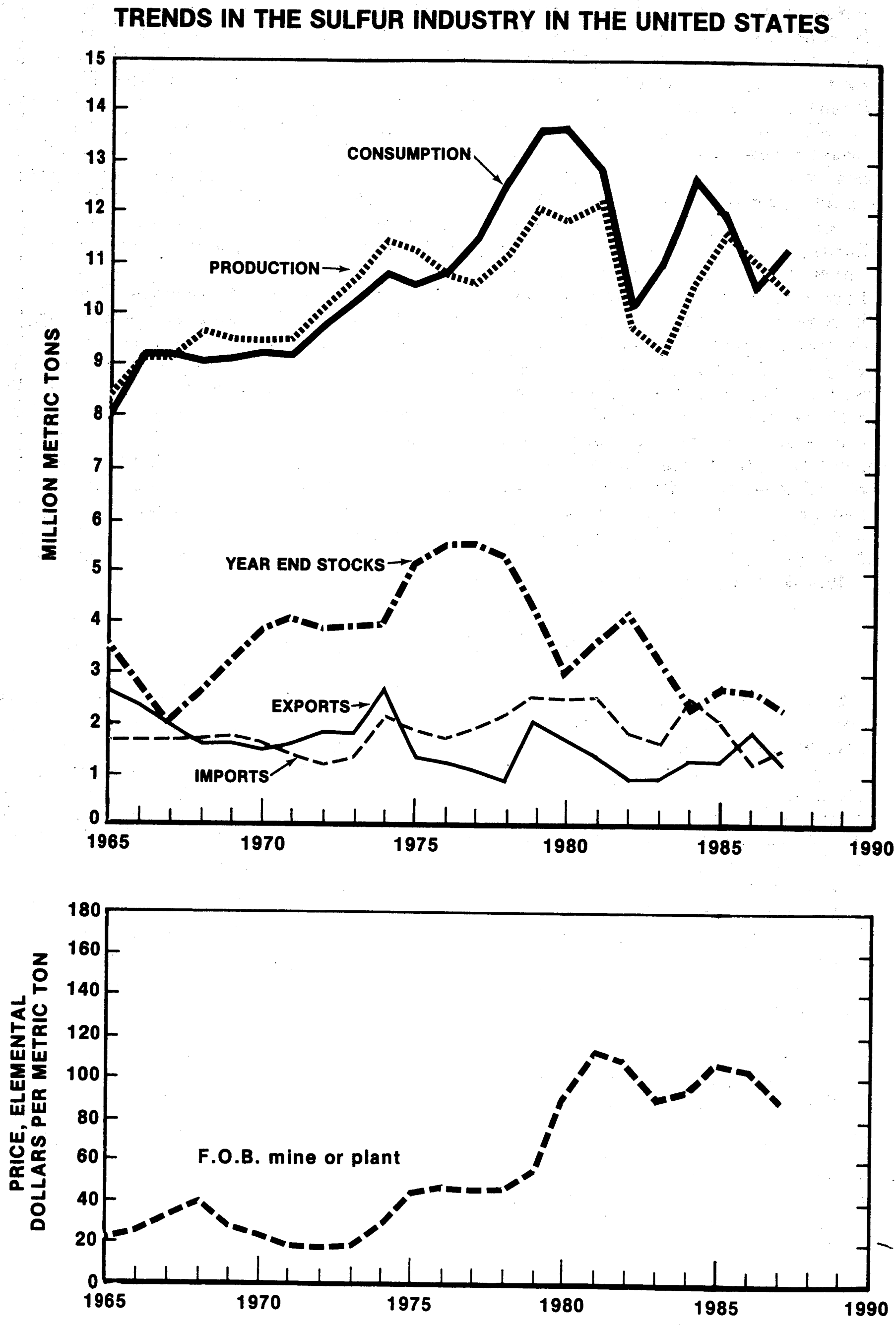

Figure 1.—Trends in the sulfur industry in the United States.

Byproduct sulfuric acid from the Nation's nonferrous smelters and roasters, essentially mandated by laws concerning sulfur dioxide (SO_2) emissions, supplied a significant quantity of sulfuric acid to the domestic merchant acid market. Marketing sulfuric acid continued to be a problem for most producers because smelters were near Western copper mines and not close to large sulfuric acid markets.

Total world production of sulfur in all forms increased over that of 1986; however, mined sulfur and pyrites output were lower. Recovered elemental production increased in Asia, Eastern Europe, and North America, and was slightly less in Western Europe, where declining production from gas plants was nearly offset by increased output from petroleum refineries. Nearly two-thirds of the world's elemental sulfur production came from recovered sources. The quantity of sulfur supplied from these sources was dependent on the world demand for fuels and petroleum products, not on the demand for sulfur.

World consumption increased, especially in the fertilizer sector. Consumption for other industrial uses continued to be pressured by environmental constraints placed on either the products produced or by effluents from the processes. World trade also increased, but the trade patterns were altered significantly because of restricted imports by the U.S.S.R. and by lower international prices. World stocks of elemental sulfur declined by an estimated 700,000 metric tons and contributed to an oversupply condition in the international marketplace.

Domestic Data Coverage.—Domestic production data for sulfur are developed by the Bureau of Mines from four separate, voluntary surveys of U.S. operations. Typical of these surveys is the "Elemental Sulfur" survey. Of the 184 operations to which a survey request was sent, 182 responded, representing 99.91% of the total production shown in tables 1 and 2. The production of the two nonrespondents was estimated using prior production histories adjusted to reflect trends in output of their primary products.

DOMESTIC PRODUCTION

Sulfur is one of the few elements that occur in the native, or elemental, state. It also occurs combined with iron and base metals as sulfide minerals, and with the alkali metals and alkali earths as sulfate minerals. In coal and petroleum, sulfur is found in a variety of complex organosulfur compounds, and in natural gas as hydrogen sulfide (H_2O) gas. Commercial production of sulfur in the United States is accomplished by a variety of methods dictated by the source of sulfur.

Frasch.—Native sulfur associated with the caprocks of salt domes and in sedimentary deposits is mined by the Frasch hot-water method, in which the native sulfur is melted underground and brought to the surface with an airlift. In January 1987, the United States had four Frasch mines operating in Texas and Louisiana. Mines in Louisiana were Freeport Minerals Co. at Garden Island Bay on the Mississippi River Delta and Grand Isle, 7 miles offshore in the Gulf of Mexico. Mines in Texas were Pennzoil Sulphur Co. at Culberson and Texasgulf Inc. at Boling Dome in Wharton County. Texasgulf's Comanche Creek facility in western Texas was idle for the entire year. Freeport continued to rehabilitate its Caminada Pass, LA, property, which had last produced sulfur in 1968. At yearend, the Frasch mining industry was operating at about 65% of capacity.

Frasch sulfur output decreased 841,000 tons from the quantity produced in 1986. Total shipments to domestic and overseas consumers declined by 500,000 tons. Frasch sulfur accounted for 30% of domestic production in 1987, compared with 36% in 1986. Approximately 87% of Frasch sulfur shipments was for domestic consumption, and 13% for export. The total value of Frasch sulfur shipments decreased nearly $122 million.

Recovered.—Production of recovered elemental sulfur, a nondiscretionary byproduct from petroleum refining, natural gas processing, and coking plants, accounted for 59% of the total domestic output of sulfur in all forms, compared with 52% in 1986. Both production and shipments reached alltime-high levels of over 6.16 million tons owing to record-high production from the Nation's petroleum refineries and gas processing plants. Recovered elemental sulfur was produced by 56 companies at 157 plants in 26 States, 1 plant in Puerto Rico, and 1 plant in the Virgin Islands. Most of these plants were of relatively small size, with only 13 reporting an annual production exceeding

100,000 tons. By source, 59% was produced at 84 refineries or satellite plants treating refinery gases and 3 coking plants, and 41% was produced by 28 companies at 70 natural gas treatment plants. The five largest recovered sulfur-producing companies in 1987 were Chevron U.S.A. Inc., Exxon Co. U.S.A., Shell Oil Co., Standard Oil Co. (Indiana), and Texaco Inc. These companies' 60 plants accounted for 63% of recovered elemental sulfur output during the year.

A full year of production from Exxon's La Barge gas plant was responsible for pushing Wyoming sulfur output over 1 million tons for the first time. Texas continued to lead all other States in recovered elemental production and accounted for one-fourth of all recovered sulfur shipments.

Table 2.—Production of sulfur and sulfur-containing raw materials in the United States

(Thousand metric tons)

	1986		1987	
	Gross weight	Sulfur content	Gross weight	Sulfur content
Frasch sulfur	4,043	4,043	3,202	3,202
Recovered sulfur[1]	5,816	5,816	6,161	6,161
Byproduct sulfuric acid (100% basis) produced at copper, lead, molybdenum, and zinc plants	2,811	919	3,069	1,003
Other forms[2]	767	309	445	173
Total	XX	11,087	XX	10,539

XX Not applicable.
[1]Includes Puerto Rico and the Virgin Islands.
[2]Includes hydrogen sulfide, liquid sulfur dioxide, and pyrites.

Table 3.—Sulfur produced and shipped from Frasch mines in the United States

(Thousand metric tons and thousand dollars)

Year	Production			Shipments	
	Texas	Louisiana	Total[1]	Quantity	Value[2]
1983	1,915	1,286	3,202	4,111	414,210
1984	2,257	1,937	4,193	5,001	546,106
1985	2,940	2,071	5,011	4,678	573,570
1986	2,463	1,579	4,043	4,108	508,512
1987	1,833	1,369	3,202	3,610	386,834

[1]Data may not add to totals shown because of independent rounding.
[2]F.o.b. mine.

Table 4.—Recovered sulfur produced and shipped in the United States[1]

(Thousand metric tons and thousand dollars)

Year	Production			Shipments	
	Natural gas plants	Petroleum refineries[2]	Total	Quantity	Value[3]
1983	2,371	2,584	4,955	5,041	384,214
1984	2,407	2,807	5,214	5,210	416,878
1985	2,373	2,940	5,313	5,266	485,084
1986	2,246	3,570	5,816	5,798	533,752
1987	2,536	3,624	[4]6,161	6,180	492,136

[1]Includes Puerto Rico and the Virgin Islands.
[2]Includes a small quantity from coking operations.
[3]F.o.b. plant.
[4]Data do not add to total shown because of independent rounding.

Table 5.—Recovered sulfur produced and shipped in the United States, by State

(Thousand metric tons and thousand dollars)

State	1986			1987		
	Production	Shipments		Production	Shipments	
		Quantity	Value		Quantity	Value
Alabama	338	341	36,452	319	319	30,629
California	634	630	50,964	656	670	39,764
Florida	80	80	W	72	72	W
Illinois	372	368	36,581	255	256	26,034
Louisiana	524	527	57,418	538	536	51,074
Michigan and Minnesota	158	158	13,938	152	152	12,648
Mississippi	702	707	79,287	778	780	70,379
New Mexico	46	46	3,621	46	46	2,870
North Dakota	105	104	7,043	126	127	8,000
Ohio	46	46	5,188	42	43	3,915
Pennsylvania	52	53	4,540	59	58	4,417
Texas	1,517	1,516	141,223	1,516	1,532	134,232
Wisconsin	2	2	117	W	W	W
Wyoming	684	676	33,517	1,010	1,015	46,629
Other[1]	558	545	63,863	591	576	61,548
Total[2]	5,816	5,798	533,752	6,161	6,180	492,136

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Includes Arkansas, Colorado, Delaware, Indiana, Kansas, Kentucky, Montana, New Jersey, Utah, Virginia, Washington, Puerto Rico, the Virgin Islands, and data indicated by symbol W.
[2]Data may not add to totals shown because of independent rounding.

Table 6.—Recovered sulfur produced and shipped in the United States, by Petroleum Administration for Defense (PAD) district

(Thousand metric tons)

District and source	1986		1987	
	Production	Shipments	Production	Shipments
PAD 1:				
Petroleum and coke	254	258	253	246
Natural gas	79	79	72	72
Total[1]	334	338	325	319
PAD 2:				
Petroleum and coke	715	712	602	603
Natural gas	107	106	128	128
Total	822	818	730	731
PAD 3:[2]				
Petroleum	1,830	1,818	1,961	1,966
Natural gas	1,385	1,390	1,336	1,339
Total[1]	3,215	3,208	3,298	3,306
PAD 4 and 5:				
Petroleum	769	766	806	818
Natural gas	673	666	999	1,004
Total[1]	1,443	1,432	1,806	1,823
Grand total[1]	5,816	5,798	6,161	6,180

[1]Data may not add to totals shown because of independent rounding.
[2]Includes Puerto Rico and the Virgin Islands.

Byproduct Sulfuric Acid.—Sulfur contained in byproduct sulfuric acid produced at copper, lead, molybdenum, and zinc roasters and smelters amounted to 10% of the total domestic production of sulfur in all forms. Eight acid plants operated in conjunction with copper smelters and eight were accessories to lead, molybdenum, and zinc smelting and roasting operations. The five largest acid plants accounted for 70% of the output, and production in five States was 87% of the total. The five largest producers of byproduct sulfuric acid were ASARCO Incorporated, Inspiration Consolidated Copper Co., Kennecott, Magma Copper Co., and Phelps Dodge Corp. Their eight plants produced 84% of the 1987 total.

Table 7.—Byproduct sulfuric acid[1] produced in the United States

(Thousand metric tons, sulfur content, and thousand dollars)

Year	Copper plants[2]	Zinc plants[3]	Lead and molybdenum plants[3]	Total	Value
1983	601	126	104	831	54,995
1984	736	145	81	962	59,098
1985	729	141	87	957	56,299
1986	755	124	40	919	54,164
1987	831	134	38	1,003	61,996

[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.—Contained sulfur in these products represented 2% of the total domestic production of sulfur in all forms. The total sulfur contained in these products was less than that in 1986. The leading producers were Chevron, Magma, Phelps Dodge, and Tennessee Chemical Co. Tennessee Chemical terminated pyrite-mining operations, began burning purchased sulfur for sulfuric acid production at its Copper Hill, TN, facility, and restarted its Augusta, GA, sulfur-based acid plant.

Table 8.—Pyrites, hydrogen sulfide, and sulfur dioxide sold or used in the United States

(Thousand metric tons, sulfur content, and thousand dollars)

Year	Pyrites	Hydrogen sulfide	Sulfur dioxide	Total	Value
1983	W	W	50	302	61,260
1984	W	W	45	283	62,594
1985	W	W	43	328	67,638
1986	W	W	W	309	51,475
1987	W	W	W	173	28,711

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

TRENDS IN THE PRODUCTION OF SULFUR IN THE UNITED STATES

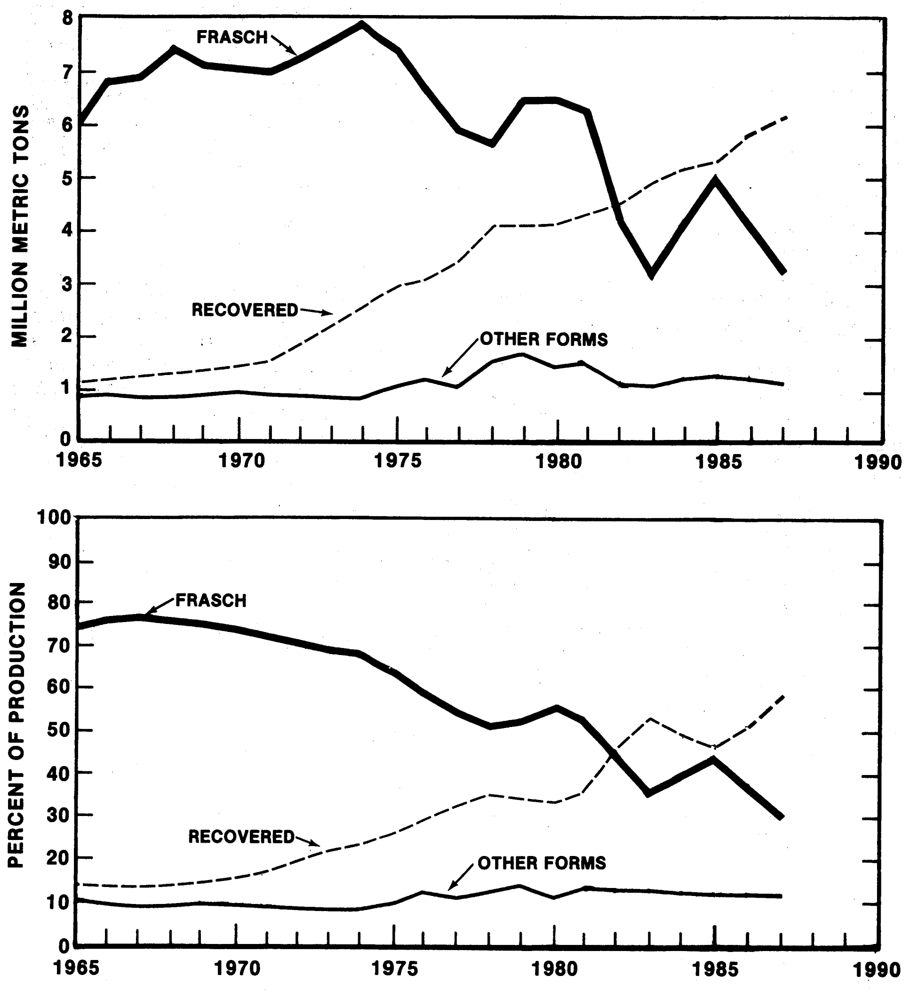

Figure 2.—Trends in the production of sulfur in the United States.

CONSUMPTION AND USES

Domestic consumption of sulfur in all forms increased 7% over that of 1986. In 1987, 86% of the sulfur was obtained from domestic sources, compared with 87% in 1986. The sources of supply were domestic recovered elemental sulfur, 48%; domestic Frasch sulfur, 28%; and combined domestic byproduct sulfuric acid, pyrites, H_2O, and SO_2, 10%. The remaining 14% was supplied by imports of Frasch and recovered elemental sulfur.

The Bureau of Mines collected end-use data on sulfur and sulfuric acid according to the Standard Industrial Classification of industrial activities. Shipments by end use of elemental sulfur were reported by 60 companies, and shipments of sulfuric acid were reported by 55 companies. Shipments of elemental sulfur and sulfuric acid were reported by 12 companies.

The largest sulfur end use, sulfuric acid, represented 87% of shipments for domestic consumption. Some identified end uses were tabulated in the "Unidentified" category because these data were proprietary. Data collected from companies that did not identify shipment by end use were also tabulated as "Unidentified." Although there are no supporting data, it could be reasonably assumed that a significant portion of the sulfur in the "unidentified" category could have been shipped to sulfuric acid producers or exported. The difference between exports reported in the canvass and exports of 1.2 million tons reported by the Bureau of the Census may have been caused by differences in accounting between company records and compilations of Census, or by sales to other parties that exported sulfur and were not included in the Bureau of Mines canvass.

In 1987, sulfuric acid retained its position, both domestically and worldwide, as the most universally used mineral acid and the largest volume inorganic chemical in terms of the quantity produced and consumed annually. U.S. shipments of 100% sulfuric acid increased by over 1.7 million tons in 1987 because demand for the production of phosphatic fertilizers, the largest single end use of sulfuric acid, increased 8%. Shipments of sulfuric acid for petroleum refining and other petroleum and coal products, the second largest end use, decreased 7% from those of 1986. Demand for sulfuric acid in copper ore leaching was over 1 million tons because high-purity copper from solvent extraction-electrowinning (SX-EW) operations could be produced at a significantly lower cost than that from conventional smelting methods.

According to the 1987 canvass reports, company receipt of spent or contaminated sulfuric acid for reclaiming totaled 2.7 million tons. The largest source of this spent acid continued to be the petroleum refining industry, which accounted for 60% of the total returned. The petroleum refining industry was a net user of 820,000 tons of sulfuric acid. About 875,000 tons of spent acid was reclaimed from plastic and synthetic materials operations. The remaining reclaimed acid was returned from manufacturers of soaps and detergents, steel, industrial organic chemicals, other chemical products, storage batteries, drugs, explosives, agricultural chemicals, and some unidentified sources. The largest use of sulfur in all forms, for agricultural purposes, increased from 7.7 million tons in 1986 to 8.2 million tons.

Table 9.—Consumption of sulfur[1] in the United States

(Thousand metric tons)

	1983	1984	1985	1986	1987
Frasch:					
Shipments	4,111	5,001	4,678	4,108	3,610
Imports	604	722	724	726	793
Exports	601	911	986	1,250	465
Total	4,114	4,812	4,416	3,584	3,938
Recovered:					
Shipments[2]	5,041	5,210	5,266	5,798	6,180
Imports	1,091	1,835	1,380	621	806
Exports	391	423	379	645	777
Total	5,741	6,622	6,267	5,774	6,209
Pyrites, shipments	W	W	W	W	W
Byproduct sulfuric acid, shipments	831	962	957	919	1,003
Other forms, shipments[3]	302	283	328	309	173
Total, all forms	10,988	12,679	11,968	10,586	11,323

W Withheld to avoid disclosing company proprietary data; included with "Other forms, shipments."
[1]Crude sulfur or sulfur content.
[2]Includes Puerto Rico and the Virgin Islands.
[3]Includes consumption of hydrogen sulfide, liquid sulfur dioxide, and data indicated by symbol W.

Table 10.—Elemental sulfur sold or used in the United States, by end use

(Thousand metric tons)

SIC	End use	1986	1987
20	Food and kindred products	W	W
26, 261	Pulp and paper products	21	32
282, 2822	Synthetic rubber, and other plastic products	W	W
287	Agricultural chemicals	551	541
28,286	Other chemical products and industrial organic chemicals	19	55
284	Soaps and detergents	52	26
29, 291	Petroleum refining and petroleum and coal products	92	180
281	Other industrial inorganic chemicals	76	80
30	Rubber and miscellaneous plastic products	W	W
	Sulfuric acid:		
	Domestic sulfur	7,017	7,420
	Imported sulfur	1,079	1,493
	Total	8,096	8,913
	Unidentified	620	403
	Total domestic uses	9,527	10,230
	Exports	1,511	1,127
	Grand total	11,038	11,357

W Withheld to avoid disclosing company proprietary data; included with "Unidentified."

Table 11.—Sulfuric acid sold or used in the United States, by end use

(Thousand metric tons of 100% H_2SO_4)

SIC	End use	1986	1987
102	Copper ores	830	1,046
1094	Uranium and vanadium ores	98	85
10	Other ores	81	52
261	Pulpmills	701	740
26	Other paper products	48	62
285, 2816	Inorganic pigments and paints and allied products	363	360
281	Other inorganic chemicals	915	899
282, 2822	Synthetic rubber and other plastic materials and synthetics	766	773
2823	Cellulosic fibers, including rayon	138	140
283	Drugs	50	90
284	Soaps and detergents	232	246
286	Industrial organic chemicals	973	1,178
2873	Nitrogenous fertilizers	251	201
2874	Phosphatic fertilizers	21,330	23,116
2879	Pesticides	72	(1)
287	Other agricultural chemicals	80	108
2892	Explosives	93	150
2899	Water-treating compounds	371	301
28	Other chemical products	136	140
29, 291	Petroleum refining and other petroleum and coal products	2,617	2,427
30	Rubber and miscellaneous plastic products	9	12
331	Steel pickling	211	206
333	Nonferrous metals	103	93
33	Other primary metals	41	24
3691	Storage batteries (acid)	151	124
	Unidentified	1,480	1,316
	Total domestic	32,140	33,889
	Exports	36	44
	Grand total	32,176	33,933

[1]Included with "Other agricultural chemicals."

Table 12.—Sulfur and sulfuric acid sold or used in the United States, by end use

(Thousand metric tons, sulfur content)

SIC	End use	Elemental sulfur[1]		Sulfuric acid (sulfur equivalent)		Total	
		1986	1987	1986	1987	1986	1987
102	Copper ores	--	--	271	342	271	342
1094	Uranium and vanadium ores	--	--	32	28	32	28
10	Other ores	--	--	26	17	26	17
20	Food and kindred products	W	W	--	--	W	W
26, 261	Pulpmills and paper products	21	32	245	262	266	294
28, 285, 286, 2816	Inorganic pigments, paints and allied products, industrial organic chemicals, other chemical products	[2]19	[2]55	119	118	138	173
281	Other inorganic chemicals	76	80	299	294	375	374
282, 2822	Synthetic rubber and other plastic materials and synthetics	W	W	250	253	250	253
2823	Cellulosic fibers, including rayon	--	--	45	46	45	46
283	Drugs	--	--	16	29	16	29
284	Soaps and detergents	52	26	76	80	128	106
286	Industrial organic chemicals	--	--	318	385	318	385
2873	Nitrogenous fertilizers	--	--	82	66	82	66
2874	Phosphatic fertilizers	--	--	6,973	7,556	6,973	7,556
2879	Pesticides	--	--	24	(3)	24	(3)
287	Other agricultural chemicals	551	541	26	35	577	576
2892	Explosives	--	--	30	49	30	49
2899	Water-treating compounds	--	--	121	98	121	98
28	Other chemical products	--	--	45	46	45	46
29, 291	Petroleum refining and other petroleum and coal products	92	180	855	793	947	973
30	Rubber and miscellaneous plastic products	W	W	3	4	3	4
331	Steel pickling	--	--	69	67	69	67
333	Nonferrous metals	--	--	34	31	34	31
33	Other primary metals	--	--	13	8	13	8
3691	Storage batteries (acid)	--	--	50	41	50	41
	Exported sulfuric acid	--	--	12	14	12	14
	Total identified	811	914	10,034	10,662	10,845	11,576
	Unidentified	620	403	484	430	1,104	833
	Grand total	1,431	1,317	10,518	11,092	11,949	12,409

W Withheld to avoid disclosing company proprietary data; included with "Unidentified."
[1]Does not include elemental sulfur used for production of sulfuric acid.
[2]No elemental sulfur used in inorganic pigments and paints and allied products.
[3]Included with "Other agricultural chemicals."

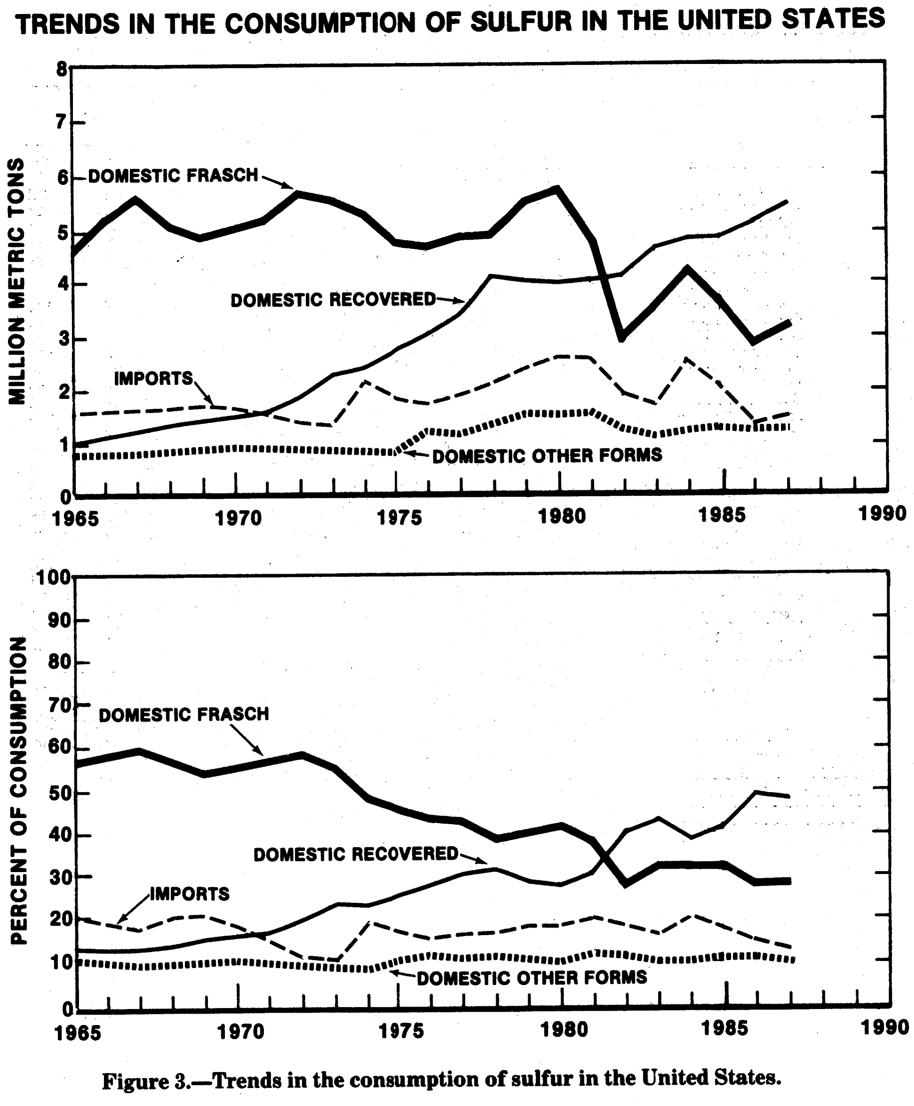

Figure 3.—Trends in the consumption of sulfur in the United States.

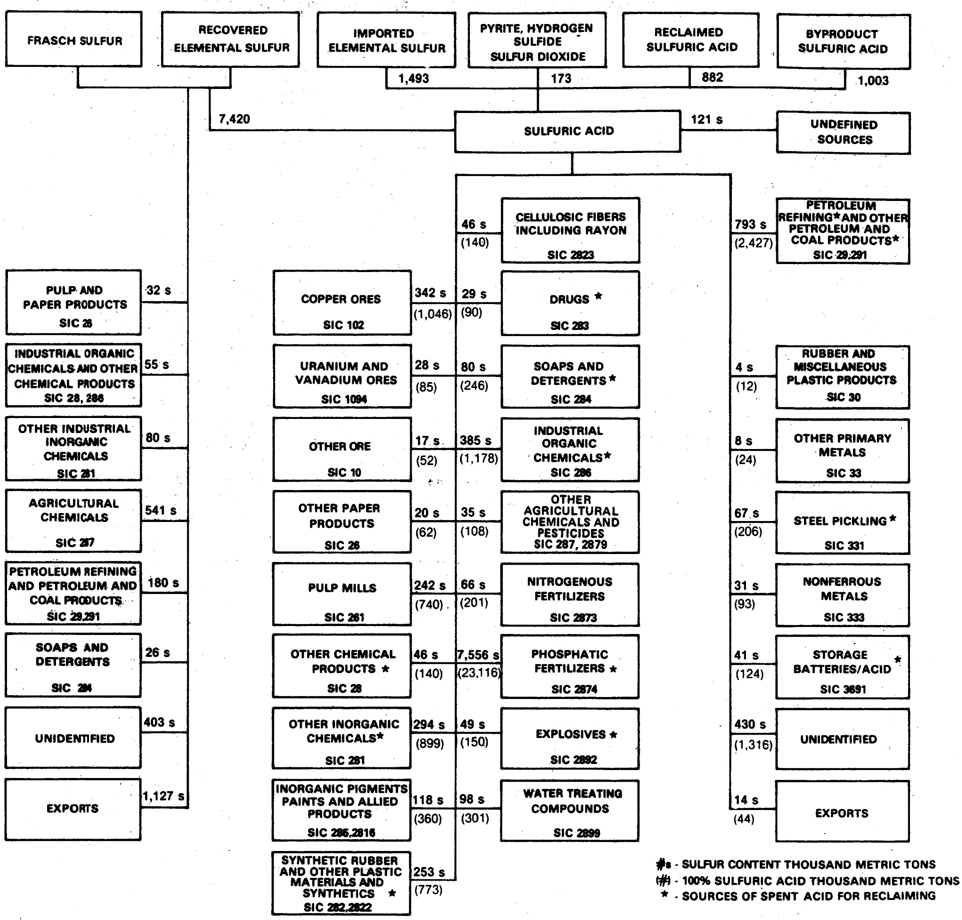

Figure 4.—Sulfur-sulfuric acid supply and end-use relationship in 1987.

STOCKS

Yearend inventories held by producers of Frasch and recovered elemental sulfur decreased 16%, after inventory adjustments, from those at yearend 1986. Combined yearend stocks amounted to approximately a 2.8-month supply compared with a 3.3-month supply in 1986, based on domestic and export demands for Frasch and recovered sulfur.

Table 13.—Yearend sulfur stocks of U.S. producers

(Thousand metric tons)

Year	Frasch	Recovered	Total
1983	3,070	153	3,223
1984	2,264	155	2,419
1985	2,598	201	2,799
1986	2,532	216	2,748
1987	2,122	194	2,316

PRICES

The posted price for liquid sulfur ex-terminal Tampa, FL, was reduced to $135 per long ton from $152.50 per long ton in April. Price discounts, which began in 1983 for large-volume customers, of $10 per long ton were eliminated at the same time. The posted price was reduced again for second-half purchases to $127.50 to $128 per long ton. Spot prices and contract prices for sulfur, f.o.b. Vancouver, British Columbia, Canada, were $110 to $115 per metric ton during the first quarter of the year. Vancouver spot prices were reduced $12 to $15 per ton in the second quarter, reaching a low level of $90 to $93 per ton for the year in September. Fourth-quarter spot prices from Vancouver recovered slightly by yearend but remained below $100 per ton. The Vancouver first-half contract price of $110 per ton was reduced to $100 for second-half loadings.

On the basis of total shipments and value reported to the Bureau of Mines, the average value of shipments of Frasch sulfur, f.o.b. mine, for domestic consumption and exports combined decreased from $105.22 to $89.78 per ton. The average value, f.o.b. plant, for shipments of recovered elemental sulfur varied widely by geographic region: lowest in the Rocky Mountain States, higher on the west coast, somewhat higher in the midcontinent, and near the values for Frasch sulfur in the East and South. Although reported values for recovered elemental sulfur were generally lower throughout the Nation, the disproportionately low average value for Wyoming distorts the average calculation for all recovered elemental sulfur shipments.

Table 14.—Reported sales values of shipments of sulfur, f.o.b. mine or plant

(Dollars per metric ton)

Year	Frasch	Recovered	Average
1983	100.76	76.22	87.24
1984	109.20	80.02	94.31
1985	122.62	92.11	106.46
1986	123.79	92.06	105.22
1987	107.15	79.63	89.78

FOREIGN TRADE

Exports of elemental sulfur from the United States, including the Virgin Islands, decreased 34% in quantity and 45% in value. According to the Bureau of the Census, exports from the west coast increased by over 25% to 577,000 tons or 46% of total U.S. exports.

The United States was again a net importer of sulfur with imports exceeding exports by over 357,000 tons in 1987. Frasch sulfur from Mexico and recovered elemental sulfur from Canada, both delivered to U.S. terminals and consumers in the liquid phase, continued to furnish nearly all U.S. sulfur import requirements. Total elemental sulfur imports increased 19% in quantity; imports by rail from Canada increased 26%, while waterborne shipments from Mexico were 9% higher. An estimated 540,000 tons of sulfur shipped to the west coast of Mexico from Canada and the United States was exchanged for Mexican sulfur delivered to Florida and U.S. east coast ports.

The United States also had significant trade in sulfuric acid. Sulfuric acid exports increased by 46% from those of 1986. Imports, which were significantly greater than exports, were mostly from Canada and increased slightly from the quantity reported in 1986. The value of imported sulfuric acid, however, decreased by over 17%.

Table 15.—U.S. exports[1] of elemental sulfur, by country

(Thousand metric tons and thousand dollars)

Country	1986		1987	
	Quantity	Value	Quantity	Value
Algeria	22	2,990	--	--
Argentina	11	1,605	13	1,850
Australia	1	720	12	1,862
Belgium-Luxembourg	249	30,907	217	26,801
Brazil	188	28,880	258	31,532
Canada	19	1,116	15	1,386
Colombia	14	1,869	21	2,255

See footnote at end of table.

Table 15.—U.S. exports[1] of elemental sulfur, by country —Continued

(Thousand metric tons and thousand dollars)

Country	1986 Quantity	1986 Value	1987 Quantity	1987 Value
Egypt	40	4,585	--	--
France	11	1,335	25	2,574
India	66	8,663	85	8,409
Indonesia	53	6,839	24	2,332
Israel	25	3,533	(2)	5
Korea, Republic of	1	553	14	2,498
Mexico	139	13,768	222	20,798
Morocco	564	77,920	108	10,449
Netherlands	7	820	3	173
Romania	--	--	21	2,110
Senegal	56	7,101	48	5,127
South Africa, Republic of	19	2,308	26	2,575
Taiwan	49	6,590	23	2,402
Tunisia	322	42,215	64	6,948
Turkey	19	2,439	18	2,064
Uruguay	8	1,133	(2)	71
Other	r13	r3,775	24	5,207
Total[3]	1,895	251,664	1,242	139,431

rRevised.
[1]Includes exports from the Virgin Islands.
[2]Less than 1/2 unit.
[3]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

Table 16.—U.S. exports of sulfuric acid (100% H_2SO_4), by country

Country	1986 Quantity (metric tons)	1986 Value (thousands)	1987 Quantity (metric tons)	1987 Value (thousands)
Canada	16,890	$680	27,695	$943
Chile	499	27	9,867	488
Costa Rico	589	40	1,557	86
Dominican Republic	382	63	263	44
Ecuador	144	16	5,044	220
Egypt	239	53	1,493	67
France	376	19	--	--
Japan	693	47	19	22
Korea, Republic of	1,208	848	1,973	991
Mexico	21,427	833	16,497	692
Namibia	1,495	60	--	--
Netherlands Antilles	6,400	320	8,966	371
Panama	3,613	193	2,920	128
Saudi Arabia	418	78	1,380	71
Taiwan	526	159	3,380	350
Trinidad and Tobago	38	5	803	34
United Kingdom	695	25	3,194	108
Venezuela	6,664	476	6,368	375
Other	r4,710	r679	6,535	855
Total	67,006	4,621	97,954	[1]5,844

rRevised.
[1]Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

Table 17.—U.S. imports of elemental sulfur, by country

(Thousand metric tons and thousand dollars)

Country	1986 Quantity	1986 Value[1]	1987 Quantity	1987 Value[1]
Canada	605	50,342	764	52,048
Mexico	726	89,709	793	94,444
Venezuela	16	1,891	41	4,897
Other[2]	([3])	278	1	708
Total	1,347	142,220	1,599	[4]152,096

[1]Declared customs valuation.
[2]Includes the Dominican Republic, France, the Federal Republic of Germany, and Japan in 1986; and Belgium, Chile, the Federal Republic of Germany, Japan, and Switzerland in 1987.
[3]Less than 1/2 unit.
[4]Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

Table 18.—U.S. imports of sulfuric acid (100% H_2SO_4), by country

Country	1986 Quantity (metric tons)	1986 Value[1] (thousands)	1987 Quantity (metric tons)	1987 Value[1] (thousands)
Belgium	16	$8	12	$42
Canada	589,174	20,511	715,008	22,284
Denmark	8,408	457	--	--
Finland	15,712	590	--	--
France	67	184	49	155
Germany, Federal Republic of	33,183	2,544	2	12
Italy	6,943	283	9,444	479
Japan	8	40	30,634	916
Netherlands	2,877	118	--	--
Spain	61,843	2,888	5,112	281
Sweden	21,583	828	2,281	348
Switzerland	596	381	3,600	171
United Kingdom	19,167	1,006	([2])	2
Other	[r]123	[r]46	68	70
Total[3]	759,702	29,883	766,210	24,760

[r]Revised.
[1]Declared c.i.f. valuation.
[2]Less than 1/2 unit.
[3]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

WORLD REVIEW

World sulfur production, consumption, and trade increased; however, international prices for elemental sulfur decreased. The U.S.S.R., which had imported over 800,000 tons of elemental sulfur from Canada in 1986, indicated early in the first quarter that it would not require more than 60,000 tons during 1987. Consumers of elemental sulfur, perceiving an oversupply condition in the international market, pressed for price reductions and other considerations from major exporters. Canadian exporters, faced with the loss of one-seventh of their export business, adopted an aggressive marketing stance and reduced prices f.o.b. Vancouver, British Columbia, Canada, by $12 to $15 per ton for deliveries beginning in the second quarter. Saudi Arabia reduced the "Government Expected Price," f.o.b. Jubail, $13 per ton to $100 per ton on April 1. In the highly competitive northern European market, liquid price quotes for the second half dropped about $20 per ton to $120 per ton. Second-half prices for liquid sulfur in the Tampa, FL, area were settled at $127.50 to $128 per long ton, a $15 decrease from January. International prices in the $96 to $100 range, f.o.b. from Canada and Persian Gulf countries, effectively restricted U.S. Frasch exporters from many of their traditional markets; Frasch sulfur exports were reduced to the lowest levels since the early 1950's, when U.S. Government controls were in place.

Despite the perceived oversupply in the international marketplace, stocks of sulfur worldwide were reduced by nearly 700,000 tons. Stock levels were reduced by 1.4 million tons in Canada, and over 400,000 tons in the United States. Stocks increased in Iran, Iraq, Mexico, Saudi Arabia, and the U.S.S.R.

Canada.—Shipments of sulfur in all forms were about 7.98 million tons, or 1.41 million tons greater than production. Elemental sulfur exports increased in quantity by about 300,000 tons to nearly 6.57 million tons. The value of sulfur exports, however, decreased by over 20%. Canada remained the world's largest exporting country.

In February, Shell Canada Ltd. announced the discovery of a major new gas condensate field at Caroline, near Sundre, Alberta. The Caroline Field was the largest Albertan discovery in over a decade; gas reserves were estimated to be nearly 57 billion cubic meters with a hydrogen sulfide content 30% to 35%. Shell and its partners expected to begin development of the field and be producing over 1 million tons of sulfur by the early 1990's.

An October fire at Suncor Inc.'s Fort McMurray, Alberta, oil sands-bitumen extraction plant caused damages estimated at Canadian $50 to $60 million. Prior to the accident the facility was producing over 300 tons per day of elemental sulfur. Repairs were begun and full production is to be resumed by April 1988.

Canterra Energy Ltd. commissioned a cold flotation facility at its Ram River, Alberta, gas processing plant to recover contaminated sulfur from its block base pad. The company reduced its block inventory by several million tons during the 1980's and the 100,000-ton-per-year unit was to aid in recovering material not suitable for remelt.

Noranda Inc., in an agreement with the Federal and Provincial Governments, announced plans to construct a 350,000-ton-per-year sulfuric acid plant at its Horne copper smelter in Rouyn-Noranda, Quebec.[2] The acid plant was to reduce SO_2 emissions from the smelter by over 50%. Construction was to begin in 1988 with commissioning set for mid-1989.

Chile.—Misubishi Heavy Industries Ltd. of Japan began construction of a 600,000-ton-per-year sulfuric acid plant designed to recover exhaust gases from the Chuquicamata copper smelter. Corporación Nacional del Cobra de Chile contracted for the acid plant in 1986 to service its new flash smelter designed by Outokumpu Oy of Finland. Most of the acid plant's output was to be used to treat Chuquicamata's oxide zone copper ore in a heap leach, SX-EW system that was scheduled to recover 80,000 tons per year of copper by 1990.

China.—A new 3-million-ton-per-year pyrite mine was reportedly commissioned near Yunfu, Guangdong Province. China continued to explore for sulfur resources to augment production from pyrites for use in its program to increase fertilizer production from indigenous resources.

Egypt.—In November, Freeport Egyptian Sulphur Co., a subsidiary of Freeport-McMoRan Inc., reported a sulfur discovery near El 'Arish in the northern Sinai Desert.[3] A 140-foot interval containing sulfur was discovered at a depth of 1,200 to 1,340 feet. Further drilling was scheduled for the rest of the year and into 1988 to determine the size and extent of the deposit.

Iran.—Sulfur production remained below rated capacity of the nation's gas treatment facilities and petroleum refineries because of the ongoing war with neighboring Iraq. An estimated 150,000 tons of sulfur was put into inventories, and exports were estimated at 70,000 tons.

Iraq.—Sulfur exports continued to be routed overland through neighboring nations because safe passage could not be assured for Iraqi material in the Persian Gulf. Production was increased at the Mishraq Mine and from the Kurkuk gas plant. Freeport-McMoRan of the United States and the State Organization for Minerals discussed setting up a filtration plant, using Freeport technology, to treat production from the Mishraq Mine that had a high bitumen content.

Mexico.—Frasch sulfur production continued to increase and was scheduled to increase further with the commissioning of the Otapan Mine in 1988. Sulfur imports from Canada and the U.S. west coast were nearly 540,000 tons, which did not appear in official Mexican trade statistics. Most of these imports occurred by means of exchange agreements for deliveries of Mexican Frasch sulfur to the United States.

Construction began on a 600,000-ton-per-year sulfuric acid plant at Mexicana de Cobre S.A.'s La Caridad copper smelter. The smelter operated with a high stack to disperse sulfur dioxide, but Mexico was obligated to install the acid plant as part of a 1985 agreement with the United States to limit emissions from Mexican smelters and Phelps Dodge's Douglas, AZ, smelter.

Morocco.—Morocco became the world's leading importer of elemental sulfur because of increasing consumption at its phosphate fertilizer facilities at Safi and Jorf Lasfar. Imports increased to nearly 2 million tons from 1.7 million tons and were projected to increase additionally by 500,000 tons in 1988-89 when the Jorf Lasfar facility was expected to become fully operational.

Poland.—Sulfur exports of 3.85 million tons included nearly 2 million tons to Eastern Europe and 915,000 tons to Western Europe. Most of the remainder was shipped to Brazil, India, and Morocco.

Saudi Arabia.—Sulfur production from natural gas processing plants and oil refineries increased slightly. Excess production of sulfur over domestic and export demand created a stock increase at the Berri gas plant of an estimated 500,000 tons.

U.S.S.R.—Production of elemental sulfur increased substantially because the new Astrakhan natural gas processing plant commenced operations. Output from the facility, which had four processing trains, was significantly less than the design capacity of 2.7 million tons per year. Each of the four trains had successfully been tested at full capacity during the year, and output at yearend was estimated to be nearly 4,000 tons per day. Construction of the second phase will double the size of the Astrakhan facility.

In November, it was announced in Moscow that Montedison S.p.A. of Italy and Occidental Petroleum Corp. of the United States signed an agreement with the U.S.S.R. to build and operate a petrochemical plant near the Tengiz oil-gas-condensate field. The facility was designed to produce 1 million tons per year of commercial sulfur. A separate facility under construction was planned to produce 450,000 tons per year of sulfur at Tengiz by 1989. The Tengiz Field had reserves of over 2.5 billion tons (18 billion barrels), making it one of the world's largest oil discoveries.[4] Production of oil from the field was scheduled to reach 30 million tons per year by 1995, which would yield 4.5 to 5 million annual tons of sulfur. By 1995, the total annual output of elemental sulfur from Tengiz and Astrakhan combined could be over 10 million tons.

Sulfur production from the Noril'sk nonferrous metallurgical center reportedly began late in 1987.[5]

Table 19.—Sulfur: World production in all forms, by country and source[1]

(Thousand metric tons)

Country[2] and source[3]	1983	1984	1985	1986[p]	1987[e]
Algeria: Byproduct, natural gas and petroleum[e]	15	20	20	20	20
Australia:					
Byproduct:					
Metallurgy	170	190	435	433	435
Petroleum	13	13	12	10	[4]9
Total	183	203	447	443	444
Austria:					
Byproduct:					
Metallurgy	9	10	11	11	11
Natural gas and petroleum	32	28	24	29	28
Gypsum	26	26	27	24	25
Total[5]	[r]68	[r]65	62	64	64
Bahamas: Byproduct, petroleum[e]	5	3	1	--	--
Bahrain: Byproduct, petroleum	49	[e]50	42	[e]45	45
Belgium: Byproduct, all sources[e]	250	240	250	260	250
Bolivia: Native	3	2	3	5	10
Brazil:					
Frasch	[r]3	4	4	6	6
Pyrites	[r]76	89	91	92	92
Byproduct:					
Metallurgy	[r]44	52	79	100	115
Petroleum	[r]65	71	55	74	75
Total	[r]188	216	229	272	288

See footnotes at end of table.

Table 19.—Sulfur: World production in all forms, by country and source[1] —Continued

(Thousand metric tons)

Country[2] and source[3]	1983	1984	1985	1986[p]	1987[e]
Bulgaria:[e]					
Pyrites	80	75	65	80	80
Byproduct, all sources	56	62	53	62	65
Total	136	137	118	142	145
Canada:					
Pyrites[e] [6]	9	(7)	(7)	(7)	--
Byproduct:					
Metallurgy	678	875	822	758	[4]803
Natural gas	5,390	5,260	5,296	5,161	[4]5,249
Petroleum[e]	170	165	[r]174	[r]189	190
Tar sands	330	296	392	435	[4]426
Total	[4]6,577	[r]6,596	[r]6,684	[r]6,543	6,668
Chile:					
Native:					
Refined	16	14	15	13	13
From caliche	83	40	64	44	44
Byproduct, metallurgy	32	32	30	41	40
Total	131	86	109	98	97
China:[e]					
Native	200	200	300	300	300
Pyrites	2,300	2,100	2,200	2,500	2,500
Byproduct, all sources	350	350	400	300	300
Total	2,850	2,650	2,900	3,100	3,100
Colombia:					
Native	31	36	41	36	40
Byproduct, petroleum	6	10	10	[e]10	10
Total	37	46	51	[r e]46	50
Cuba:[e]					
Pyrites	5	--	--	--	--
Byproduct, petroleum	8	8	8	8	8
Total	13	8	8	8	8
Cyprus:[8] Pyrites	21	10	31	25	25
Czechoslovakia:[e]					
Native	5	5	[4]6	6	6
Pyrites	60	60	[4]62	60	60
Byproduct, all sources	10	10	[4]12	10	11
Total	75	75	[4]80	76	77
Denmark: Byproduct, petroleum	[e]9	11	7	13	13
Ecuador:[e]					
Native	5	5	4	4	5
Byproduct:					
Natural gas	5	5	5	5	5
Petroleum	5	5	5	5	5
Total	15	15	14	14	15
Egypt: Byproduct, natural gas and petroleum[e]	1	[r]1	[r]3	[r]4	5
Finland:					
Pyrites	224	211	248	275	[4]311
Byproduct:					
Metallurgy	264	265	257	[r e]260	220
Petroleum	48	45	45	42	40
Total	536	521	550	577	571
France:					
Byproduct:					
Natural gas	1,653	1,589	1,386	946	872
Petroleum	157	163	[e]160	[e]180	200
Unspecified[e]	100	110	177	180	180
Total	1,910	1,862	1,723	1,306	1,252
German Democratic Republic: Byproduct, all sources[e]	360	350	330	315	315

See footnotes at end of table.

Table 19.—Sulfur: World production in all forms, by country and source[1] —Continued

(Thousand metric tons)

Country[2] and source[3]	1983	1984	1985	1986[p]	1987[e]
Germany, Federal Republic of:					
Byproduct:					
Metallurgy[e 9]	400	350	320	300	300
Natural gas	632	851	964	998	1,030
Petroleum[e]	195	190	200	190	210
Unspecified[e]	95	90	85	85	85
Total[e]	1,322	1,481	1,569	[r]1,573	1,625
Greece:					
Pyrites	67	78	[e]78	[r e]66	70
Byproduct:[e]					
Natural gas	115	120	130	130	130
Petroleum	[4]5	5	5	5	5
Total[e]	187	203	213	[r]201	205
Hungary:[e]					
Pyrites	3	2	2	1	1
Byproduct, all sources	9	9	9	10	10
Total	12	11	11	11	11
India:					
Pyrites	25	18	7	8	12
Byproduct:					
Metallurgy[e]	110	115	120	120	120
Petroleum	4	[e]5	([10])	[e]1	--
Total[e]	139	138	[r]127	[r]129	132
Indonesia:[8] Native	3	5	4	[e]4	4
Iran:					
Native[e]	20	30	30	30	30
Byproduct, natural gas and petroleum	16	130	150	[r e]250	300
Total[e]	36	160	180	[r]280	330
Iraq:[e]					
Frasch	300	500	500	600	620
Byproduct, natural gas and petroleum	40	70	70	[r]200	250
Total	340	570	570	[e]800	870
Israel: Byproduct, natural gas and petroleum[e]	10	10	10	[e]15	20
Italy:					
Native	9	8	1	--	--
Pyrites	271	192	280	309	300
Byproduct, all sources[e 11]	210	200	200	185	190
Total[e]	490	400	481	494	490
Japan:					
Pyrites	272	259	253	158	79
Byproduct:					
Metallurgy	1,239	1,191	1,201	1,228	1,215
Petroleum	1,102	1,142	1,044	985	927
Total	2,613	2,592	2,498	2,371	2,221
Korea, North:[e]					
Pyrites	200	200	200	200	200
Byproduct, metallurgy	30	30	30	30	30
Total	230	230	230	230	230
Korea, Republic of:					
Pyrites	([10])	([10])	--	--	--
Byproduct:[e]					
Metallurgy	54	54	55	55	55
Petroleum	36	36	35	35	35
Total[e]	90	90	90	90	90
Kuwait: Byproduct, natural gas and petroleum[e]	145	151	198	[4]260	350
Libya: Byproduct, natural gas and petroleum[e]	14	14	14	14	14

See footnotes at end of table.

Table 19.—Sulfur: World production in all forms, by country and source[1] —Continued

(Thousand metric tons)

Country[2] and source[3]	1983	1984	1985	1986[p]	1987[e]
Mexico:					
Frasch	1,225	1,364	1,551	1,588	[4]1,806
Byproduct:					
Metallurgy[e]	100	160	160	[r]170	180
Natural gas and petroleum	377	461	469	462	[4]413
Total[e]	1,702	1,985	2,180	[r]2,220	2,399
Namibia: Pyrites	81	104	108	134	135
Netherlands:[e]					
Byproduct:					
Metallurgy	100	--	--	--	--
Petroleum	105	245	250	250	245
Total	205	245	250	250	245
Netherlands Antilles: Byproduct, petroleum	87	63	[e]25	[e]40	35
New Zealand: Byproduct, all sources	1	1	[e]1	[e]1	1
Norway:					
Pyrites	179	[r]203	193	181	170
Byproduct:					
Metallurgy	[e]95	62	60	67	80
Petroleum	8	8	10	[r e]13	15
Total	282	273	263	261	265
Oman: Pyrites[e]	11	31	31	31	30
Pakistan:					
Native	1	1	1	1	2
Byproduct, all sources[e]	26	26	26	26	26
Total	27	27	27	27	28
Peru:					
Native	([10])	([10])	([10])	([10])	([10])
Byproduct, all sources	65	64	68	[e]66	66
Total	65	64	68	[e]66	66
Philippines:					
Pyrites	29	[r]39	108	113	[4]158
Byproduct, metallurgy[e]	57	95	100	120	140
Total[e]	86	[r]134	[r]208	[r]233	298
Poland:[e 12]					
Frasch	4,460	4,500	[4]4,386	4,400	4,500
Native	500	490	490	500	500
Byproduct:					
Metallurgy	170	170	170	170	170
Petroleum	30	30	30	30	30
Gypsum	20	20	20	20	20
Total	5,180	5,210	5,096	5,120	5,220
Portugal:					
Pyrites	124	140	155	144	140
Byproduct, all sources	5	4	[e]5	[e]5	5
Total	129	144	[e]160	[e]149	145
Qatar: Byproduct, natural gas	19	33	37	[e]37	35
Romania:[e]					
Pyrites	200	200	200	150	150
Byproduct, all sources	150	150	150	140	130
Total	350	350	350	290	280
Saudi Arabia: Byproduct, natural gas and petroleum	[r]793	833	1,100	[e]1,300	1,400
Singapore: Byproduct, petroleum	4	6	[e]5	[e]5	5
South Africa, Republic of:					
Pyrites	474	464	562	499	500
Byproduct:[e]					
Metallurgy	125	[4]91	[4]85	[r]108	110
Petroleum[13]	32	30	100	110	110
Total[e]	631	585	747	[r]717	720

See footnotes at end of table.

Table 19.—Sulfur: World production in all forms, by country and source[1] —Continued

(Thousand metric tons)

Country[2] and source[3]	1983	1984	1985	1986[p]	1987[e]
Spain:					
Pyrites	1,073	1,094	1,231	1,195	1,000
Byproduct:[e]					
Coal (lignite) gasification	3	3	2	2	2
Metallurgy	120	125	115	105	110
Petroleum	8	9	7	8	8
Total[e]	1,204	1,231	1,355	1,310	1,120
Sweden:					
Pyrites	[r]219	[r]212	210	227	220
Byproduct:					
Metallurgy	114	122	123	125	125
Petroleum	20	26	23	49	50
Total	353	[r]360	356	401	395
Switzerland: Byproduct, all sources	3	3	3	3	3
Syria: Byproduct, natural gas and petroleum[e]	30	35	35	35	40
Taiwan: Byproduct, all sources	27	29	43	63	65
Trinidad and Tobago: Byproduct, petroleum[e]	8	7	5	5	3
Turkey:					
Native	35	41	44	41	40
Pyrites[e]	2	--	--	--	--
Byproduct, all sources[e]	75	78	80	80	80
Total[e]	112	119	[r]124	[r]121	120
U.S.S.R.:[e]					
Frasch	800	800	850	875	950
Native	1,800	1,800	[r]1,800	[r]1,900	1,900
Pyrites	[r]2,700	[r]2,600	[r]2,500	[r]2,350	2,300
Byproduct:					
Metallurgy	[r]1,600	[r]1,700	[r]1,700	[r]1,700	1,650
Natural gas	[r]1,800	[r]1,850	[4]1,974	[r]2,000	2,300
Petroleum	450	450	450	450	450
Total	[r]9,150	[r]9,200	[r]9,274	[r]9,275	9,550
United Arab Emirates: Abu Dhabi:					
Byproduct:					
Natural gas	--	35	104	[e]90	90
Petroleum	10	15	1	[e]1	1
Total	10	50	105	[e]91	91
United Kingdom:					
Byproduct:					
Metallurgy	69	71	79	70	[4]64
Petroleum	55	75	80	105	110
Spent oxides	3	1	--	--	--
Total[5]	127	[r]146	149	175	174
United States:					
Frasch	3,202	4,193	5,011	4,043	[4]3,202
Pyrites	W	W	W	W	W
Byproduct:					
Metallurgy	831	962	957	919	[4]1,003
Natural gas	2,371	2,407	2,373	2,246	[4]2,536
Petroleum	2,584	2,807	2,940	3,570	[4]3,624
Unspecified	302	283	328	309	[4]173
Total[5]	9,290	10,652	11,609	11,087	[4]10,539
Uruguay: Byproduct, petroleum[e]	2	2	2	2	2
Venezuela: Byproduct, natural gas and petroleum[e]	85	86	88	90	92
Yugoslavia:					
Pyrites and pyrrhotite	298	301	323	344	[4]323
Byproduct:[e]					
Metallurgy	180	160	170	[r]175	175
Petroleum	3	3	3	3	3
Total[e]	481	464	496	[r]522	501
Zaire: Byproduct, metallurgy[e]	36	37	36	36	36

See footnotes at end of table.

Table 19.—Sulfur: World production in all forms, by country and source[1] —Continued

(Thousand metric tons)

Country[2] and source[3]	1983	1984	1985	1986[p]	1987[e]
Zambia:					
Pyrites	[r]26	18	28	19	19
Byproduct, all sources[e]	80	80	80	80	80
Total[e]	[r]106	98	108	99	99
Zimbabwe:[e]					
Pyrites	25	25	25	25	25
Byproduct, all sources	5	5	5	5	5
Total	30	30	30	30	30
Grand total[5]	[r]49,770	[r]51,859	54,331	54,074	54,221
Of which:					
Frasch	[r]9,990	[r]11,361	12,302	11,512	11,084
Native	2,711	2,677	2,803	2,884	2,894
Pyrites	[r]9,054	[r]8,725	9,191	9,186	8,900
Byproduct:					
Coal (lignite) gasification	3	3	2	2	2
Metallurgy	[r]6,627	[r]6,919	7,105	7,101	7,187
Natural gas	[r]11,985	[r]12,150	12,269	11,613	12,247
Natural gas and petroleum, undifferentiated	[r]1,558	[r]1,839	2,181	2,679	2,932
Petroleum	[r]5,283	[r]5,698	5,734	6,433	6,463
Spent oxides	3	1	--	--	--
Tar sands	330	296	392	435	426
Unspecified sources	2,179	2,144	2,305	2,185	2,040
Gypsum	46	46	47	44	45

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Byproduct: Unspecified sources."

[1]Table includes data available through June 3, 1988.

[2]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 that may recover byproduct sulfur from oil refining include Albania, Bangladesh, Brunei, Burma, Costa Rica, Guatemala, Honduras, Jamaica, Malaysia, Nicaragua, Paraguay, and Yemen-Aden. Albania and Burma may also produce byproduct sulfur from crude oil and natural gas extraction. No complete listing of other nations that 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 this table that may have production from sources other than those listed are identified by individual footnotes.

[3]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) pyrites (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, pyrites-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.

[4]Reported figure.

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

[6]Byproduct pyrite and pyrrhotite from the processing of metallic sulfide ores.

[7]Revised to zero.

[8]In addition, may produce limited quantities of byproduct sulfur from oil refining.

[9]Includes only the elemental sulfur equivalent of sulfuric acid produced as a byproduct from metallurgical furnaces; additional output may be included under "Byproduct: Unspecified sources."

[10]Less than 1/2 unit.

[11]Includes recovery from gypsum, if any.

[12]Official Polish sources report total Frasch and native mined elemental sulfur output annually, undifferentiated; this figure has been divided between Frasch and other native sulfur on the basis of information obtained from supplementary sources.

[13]Estimates for 1985 and 1987 include byproduct production from synthetic fuels.

TECHNOLOGY

Monsanto Enviro-Chem Systems Inc. entered into an agreement with E. I. du Pont de Nemours & Co. Inc. to become the worldwide licensee for Du Pont's froth scrubbing technology for use in sulfuric acid applications. Monsanto, which designs and constructs sulfuric acid plants, believed that this technology was well suited to clean the exit gases from copper smelters and pyrites roasting plants prior to their introduction into the associated sulfuric acid plant. Monsanto stated that the advantages over conventional gas-cleaning facilities included lower capital and maintenance costs, high cleaning efficiency, lower energy requirements, and a simple reliable design with few moving parts. The 25% savings in energy consumption was especially attractive to copper smelting companies because of the reduced acid production costs.[6]

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[1]Physical scientist, Branch of Industrial Minerals.
[2]Canadian Mining Journal. Mar. 1988, p. 67.
[3]Sulphur. No. 194, Jan.-Feb. 1988, pp. 12-13.
[4]Fertilizer Focus. V. 5, No. 3, Apr. 1988, p. 4.
[5]Sotsialisticheskaya Industriya (Socialist Industry) Moscow). Oct. 8, 1987, p. 1.
[6]Fries, R. M., and R. M. Brendel, Monsanto Dynawave Scrubbers. Monsanto Enviro-Chem. Syst. Inc., St. Louis, MO.

Talc and Pyrophyllite

By Robert L. Virta[1]

Domestic production of talc and pyrophyllite increased 4% from that of 1986. Sales of crude and processed talc and pyrophyllite decreased slightly in tonnage and increased slightly in value. Imports for consumption increased slightly. Exports increased 36% in tonnage and 29% in value.

Domestic Data Coverage.—Domestic production and sales data for talc and pyrophyllite are developed by the Bureau of Mines from a voluntary survey of U.S. mines and mills. Of the 82 mines and mills to which a survey request was sent, 56 responded, representing 68% of the U.S. production data shown in table 1. Production for the 26 nonrespondents was estimated using reported prior year production levels adjusted by trends in employment and other guidelines.

Table 1.—Salient talc and pyrophyllite statistics

(Thousand short tons and thousand dollars)

	1983	1984	1985	1986	1987
United States:					
Mine production, crude:					
Talc	980	1,042	1,188	1,219	1,258
Pyrophyllite	87	85	81	83	92
Total[1]	1,066	1,127	1,269	1,302	1,349
Value:					
Talc	$18,998	$21,755	$27,768	$29,687	$27,178
Pyrophyllite	1,282	1,412	1,420	1,540	1,607
Total	20,280	23,167	29,188	31,227	28,785
Sold by producers, crude and processed:					
Talc	1,038	1,101	1,067	1,070	1,057
Pyrophyllite	125	97	81	83	90
Total	1,163	1,198	1,148	1,153	1,147
Value:					
Talc	$104,739	$112,515	$114,542	$111,924	$112,716
Pyrophyllite	4,057	3,578	3,273	3,366	3,712
Total[1]	108,796	116,093	117,815	115,290	[e]116,429
Exports[2] (talc)	218	256	237	234	318
Value	$12,916	$16,162	$14,282	$16,302	$21,040
Imports for consumption[3] (talc)	44	45	47	52	53
Value	$7,691	$9,156	$9,532	$8,715	$10,348
Consumption, apparent[4]	989	1,009	1,079	1,120	1,084
World: Production	7,781	[r]8,303	[r]8,423	[p]8,256	[e]8,310

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Data may not add to total shown because of independent rounding.
[2]Excludes powders—talcum (in package), face, and compact.
[3]Does not include imported pyrophyllite.
[4]Production, plus imports, minus exports, plus adjustments in Government and industry stock changes.

Legislation and Government Programs.—The Occupational Safety and Health Administration (OSHA) extended through July 21, 1988, an administrative stay on its 1986 regulation governing worker exposure to the nonasbestiform varieties of actinolite, anthophyllite, and tremolite. During the stay, OSHA continued to analyze the impact of using the asbestos standard to regulate the nonasbestiform varieties of the minerals.[2]

U.S. import duties on talc minerals from most favored nations were crude and unground, 0.02 cent per pound; ground, washed, powdered, and/or pulverized, 2.4% ad valorem; cut, sawed, or in blanks, crayons, cubes, disks, or other forms, free; and other not specifically provided for, 4.8% ad valorem.

The stockpile inventories of 1,081 short tons for block or lump talc and 1,809 tons for ground talc at yearend were unchanged from those of 1986.

DOMESTIC PRODUCTION

Talc.—U.S. mine production of crude talc increased 3% in tonnage and decreased 8% in value. Talc and soapstone were produced at 28 mines in 10 States. Mines that operated in Montana, New York, Texas, and Vermont accounted for 95% of domestic talc production. Montana led all States in the tonnage and value of talc produced.

The largest domestic producers of talc, listed alphabetically, are Cyprus Industrial Minerals Co.; Dal-Tile (Texas Talc Co.) Gouverneur Talc Co., a subsidiary of R. T. Vanderbilt Co. Inc.; Pfizer Inc., Minerals, Pigments and Metals Div.; Vermont Talc Co.; and Windsor Minerals Inc.

Vermont Talc opened a mine near Troy, VT, to supply talc to its flotation mill at Johnson, VT.

Cyprus completed developmental work and began mining talc from a deposit near Alpine, AL. Talc from the deposit will be processed at the Cyprus mill facilities in Alpine.

Pyrophyllite.—Pyrophyllite was produced by four companies operating six mines in California and North Carolina. Production increased 11% over that of 1986.

Table 2.—Crude talc and pyrophyllite produced in the United States, by State

(Thousand short tons and thousand dollars)

State	1986		1987	
	Quantity	Value	Quantity	Value
California	64	1,528	W	W
Georgia (talc)	9	61	20	286
Montana	W	W	386	12,320
North Carolina	83	1,552	W	W
Texas (talc)	283	6,456	255	4,380
Other[1] (talc)	863	21,630	688	11,799
Total	1,302	31,227	1,349	28,785

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1]Includes Arkansas, New York, Oregon, Vermont, Virginia (1987).

CONSUMPTION AND USES

Apparent domestic consumption of crude and processed talc and pyrophyllite decreased 3%. Sales of talc and pyrophyllite decreased slightly in tonnage and increased slightly in value.

End-use distribution of ground talc was ceramics, 33%; paint, 15%; paper, 14%; roofing, 12%; plastics, 8%; cosmetics, 6%; and insecticide, refractory, rubber, and other, 12%.

The largest portion, 61%, of domestically produced ground pyrophyllite was used in ceramics, 16% was used in refractories, 9% in insecticides, and 14% in paint, plastic, roofing, rubber, and other.

A survey of the European paper industry indicated that talc consumption was approximately 550,000 tons per year. Over 75% of the talc consumed was used as paper filler. Slightly less than 8% was used for pitch-control and 8% was used as a coating pigment. Talc's importance as a pitch control agent was reduced through the use of chemical additives. The major consuming European countries were Austria, Finland, France, Italy, and Spain.[3]

A survey of the talc industry in Europe indicated that changes in the general economy, overcapacities at processing plants, and loss of markets to other minerals resulted in more competition within the talc industry. Growth within the pulp and paper industry was expected to slow because of increased use of calcium carbonate as a paper filler. With increasing restrictions on the use of chemicals, new papermaking machines, and increased waste paper recycling, the market for talc as a pitch control agent had the greatest potential for growth. Growth within the roofing industry was not expected because of competition from limestone, sand, slate, and antistick polyolefin films, and the increasing use of single-ply roofing applications. Talc consumption by the ceramics industry was expected to increase because of demand for earthenware, electroceramics, floor tiles, and sanitary ware. Consumption of talc by the plastics industry was expected to increase 7% to 10% because of the demand for talc-filled polypropylene.[4]

Table 3.—End uses for ground talc and pyrophyllite

(Thousand short tons)

Use	1986			1987		
	Talc	Pyrophyllite	Total[1]	Talc	Pyrophyllite	Total
Ceramics	343	64	407	313	83	396
Cosmetics[2]	46	3	49	60	--	60
Insecticides	6	13	18	(3)	12	12
Paint	168	2	170	138	2	140
Paper	127	--	127	127	--	127
Plastics	69	1	69	79	1	80
Refractories	3	20	22	2	21	23
Roofing	106	2	108	112	1	113
Rubber	25	(3)	25	19	(3)	19
Other[4]	90	13	103	88	14	102
Total[1]	983	116	1,099	938	135	1,073

[1]Data may not add to totals shown because of independent rounding.
[2]Incomplete data. Some cosmetic talc known to be included with "Other."
[3]Less than 1/2 unit.
[4]Includes art sculpture, asphalt filler and coatings, crayons, floor tile, foundry facings, rice polishing, stucco, and other uses not specified.

PRICES

Talc prices varied depending on the quality, and on the degree and method of processing.

Prices, quoted by the Engineering and Mining Journal, December 1987, per short ton of domestic ground talc, in carload lots, f.o.b. mine or mill, including containers follow:

New Jersey:	
Mineral pulp, bags extra	$18.50-$20.50
Vermont:	
98% through 325 mesh, bulk	70.00
99.99% through 325 mesh, bags:	
Dry processed	147.00
Water beneficiated	213.00-228.00
New York:	
96% through 200 mesh	67.00- 75.00
98% to 99.25% through 325 mesh	83.00-100.00
100% through 325 mesh, fluid-energy ground	165.00
California:	
Standard	130.00
Fractionated	37.00- 71.00
Micronized	150.00-220.00
Cosmetic steatite	44.00- 65.00
Georgia:	
98% through 200 mesh	50.00
99% through 325 mesh	60.00
100% through 325 mesh, fluid-energy ground	100.00

Approximate equivalents, in dollars per short ton, of price ranges quoted in Industrial Minerals (London), December 1987, for talc, c.i.f. main European ports, were as follows:

Norwegian:	
Ground (ex store)	$162-$180
Micronized (ex store)	207- 288
French, fine-ground	216- 342
Italian, cosmetic-grade	315
Chinese, normal (ex store):	
UK 200 mesh	254
UK 325 mesh	265
New York, paint, minimum 20-ton lot	175

FOREIGN TRADE

Talc exports increased 36% in tonnage and 29% in value. Prices ranged from $12 to $596 per ton, averaging $66 per ton.

Table 4.—U.S. exports of talc[1]

(Thousand short tons and thousand dollars)

Year	Belgium-Luxembourg		Canada[2]		Japan		Mexico		Other[3]		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1983	1	55	74	4,629	16	1,077	86	2,805	41	4,350	218	12,916
1984	11	722	76	5,265	22	1,518	107	3,696	40	4,961	256	16,162
1985	6	373	81	4,864	18	1,422	108	4,492	24	3,131	237	14,282
1986	15	1,273	59	4,411	22	1,707	112	4,464	27	4,447	[4]234	16,302
1987	30	2,482	61	5,000	26	2,405	149	5,614	52	5,538	318	[4]21,040

[1]Excludes powders—talcum (in package), face, and compact.
[2]Probably includes shipments in transit through Canadian ports.
[3]Includes 48 countries in 1987.
[4]Data do not add to total shown because of independent rounding.

Table 5.—U.S. imports for consumption of talc, by country

Country	Crude and unground		Ground, washed, powdered, or pulverized		Cut and sawed		Talc, n.s.p.f.	Total unmanufactured[1]	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Value (thousands)	Quantity (short tons)	Value (thousands)
1985	10,772	$1,350	33,234	$5,140	2,889	$2,097	$945	46,895	$9,532
1986:									
Australia	9,353	569	--	--	--	--	--	9,353	569
Brazil	--	--	112	39	750	334	50	862	423
Canada	54	4	37,307	4,949	116	153	46	37,475	5,152
China	418	25	--	--	485	438	237	903	699
Italy	6	2	141	37	--	--	5	147	44
Korea, Republic of	--	50	1,077	240	53	26	3	1,130	319
Other[2]	256	66	1,616	685	230	304	454	2,102	1,509
Total[1]	10,086	715	40,253	5,951	1,634	1,254	795	51,973	8,715
1987:									
Australia	1,450	87	--	--	--	--	--	1,450	87
Brazil	--	--	277	42	398	151	12	675	205
Canada	--	--	38,729	5,362	108	128	65	38,837	5,555
China	--	--	--	--	386	288	275	386	563
Italy	216	24	85	24	1,123	1,090	--	1,424	1,138
Korea, Republic of	--	--	917	252	34	19	--	951	271
Other[3]	8,438	805	777	431	288	341	952	9,503	2,529
Total[1]	10,104	916	40,784	6,112	2,337	2,017	1,304	53,225	10,348

[1]Data may not add to totals shown because of independent rounding.
[2]Includes 17 countries.
[3]Includes 21 countries.

Source: Bureau of the Census.

WORLD REVIEW

The United States remained the world's largest talc producer, and Japan remained the largest pyrophyllite producer. China, Japan, and the United States accounted for 46% of the world's talc and pyrophyllite production.

Australia.—Thames Mining NL opened its Mount Seabrook Mine in Western Australia following completion of mine planning and plant design studies. The company will produce cosmetic and industrial-grade talc.[5]

Table 6.—Talc and pyrophyllite: World production, by country[1]

(Short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Argentina (talc, steatite, pyrophyllite)	32,729	30,629	23,366	[r] [e]27,900	27,900
Australia	194,644	[r]205,867	153,652	207,287	193,000
Austria (unground talc)	134,623	147,722	144,903	146,959	143,000
Brazil (talc and pyrophyllite)[3]	437,025	455,637	426,647	463,742	468,500
Burma	141	100	141	62	66
Canada (shipments) (talc, pyrophyllite, soapstone)	106,924	138,891	139,993	135,584	155,000
Chile	702	465	1,432	2,488	2,200
China[e]	1,050,000	1,050,000	1,100,000	1,100,000	1,100,000
Colombia	7,318	7,479	9,492	20,393	20,400
Egypt	4,981	13,463	8,488	9,700	9,900
Finland	351,009	360,976	351,138	313,253	364,000
France (ground talc)	315,812	322,315	342,705	347,189	346,000
Germany, Federal Republic of (marketable)	15,773	19,030	22,835	24,123	23,100
Greece (steatite)	2,388	1,887	1,901	[e]2,000	2,050
Hungary[e]	18,700	19,300	18,700	17,700	16,500
India (pyrophyllite and steatite)	389,162	460,473	422,111	436,520	457,500
Italy (talc and steatite)	175,239	157,329	142,875	166,676	166,400
Japan[4]	1,615,791	1,652,303	1,580,978	1,470,441	1,380,000
Korea, North[e]	185,000	185,000	185,000	185,000	185,000
Korea, Republic of (talc and pyrophyllite)	696,810	935,475	1,027,880	879,291	880,000
Mexico	12,161	9,811	32,959	[e]22,000	27,500
Nepal[5]	16,825	8,372	6,630	9,678	9,900
Norway[e]	110,000	[6]124,561	[r]110,000	[r]110,000	110,000
Pakistan (pyrophyllite)	17,588	17,161	22,248	25,376	27,500
Paraguay	132	165	[e]132	[e]132	132
Peru (talc and pyrophyllite)	5,767	10,183	551	[r] [e]1,200	1,100
Philippines	968	1,022	380	[e]1,100	1,100
Portugal	6,018	6,838	3,976	4,565	4,400
Romania[e]	66,000	72,000	72,000	72,000	72,000
South Africa, Republic of[7]	12,337	15,886	15,925	14,602	14,600
Spain (steatite)	76,574	79,628	97,859	81,476	88,000
Sweden	23,210	19,712	15,432	2,205	2,200
Taiwan	29,821	20,591	19,357	23,757	22,000
Thailand (talc and pyrophyllite)	22,209	31,393	47,926	43,046	44,000
U.S.S.R.[e]	560,000	570,000	570,000	570,000	580,000
United Kingdom	17,600	21,000	22,046	13,230	13,200
United States (talc and pyrophyllite)	1,066,400	1,127,421	1,268,750	1,302,179	[6]1,349,440
Uruguay	755	1,828	[e]1,700	[e]1,700	1,700
Zambia	1,447	405	10,504	293	290
Zimbabwe	607	314	482	879	880
Total	7,781,190	[r]8,302,632	8,432,094	8,255,726	8,310,458

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through May 27, 1988.
[2]In addition to the countries listed, Czechoslovakia produces talc, but available information is inadequate to make reliable estimates of output levels.
[3]Total of beneficiated and salable direct-shipping production of talc and pyrophyllite.
[4]Includes talc, pyrophyllite, and pyrophyllite clay.
[5]Data based on Nepalese fiscal year beginning mid-July of year stated.
[6]Reported figure.
[7]Includes talc and wonderstone.

Western Mining Corp. Ltd. assumed complete control of Three Springs Talc Pty. Ltd. Three Springs Talc operated one of the world's largest talc mines. The talc was used in ceramics, paint, paper, and plastics.[6]

Canada.—Carey Canada Inc. discovered a large, high-grade talc deposit near East Boughton, Quebec. The deposit contains 78% to 80% talc. Mine reserves were estimated to be 8.8 million tons. The company planned additional studies of the deposit to determine its commercial potential.[7]

China.—A deposit estimated to contain 18 million tons of pyrophyllite was discovered in the Fujian Province.[8]

Korea, Republic of.—The Department of Energy and Resources discovered a talc deposit near Kongju. Reserves were estimated to be 10 million tons.[9]

United Kingdom.—Shetland Talc Ltd., jointly owned by Dalriada Mineral Ventures Ltd. and Anglo-European Minerals Ltd., continued exploratory work on a talc-magnesite deposit in the Shetland Islands. Samples were collected and tested in a pilot plant operation.[10]

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[1]Physical scientist, Branch of Industrial Minerals.

[2]Federal Register. Occupational Safety and Health Administration. Occupational Exposure to Asbestos, Tremolite, Anthophyllite, and Actinolite. V. 52, No. 83, Apr. 30, 1987, pp. 15722-15723.

[3]Benbow, J. European Paper. Ind. Miner. (London), No. 243, Dec. 1987, pp. 73-89.

[4]Schober, W. Talc in Europe. Ind. Miner. (London), No. 237, June 1987, pp. 40-51.

[5]Mining Journal (London). More Talc From Thames. V. 309, No. 7946, Dec. 4, 1987, p. 458.

[6]Industrial Minerals (London). Three Springs Talc Takeover. No. 231, Jan. 1987, p. 9.

[7]Rock Products. Large Talc Deposit Found in Canada. V. 90, No. 8, Aug. 1987, p. 16.

[8]Industrial Minerals (London). Fujian Pyrophyllite Discovery. No. 239, Aug. 1987, p. 83.

[9]———. South Korean Talc Deposits. No. 239, Aug. 1987, p. 83.

[10]———. Talc Development in the Shetlands. No. 236, May 1987, p. 15.

Thorium

By James B. Hedrick[1]

Mine production of monazite, the principal source of thorium, decreased slightly in 1987 from the only domestic monazite producer. Monazite produced in the United States was exported, and thorium products used domestically were derived from imported materials, existing company stocks, and thorium nitrate previously released from the National Defense Stockpile (NDS).

Major nonenergy uses were in aerospace alloys, mantles for incandescent lanterns, welding electrodes, and refractory applications. The only energy use of thorium in the United States was in the high-temperature gas-cooled (HTGC) nuclear reactor at Fort St. Vrain, CO. High-technology applications included investment molds for casting high-temperature metals and alloys and as thoriated tungsten elements in microwave magnetron tubes.

Domestic Data Coverage.—Domestic mine production data for thorium-bearing monazite are developed by the Bureau of Mines from a voluntary survey of U.S. operations, the "Rare Earths and Thorium" survey. The one mine to which a survey form was sent responded, representing 100% of total production. Mine production data for thorium contained in monazite are withheld to avoid disclosing company proprietary data. Additional statistics on thorium were developed by surveying various processors and end users, and evaluating import-export reports.

Table 1.—Salient U.S. thorium statistics[1]

(Metric tons of ThO_2, unless otherwise specified)

	1983	1984	1985	1986	1987
Exports: Metal, waste and scrap	1.06	1.01	1.64	17.01	20.41
Imports: Compounds, gas mantles, metals	45.80	45.37	69.34	19.71	30.69
Shipments from Government stockpile excesses	--	--	2.17	--	--
Consumption, apparent nonenergy applications[e 2]	44.74	44.36	74.36	72.38	39.41
Prices, yearend, dollars per kilogram, ThO_2:[3]					
Nitrate, mantle-grade	$10.60	$10.10	$10.10	$13.60	$10.10
Oxide, 99% grade	$31.00	$35.85	$35.85	$40.00	$41.00

[e]Estimated.
[1]Some data through 1985 have been revised to reflect only refined products; excludes monazite concentrates with 1985.
[2]All domestically consumed thorium was derived from imported metals, alloys, and compounds; monazite containing 350 to 550 tons of thorium oxide has been imported annually but has not been recently used to produce thorium products.
[3]Rhône-Poulenc Inc.

Legislation and Government Programs.—Sales of materials held in the NDS, including thorium nitrate, continued to be suspended during 1987 because the $250 million limit imposed on the NDS Transaction Fund was exceeded during 1985. Two laws governed the disposal of thorium nitrate from the NDS in 1987. The Department of Defense Authorization Act, 1987, (Public Law 99-661), authorized a total of 4,536 kilograms (10,000 pounds) of thorium nitrate for disposal in fiscal year 1987. In fiscal year 1988, beginning October 1, 1987, the Department of Defense Authorization Act for fiscal years 1988 and 1989 (Public Law 100-180) continued authorization that was in effect on September 30, 1987. Public Law 100-180, signed on December 4, 1987, also authorized the President of the United States to change the stockpile requirements by less than 10% without congressional approval. However, an explanation and justification of changes were to be submitted to Congress, effective on or after the first day of the next fiscal year. Changes greater than 10% would require congressional approval.

DOMESTIC PRODUCTION

Associated Minerals, a subsidiary of the Australian-owned firm Associated Minerals Consolidated Ltd., a wholly owned subsidiary of Renison Goldfields Consolidated Ltd. (RGC) of Australia, was the only commercial minerals sands operation in the United States to produce monazite in 1987. Monazite was produced as a byproduct of minerals sands mined for titanium and zirconium minerals at Green Cove Springs, FL. W. R. Grace & Co., Davison Chemical Div., and Rhône-Poulenc Inc., a subsidiary of Rhône-Poulenc S.A. of France, were the principal processors of thorium-containing ores in the United States.

Table 2.—U.S. companies with thorium processing and fabricating capacity

Company	Plant location	Operations and products
Atomergic Chemetals Corp	Plainview, NY	Produces oxide, fluoride, metal.
Bettis Atomic Power Laboratory	West Mifflin, PA	Nuclear fuels; Government research and development.
Cerac Inc	Milwaukee, WI	Produces ceramics.
Ceradyne Inc	Santa Ana, CA	Produces advanced technical ceramics.
Chicago Magnesium Castings Co	Blue Island, IL	Magnesium-thorium alloys.
Coleman Co. Inc	Wichita, KS	Produces thoriated mantles.
Controlled Castings Corp	Plainview, NY	Magnesium-thorium alloys.
GA Technologies Inc	San Diego, CA	Nuclear fuels.
W. R. Grace & Co., Davison Chemical Div	Chattanooga, TN	Produces thorium compounds from monazite.
GTE Sylvania	Towanda, PA	Produces thoriated welding rods.
Hitchcock Industries Inc	South Bloomington, MN	Magnesium-thorium alloys.
Phillips Elmet	Lewiston, ME	Produces thoriated welding rods.
Rhône-Poulenc Inc	Freeport, TX	Produces thorium nitrate from an intermediate compound of monazite.
Spectrulite Consortium Inc	Madison, IL	Magnesium-thorium alloys.
Teledyne Cast Products	Pomona, CA	Do.
Teledyne Wah Chang	Huntsville, AL	Produces thoriated welding rods.
Union Carbide Corp., Nuclear Div	Oak Ridge, TN	Nuclear fuels; test quantities.
Wellman Dynamics Corp	Creston, IA	Magnesium-thorium alloys.
Westinghouse Materials Co. of Ohio[1]	Cincinnati, OH	Produces compounds and metals; manages DOE thorium stocks.

[1]Manager of U.S. Department of Energy stocks; formerly NLO Inc., prior to Jan. 1, 1986.

CONSUMPTION AND USES

Domestic thorium users reported consumption of an estimated 39.4 metric tons of thorium oxide equivalent in 1987, a decrease of 33 tons from the 1986 level. Nonenergy uses accounted for almost all of the total. The drop in consumption was primarily the result of reduced demand for thorium oxide used in high-temperature refractory molds, because suitable substitutes had been developed. Domestic environmental concerns over thorium's natural radioactivity substantially increased the industry's handling, storage, and disposal costs, which were expected to continue to encourage the search for nonradioactive substitutes. The approximate distribution of thorium by end use, based on information supplied by producers, primary processors, and several consumers, was as follows: refractory applications, 57%; lamp mantles, 18%; aerospace alloys, 15%; welding electrodes, 5%; and other applications, including ceramics and lighting, 5%.

Almost all thorium used in metallurgical applications was alloyed with magnesium. Magnesium-thorium alloys used by the aerospace industry are lightweight and posess high strength and excellent creep resistance at elevated temperatures, properties that are useful in aerospace applications. Small quantities of thorium were used in dispersion-hardened nickel alloys for high-strength, high-temperature applications.

Thorium oxide (thoria) had the highest melting point of all the oxides at 3,300° C, a property that contributed to its use in several refractory applications, including high-strength, high-temperature ceramics; investment molds; crucibles; and research on heat-dissipative core-retention beds for nuclear reactors.

Thorium nitrate was used in the manufacture of mantles for incandescent "camping" lanterns and for oil lamps. Thorium nitrate was also used to produce thoriated tungsten welding electrodes. Thoriated tungsten electrodes were used to join stainless steels, nickel alloys, and other alloys that usually require a continuous and stable arc to achieve quality welds. The nitrate form was also used to produce thoriated tungsten elements used in the negative pole of magnetron tubes. Thorium was used because of its ability to emit electrons at relatively low temperatures when heated in a vacuum. Magnetron tubes were used to emit electrons at microwave frequencies to heat food in microwave ovens and in radar communication.

Thorium was used in other types of electron-emitting tubes, in bulbs to light airport runways, in special high-refractivity glass, in radiation detectors, in computer memory components, in catalysts, in photoconductive films, in target materials for X-ray tubes, and in fuel cell elements.

In energy applications, thorium was used as a nuclear fuel in the thorium-232/uranium-233 fuel cycle in one domestic commercial reactor.

STOCKS

Government stocks of thorium nitrate in the NDS were 3,230,400 kilograms (1,544,845 kilograms of equivalent thorium oxide) on December 31, 1987, unchanged from the yearend 1985 inventory. The NDS goal at yearend was 272,155 kilograms of thorium nitrate (130,153 kilograms of equivalent thorium oxide); remaining stocks have been declared excess to the goal.

The U.S. Department of Energy's inventory at yearend was 1,244,048 kilograms of thorium oxide equivalent contained in ore, metal, and various compounds.

PRICES

The average declared value of imported monazite increased during 1987 to $560 per ton, up $186 from the 1986 value. The price range of Australian monazite (minimum 55% rare-earth oxide including thoria, f.o.b.-f.i.d.),[2] as quoted in Australian dollars (A$)[3] decreased from US$565-US$598[4] per ton at yearend 1986, to US$477-US$513[5] per ton by yearend 1987. Changes in the United States-Australian foreign exchange rate in 1987, resulting from the economic weakness of the U.S. dollar against Australian currency, caused the corresponding U.S. prices to be about $0.12 higher on the dollar.

The yearend price for monazite, based on a thorium oxide content of 7%, was in the range of $6.81 to $7.34 per kilogram of thorium oxide contained.

Rhône-Poulenc Inc. quoted prices for thorium compounds per kilogram, net 30 days, f.o.b. Freeport, TX, or duty paid at point of entry, effective January 1, 1987, as follows: thorium oxide, 99% purity, $44.00; and 99.99% purity, $68.00. Thorium nitrate at 99.5% purity (mantle-grade) was quoted at $13.87 per kilogram.

Thorium alloy prices quoted by Magnesium Elektron at yearend 1987 were $35.89 per pound for thorium hardener in single drum quantities and $4.97 per pound for thorium-containing HZ-32 alloy ingot.

Table 3.—U.S. foreign trade in thorium and thorium-bearing materials

(Quantity in kilograms unless otherwise specified)

	1985		1986		1987		Principal destinations and sources, 1987
	Quantity	Value	Quantity	Value	Quantity	Value	
EXPORTS							
Thorium ore, monazite	743,103	$415,024	581,854	$326,846	582,995	$427,838	France 582,076; Japan 919.
Metals[1]	1,440	182,373	14,949	954,604	17,961	402,370	United Kingdom 11,493; Federal Republic of Germany 5,000; Sweden 461; other 1,007.
IMPORTS							
Ore and concentrate:							
Thorium ore, monazite ___ metric tons	5,694	1,984,486	2,960	1,105,996	1,121	627,312	Thailand 594; Malaysia 527.
ThO_2 content	398,580	XX	211,700	XX	78,470	XX	
Compounds:							
Nitrate	16,848	210,910	21,534	283,841	34,670	653,986	France 19,248; India 15,422.
Oxide	50,777	841,331	7,084	166,334	11,625	346,218	France 7,399; Netherlands 4,226.
Oxide equivalent, in gas mantles[e] [2]	1,877	449,112	1,668	495,797	1,824	606,344	India 485; Malta 452; Malaysia 427; Taiwan 211; Israel 100; other 149.
Other	499	171,463	658	187,119	656	250,355	United Kingdom 637; Switzerland 19.
Metals and alloys	62,805	NA	60,062	NA	22,019	NA	All from United Kingdom.
Unwrought and wrought and waste and scrap	680	18,334	--	--	1,149	37,999	United Kingdom 1,149.

[e]Estimated. NA Not available. XX Not applicable.
[1]Unwrought and wrought and waste and scrap.
[2]Based on the manufacture of 2,205 gas mantles per kilogram of thorium oxide.

Sources: Bureau of the Census and a producer.

FOREIGN TRADE

France had been the only destination of U.S. exports of thorium ore, including monazite, from 1980 to 1986. However, in 1987, Japan and France were recipients of U.S. exports of thorium ore, including monazite. Thorium products processed and manufactured in the United States in 1987 were derived mainly from imported materials, primarily thorium compounds and rare-earth concentrates from France and India, and magnesium-thorium alloys from the United Kingdom.

WORLD REVIEW

Australia.—The Mineral Sands Div. of RGC announced that exploration west of its Allied Eneabba Mine, Western Australia, was successful in locating mineral sands resources of 150 million tons grading 3.5% heavy minerals. Further exploration in the area is planned. To optimize mining at its Eneabba properties, RGC reportedly will mine selected areas by dredging instead of by its present dry mining method. RGC also completed redesign of its mineral-sands-processing plant at Eneabba, which allowed increased recovery of all minerals, including thorium-bearing monazite.[6]

RGC continued exploration on Moreton Island, Queensland. The Queensland government adopted the recommendation of a report that would allow mining on 1,200 hectares (6.4%) of the island as short-term use.[7]

Western Australia's government announced that Rhône-Poulenc S.A., was to build a rare-earth separation plant at Pinjarra, Western Australia. The plant reportedly will process monazite by liquid solvent extraction to produce rare earths and byproduct thorium.[8]

Mineral Deposits Ltd., a subsidiary of The Broken Hill Pty. Co. Ltd., announced the opening of a heavy-mineral-sands mining operation at Viney Creek, New South Wales, in mid-1987. Mineral Deposits recovered heavy-mineral sands, including thorium-containing monazite, using twin dredges connected to a floating wet concentrator. Monazite and other heavy-mineral concentrates were produced at Mineral Deposits' nearby Hawks Nest dry concentrator plant.[9]

TiO_2 Corp. completed feasibility studies of its heavy-mineral sands deposit at Cooljarloo, Western Australia, and declared it viable. The deposit reportedly contains 12 million tons of ore, with a cutoff grade of 2% heavy minerals.[10]

A rare-earth and thorium deposit was discovered in the Northern Territory. Located 100 kilometers east of Alice Springs, the deposit reportedly contains significant quantities of rare earths and thorium in the mineral allanite. As part of an Australian consortium formed to study the deposit, Australia's Commonwealth Scientific and Industrial Research Organization is undertaking prefeasibility studies.[11] West Coast Holdings Ltd. announced plans to install a pilot plant at its Brockman multimineral deposit in Western Australia. The deposit reportedly contains thorium, rare earths, yttrium, gallium, zirconium, hafnium, tantalum, and niobium. The Brockman deposit, 15 kilometers southeast of Halls Creek, is a joint venture of West Coast Holdings and Greater Pacific Investments Ltd. If additional studies prove mining is feasible, a $115 million plant to process 200,000 tons per year of ore was planned.[12]

Brazil.—Production of monazite concentrate in 1985 was 3,953 tons, 281 tons from the State of Espírito Santo, a decrease from the 451 tons produced in 1984, and 3,672 tons from the State of Rio de Janerio, an increase from the 1984 production of 3,161 tons.

Measured reserves of monazite were 17,274 tons. Estimated thorium oxide content based on these reserves is 1,123 tons. Monazite reserves were in the States of Bahia, Espírito Santo, Paraná, and Rio de Janeiro.[13]

Madagascar.—QIT-Fer et Titane Inc. (QIT) of Canada announced it had completed initial feasibility studies of a heavy-mineral sands deposit in southeast Madagascar. The joint venture project is 51% owned by the Government of Madagascar and 49% by QIT. The drilling program has confirmed the existence of an ore body containing mineral sands, including thorium-bearing monazite. Further drilling and the construction of a pilot plant at the site were planned.[14]

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[1]Physical scientist, Branch of Nonferrous Metals.
[2]Free on board/free into container depot.

[3]Metal Bulletin (London). Non-Ferrous Ores in Europe. Dec. 31, 1987, p. 29.

[4]Values have been converted from Australian dollars (A$) to U.S. dollars (US$) at the exchange rate of A$1.5053=US$1.00 based on yearend 1986 foreign exchange rates reported by the Wall Street Journal.

[5]Values have been converted from Australian dollars (A$) to U.S. dollars (US$) at the exchange rate of A$1.3841=US$1.00 based on yearend 1987 foreign exchange rates reported by the Wall Street Journal.

[6]Renison Goldfields Consolidated Ltd. Annual Report 1987. 44 pp.

[7]Industrial Minerals (London). More on Moreton Island Minsands. No. 237, June 1987, p. 8.

[8]———. Rhône-Poulenc To Develop Rare-Earths Plant. Mar. 1987, p. 9.

[9]———. Mineral Deposits Up and Running. No. 237, June 1987, p. 8.

[10]———. TiO_2 Corp. Declares Cooljarloo Minsands Viable. No. 237, June 1987, p. 8.

[11]———. Potential Rare Earth Deposit. No. 243, Dec. 1987, p. 9.

[12]Australian Mining. Rare Earth Plant Under Study for Western Australia. Sept. 1987, p. 47.

[13] Anuário Mineral Brasileiro 1986. Monazita. 391 pp.

[14]Industrial Minerals (London). QIT Expanding Heavy Minerals Project. No. 236, May 1987, p. 15.

Table 4.—Monazite concentrate: World production, by country[1]

(Metric tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Australia	15,141	16,260	18,735	14,822	12,000
Brazil	5,256	3,622	1,895	1,947	2,000
India[e]	4,000	4,000	4,000	4,000	4,000
Malaysia[3]	1,051	[r]4,980	5,808	5,959	6,000
Mozambique[e]	[4]4	4	4	4	4
Sri Lanka[e]	300	[4]147	200	200	200
Thailand	277	298	245	1,609	1,500
United States	W	W	W	W	W
Zaire	15	2	--	--	--
Total	26,044	[r]29,313	30,887	28,541	25,704

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

[1]Table includes data available through Apr. 29, 1988.

[2]In addition to the countries listed, China, Indonesia, North Korea, the Republic of Korea, Nigeria, and the U.S.S.R. 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.

[3]The 1983 figure is exports and 1984-87 figures are production.

[4]Reported figure.

Tin

By James F. Carlin, Jr.[1]

For the seventh consecutive year, there was a world excess of tin. The excess in 1987 was reduced to about one-half from that of 1986, as world mine production stabilized and world consumption increased. Repercussions from the exhaustion of the International Tin Council (ITC) fund to support the tin price in late 1985 continued throughout 1987. Legal actions continued against the London Metal Exchange (LME) and the ITC, brought by tin dealers and banks who had lost money allegedly due to activities of the LME and ITC in late 1985. The price of tin ranged in a narrow band somewhat higher than in 1986, but was still well below the level of recent years. The continuation of relatively low prices led to additional restructuring of tin-mining operations in many producing countries with several mine closures and resultant unemployment.

Table 1.—Salient tin statistics

(Metric tons unless otherwise specified)

	1983	1984	1985	1986	1987
United States:					
Production:					
Mine	W	W	W	W	W
Smelter	2,500	4,000	e3,000	3,213	13,905
Secondary	14,205	15,417	14,109	r14,850	15,793
Exports[2]	1,340	1,429	1,478	1,547	1,318
Imports for consumption:					
Metal	34,048	41,224	33,830	35,768	41,150
Ore (tin content)	969	3,272	1,616	3,936	2,953
Consumption:					
Primary	34,301	r37,201	r36,524	r33,324	35,597
Secondary	11,246	r11,114	r12,145	r10,198	8,599
Stocks, yearend, U.S. industry	9,859	r9,679	r12,359	r13,857	14,641
Prices, average cents per pound:					
New York market	601.28	567.80	525.90	294.12	309.01
Metals Week composite	654.78	623.80	3595.95	r 3383.22	418.78
London	589.19	556.55	3556.26	NA	NA
Kuala Lumpur[4]	590.78	564.95	3540.70	3272.26	303.45
World: Production:					
Mine	r196,942	r198,463	188,635	p179,377	e179,713
Smelter	200,124	r201,555	197,836	p191,403	e189,556

eEstimated. pPreliminary. rRevised. NA Not available. W Withheld to avoid disclosing company proprietary data; U.S. mine production for 1983-87 was negligible.
1Reported figure.
2Exports (excluding reexports).
3Prices quoted for 10 months only.
4Beginning in 1985, Kuala Lumpur replaced Penang as the reference market.

Domestic Data Coverage.—Domestic production data for tin are developed by the Bureau of Mines from a voluntary survey of U.S. mines. Of the four mines to which a survey form was sent, all responded. Domestic production, which was negligible, was withheld to avoid disclosing company proprietary data.

Legislation and Government Programs.—The General Services Administration (GSA) sold 4,080 metric tons of tin in 1987, all of which represented payment material for GSA's Ferroalloy Upgrading Program, which started April 11, 1984.

At yearend, the National Defense Stockpile inventory was 177,053 tons; the stockpile goal was 42,674 tons.

Federal laws provided a depletion allowance of 22% for domestic operations and 14% for U.S. companies producing in other countries.

The U.S. Environmental Protection Agency (EPA) issued a Preliminary Determination on October 7, 1987, to ban all tributyl tin antifouling marine paints that have specified leaching or release rates. The EPA finding carried a 90-day comment period, offering rebuttal from concerned parties.

DOMESTIC PRODUCTION

PRIMARY TIN

Mine Production.—One mine operating in Alaska produced tin concentrates. Domestic mine production data were withheld to avoid disclosing company proprietary data, but total output amounted to only a small fraction of domestic tin requirements.

Smelter Production.—The only domestic tin smelter, Tex Tin Corp., in Texas City, TX, increased tin metal output. The smelter recovered tin primarily from imported and domestic concentrates, as well as some secondary tin-bearing materials, and its own stockpile of tin residues and slags. The smelter's main source of tin concentrates was Peru. The facility also produced a line of solders.

SECONDARY TIN

The United States was believed to be the world's largest producer of secondary tin. Tin metal recovered from tinplate scrap was the only type of secondary tin available as free tin; other secondary tin was available in scrap materials as an alloying ingredient. Secondary tin from recycled fabricated parts was an important source of material for the solder and the brass and bronze industries. The Steel Can Recycling Association in Pittsburgh, PA, funded and operated by five domestic tinplate producers, sought to advance the collection, preparation, and transportation of can scrap.

Table 2.—Secondary tin recovered from scrap processed at detinning and other plants in the United States

	1986	1987
Tinplate scrap treated — metric tons	499,652	506,514
Tin recovered in the form of:		
Metal — do.	1,134	1,151
Compounds (tin content) — do.	W	W
Total — do.	1,134	1,151
Weight of tin compounds produced — do.	W	W
Average quantity of tin recovered per metric ton of tinplate scrap used — kilograms	r2.25	2.23
Average delivered cost of tinplate scrap — per metric ton	$44.76	$44.15

rRevised. W Withheld to avoid disclosing company proprietary data.

Table 3.—Tin recovered from scrap processed in the United States, by form of recovery

(Metric tons unless otherwise specified)

Form of recovery	1986	1987
Tin metal[1]	1,134	1,151
Bronze and brass[e 2]	[r]8,869	10,082
Lead and tin alloys:		
Antimonial lead	891	623
Babbitt	66	76
Solder	3,676	3,765
Type metal	197	66
Other alloys[3]	17	30
Total	4,847	4,560
Tin content of chemical products	W	W
Grand total	[r]14,850	15,793
Value (thousands)[e 4]	$125,461	$145,809

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Includes tin metal recovered at detinning and other plants.
[2]Includes tin recovered from copper, lead, and tin-base scrap.
[3]Includes foil, terne metal, and cable lead.
[4]Based on Metals Week composite price.

Table 4.—U.S. stocks, receipts, and consumption of new and old scrap and tin recovered, by type of scrap

(Metric tons)

Type of scrap	Gross weight of scrap						Tin recovered[e 1]		
	Stocks, Jan. 1	Receipts	Consumption			Stocks, Dec. 31			
			New	Old	Total		New	Old	Total
1986[r]									
Copper-base scrap	9,489	134,056	10,194	123,086	133,280	10,265	416	4,743	5,159
Brass mills[2]	2,731	7,044	7,017	27	7,044	2,464	224	--	224
Foundries and other plants	3,464	26,221	5,845	17,470	23,315	6,370	274	720	994
Total tin from copper-base scrap	XX	XX	XX	XX	XX	XX	914	5,463	6,377
Lead-base scrap	39,501	778,359	66,024	722,251	788,275	29,585	1,730	5,311	7,041
Tin-base scrap[3]	21	139	W	95	95	65	1,345	87	1,432
Grand total	XX	XX	XX	XX	XX	XX	3,989	10,861	14,850
1987									
Copper-base scrap	10,265	142,137	11,393	131,672	143,065	9,337	475	5,105	5,580
Brass mills[2]	2,464	43,884	43,871	W	43,871	2,894	596	--	596
Foundries and other plants	6,370	26,080	7,568	18,390	25,958	6,492	357	794	1,151
Total tin from copper-base scrap	XX	XX	XX	XX	XX	XX	1,428	5,899	7,327
Lead-base scrap	29,585	893,250	68,586	818,429	887,015	35,820	1,795	5,379	7,174
Tin-base scrap[3]	65	49	W	92	92	22	1,207	85	1,292
Grand total	XX	XX	XX	XX	XX	XX	4,430	11,363	15,793

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data. XX Not applicable.
[1]Tin recovered from new and old copper-base scrap, brass mills, and foundries.
[2]Brass-mill stocks include home scrap, and purchased scrap consumption is assumed equal to receipts; therefore, line does not balance.
[3]Includes tinplate and other scrap recovered at detinning plants; Bureau of Mines not at liberty to publish separately.

CONSUMPTION AND USES

Primary tin consumption increased over that of 1986, mainly owing to gains in tinplate and tin chemicals. Solder was the largest application of primary tin, followed closely by tinplate. Tinplate consumption experienced its first increase in many years as its cost advantage relative to competitive materials for containers became significant, and as tinplate exports surged owing to the lower dollar value.

Tinplate continued to lose markets to aluminum in some container applications. Tinplated steel and tin-free steel accounted for 31% of the 109.2 billion metal cans shipped, and aluminum accounted for 69%. In 1986, when steel accounted for 33% and aluminum for 67%, 104.9 billion metal cans were shipped. Aluminum held an overwhelming segment of the beverage can market, while steel predominated in the food can and the general packaging markets.[2]

Secondary consumption declined as low prices for primary tin made secondary material less attractive.

Table 5.—U.S. consumption of primary and secondary tin

(Metric tons)

	1983	1984[r]	1985[r]	1986[r]	1987
Stocks, Jan. 1[1]	7,549	8,063	8,430	9,336	9,876
Net receipts during year:					
Primary	36,494	38,813	38,006	35,475	38,446
Secondary	5,412	6,110	8,904	11,636	11,707
Scrap	7,435	6,791	7,471	6,346	6,635
Total receipts	49,341	51,714	54,381	53,457	56,788
Total available	56,890	59,777	62,811	62,793	66,664
Tin consumed in manufactured products:					
Primary	34,301	37,201	36,524	33,324	35,597
Secondary	11,246	11,114	12,145	10,198	8,599
Total	45,547	48,315	48,669	43,522	44,196
Intercompany transactions in scrap	245	317	214	354	512
Total processed	45,792	48,632	48,883	43,876	44,708
Stocks, Dec. 31 (total available less total processed)	11,098	11,145	13,928	18,917	21,956

[r]Revised.
[1]Includes tin in transit in the United States.

Table 6.—Tin content of tinplate produced in the United States

Year	Tinplate waste (waste, strips, cobbles, etc., gross weight) (metric tons)	Tinplate (all forms): Gross weight (metric tons)	Tinplate (all forms): Tin content[1] (metric tons)	Tinplate (all forms): Tin per metric ton of plate (kilograms)
1983	166,186	2,586,810	9,328	3.6
1984[r]	151,540	2,409,399	8,659	3.6
1985	146,041	2,215,042	9,321	4.2
1986[r]	120,186	2,068,246	8,660	4.2
1987	118,870	2,275,984	10,357	4.6

[r]Revised.
[1]Includes small tonnage of secondary tin and tin acquired in chemicals.

Table 7.—U.S. consumption of tin, by finished product

(Metric tons of contained tin)

Product	1986[r] Primary	1986[r] Secondary	1986[r] Total	1987 Primary	1987 Secondary	1987 Total
Alloys (miscellaneous)[1]	W	W	W	W	W	W
Babbitt	966	358	1,324	850	210	1,060
Bar tin	449	W	449	703	--	703
Bronze and brass	1,781	1,721	3,502	1,835	1,724	3,559
Chemicals	W	W	W	W	W	W
Collapsible tubes and foil	W	W	W	W	W	W
Solder	11,955	3,855	15,810	10,928	4,312	15,240
Tinning	1,437	W	1,437	1,398	W	1,398
Tinplate[2]	8,660	W	8,660	10,357	W	10,357
Tin powder	1,002	W	1,002	W	W	W
Type metal	W	W	W	W	W	W
White metal[3]	1,067	67	1,134	1,175	W	1,175
Other	6,007	4,197	10,204	8,351	2,353	10,704
Total	33,324	10,198	43,522	35,597	8,599	44,196

[r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Includes terne metal.
[2]Includes secondary pig tin and tin acquired in chemicals.
[3]Includes pewter, britannia metal, and jewelers' metal.

Table 8.—U.S. industry yearend tin stocks

(Metric tons)

	1983	1984[r]	1985[r]	1986[r]	1987
Plant raw materials:					
Pig tin:					
Virgin[1]	6,326	5,490	5,712	5,754	6,643
Secondary	732	1,562	2,342	3,021	2,333
In process[2]	682	1,124	1,342	1,377	1,289
Total	7,740	8,176	9,396	10,152	10,265
Additional pig tin:					
Jobbers-importers	608	802	1,642	1,272	1,890
Afloat to United States	1,511	701	1,321	2,433	2,486
Total	2,119	1,503	2,963	3,705	4,376
Grand total	9,859	9,679	12,359	13,857	14,641

[r]Revised.
[1]Includes tin in transit in the United States.
[2]Data represent scrap only, tin content.

PRICES

The price of tin metal, as published in Metals Week, remained in a narrow price band all year, still in a historically low range well below the levels achieved during the past decade.

Table 9.—Monthly composite price of Straits tin for delivery in New York

(Cents per pound)

Month	1986 High	1986 Low	1986 Average	1987 High	1987 Low	1987 Average
January	NA	NA	NA	421.82	414.43	418.49
February	NA	NA	NA	422.11	411.89	417.15
March	515.68	392.94	455.79	420.25	409.11	414.01
April	372.20	350.56	364.25	421.17	414.85	418.30
May	363.23	345.22	352.24	423.66	419.43	421.79
June	350.91	343.86	346.61	418.54	408.97	414.49
July	351.53	342.38	346.52	410.52	396.99	403.09
August	351.25	344.14	347.01	421.11	403.35	411.48
September	347.44	343.21	345.83	421.87	418.93	420.73
October	382.68	343.81	353.87	431.49	416.21	424.80
November	395.05	374.16	384.22	438.92	427.37	433.28
December	411.02	393.19	402.77	431.29	425.06	427.77
Average[1]	XX	XX	r [1]383.22	XX	XX	418.78

rRevised. NA Not available. XX Not applicable.
[1]Prices quoted for 10 months only.

Source: Metals Week.

FOREIGN TRADE

Imports for consumption of tin concentrates decreased, indicating the tight supply situation for concentrates worldwide. For many years, there has existed a world excess of tin-smelting capacity compared with tin mine capacity. Imports of tin metal increased, with Brazil remaining the major source by a wide margin, followed by China, Malaysia, Indonesia, and Bolivia. China tripled its imports to the United States compared with those of the prior year. During the year, a trend emerged of foreign producers direct marketing their own refined tin metal to U.S. consumers, thus bypassing the traditional independent broker route. This approach was utilized by producers in Australia, China, and Indonesia. Imports of tin in all forms (ore and concentrate, metal, and waste and scrap) remained free of U.S. duty.

Table 10.—U.S. imports for consumption and exports of miscellaneous tin, tin manufactures, and tin compounds

Year	Miscellaneous tin and tin manufactures				Tin compounds	
	Imports			Exports	Imports	
	Tinfoil, tin powder, flitters, metallics, tin and manufactures, n.s.p.f.	Dross, skimmings, scrap, residues, 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)		
1985	$3,290	877	$2,804	$18,357	827	$5,164
1986	1,280	1,121	1,899	19,843	860	5,165
1987	1,854	2,270	9,241	13,549	838	5,162

Source: Bureau of the Census.

Table 11.—U.S. exports and imports for consumption of tin, tinplate, and terneplate in various forms; exports of ingots, pigs, bars; imports of tinplate scrap

Year	Ingots, pigs, bars		Tinplate and terneplate				Tinplate scrap	
	Exports		Exports[1]		Imports		Imports	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1985	1,478	$16,744	155,119	$85,000	381,137	$222,504	3,815	$441
1986	1,547	9,742	219,074	91,793	344,973	199,484	2,375	242
1987	1,318	9,456	209,526	106,156	329,783	193,110	2,543	380

[1]Tinplate circles, strips, and cobbles are included with exports of tinplate and terneplate.

Source: Bureau of the Census.

Table 12.—U.S. imports for consumption of tin, by country

Country	1986		1987	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Concentrates (tin content):				
Bolivia	259	$2,344	732	$1,755
Canada	1	1	--	--
Peru	3,676	11,348	2,165	7,596
Zaire	--	--	56	158
Total	3,936	13,693	2,953	9,509
Metal:[1]				
Austria	--	--	60	389
Australia	94	691	1,406	9,596
Belgium	--	--	302	2,005
Belize	99	505	--	--
Bolivia	4,893	28,943	3,476	10,579
Brazil	9,456	62,334	13,089	87,306
British Indian Ocean Territory	--	--	20	136
Burma	--	--	20	119
Canada	32	252	43	197
Chile	1,776	11,291	39	118
China	2,955	19,681	8,044	52,152
Denmark	--	--	90	609
France	35	190	40	267
Germany, Federal Republic of	18	62	([2])	4
Greece	--	--	3	3
Hong Kong	422	2,593	714	4,227
India	850	6,006	220	1,432
Indonesia	4,149	27,973	4,001	27,339
Iran	60	365	--	--
Israel	2	20	--	--
Italy	75	630	--	--
Japan	100	651	60	394
Korea, Republic of	--	--	1	5
Malaysia	6,230	43,221	4,959	32,499
Mexico	432	2,075	727	5,018
Netherlands	471	2,578	379	2,555
Nigeria	--	--	79	527
Seychelles	--	--	20	41
Singapore	691	5,163	743	5,036
Somalia	--	--	122	799
South Africa, Republic of	35	332	--	--
Switzerland	--	--	490	3,234
Taiwan	135	851	--	--
Thailand	1,901	13,965	1,460	9,452
United Arab Emirates	--	--	40	257
United Kingdom	730	4,363	467	3,178
Zaire	5	98	--	--
Zimbabwe	123	669	35	226
Total[3]	35,768	235,506	41,150	259,699

[1]Bars, blocks, pigs, or granulated.
[2]Less than 1/2 unit.
[3]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

WORLD REVIEW

The Sixth International Tin Agreement, which commenced on July 1, 1982, continued in effect throughout 1987, although its operations were restricted. Many high-level permanent employees of the ITC departed during the year and only a skeletal staff remained. The United States was not a member of the agreement.

Legal actions continued to be conducted on behalf of tin dealers and banks that had lost money, allegedly owing to activities of the LME and the ITC in late 1985, as the ITC utilized borrowed funds to support the tin price.

The Association of Tin Producing Countries (ATPC), comprising seven major producer nations—Australia, Bolivia, Indonesia, Malaysia, Nigeria, Thailand, and Zaire—completed its fourth year as an organization. ATPC viewed itself as being complementary to, and supportive of, the activities of the ITC, and the organization continued to persuade its member countries to restrain tin production and exports until a world supply-demand equilibrium was achieved. Industry sources estimated the world tin surplus at about 40,000 tons at yearend 1987.

Australia.—The Renison Bell Mine in Tasmania, owned by Renison Consolidated Goldfields Ltd., increased tin output and accounted for an estimated 90% of Australia's tin mine production as numerous smaller tin mines closed during the year due to the relatively low tin price. The Renison Mine was the world's largest hard-rock underground tin mine and was a relatively low-cost producer with substantial high-grade reserves. Renison operated at its full capacity of 850,000 tons of tin ore throughput. The entire tin concentrate output from Renison was reportedly toll smelted in Malaysia. During 1987, Renison commenced a program of direct sales of most of its refined tin metal to user firms in industrialized countries, including large tonnages to U.S. companies.

Greenbushes Ltd. continued to mine tin and tantalum, with throughput increasing to 1.4 million tons of ore. Tin output declined to 400 tons, and the overall operating rate was 40% below capacity. The firm expected improved tantalum prices in 1988 and planned to recommission its tailings retreatment plant, which would increase tin and tantalum concentrate production.

Great Northern Mining Corp. Ltd. ceased tin production in mid-1987, placing its Jumna mill near Irvinebank, Queensland, on care and maintenance until tin prices improved. During 1987, the firm produced 308 tons of tin-in-concentrate.

The Tolltreck Metal Products Ltd. tin smelter in Sydney and the Greenbushes tin smelter, at their tin-tantalum mine near Bunbury, reduced smelting operations to a part-time basis due to shortages of concentrates.

Kokan Mining Co. Ltd., a subsidiary of Nippon Kokan K.K. of Japan, and Greenbushes Tin Ltd. of Australia announced plans for a joint venture to mine tin and tantalum ore in the Pilbara mining district of Western Australia beginning in 1988. The deposits were about 200 kilometers south of Port Hedland.

Bolivia.—The Bolivian tin-mining industry continued the substantial down-sizing and restructuring that had started in 1985. Despite this, all production units within state-owned Corporacíon Minera de Bolivia (COMIBOL), the country's largest tin producer, were reportedly unprofitable. COMIBOL was authorized to lease some of its mining properties to cooperatives formed by former workers. To operate the properties, the cooperatives must pay COMIBOL a minimum rent of 1% of the net value of mineral production. Under consideration for these leases were the Catavi, Colquiri, Colquechaca, Japo, Santa Fe, Morococala, and Viloco tin mines, and the Machacamarca tin processing plant. Reportedly, in 1987, COMIBOL's production was limited to two tin mines at Viloco and Caracoles.

Brazil.—Brazil was not a member of the ATPC but agreed to cooperate with its guidelines and restrict its exports of tin to 21,000 tons during 1987. Brazil ranked as the world's second largest tin producer. Tin mine and smelter production was primarily owned by private enterprise, domestic and foreign. Brazilian tin mines generally were considered to be the lowest cost tin mines in the world.

The leading producer, Paranapanema, accounted for more than one-half of Brazil's total tin output, operating at least seven tin mines. The Pitinga Mine, about 300 kilometers northeast of Manaus in Amazonas State, was the firm's largest mine, and occupied an area of 250 square kilometers.

Pitinga's reserves were reportedly 230,000 tons of contained tin in high-grade ore. In addition to cassiterite, other valuable minerals such as columbite-tantalite and zirconite were reportedly present but not currently mined.

Brascan Recursos Naturais S.A. (BRN), jointly owned by Brascan Ltd. and BP Mineração, was Brazil's second leading tin producer. It operated several mines, all in the State of Rondônia. BRN's tin concentrates were shipped to its Cesbra smelter for refining.

Brumadinho, the third largest tin producer, operated alluvial tin mines in Rondônia and continued to explore tin properties in Goiãs State. Brumadinho transported all its tin concentrates to the tin smelter of Bera do Brasil S.A., near São Paulo. Bera was 70% owned by Brumadinho and 30% by Paul Bergsoe and Son A/S of Denmark.

Rhodia, the Brazilian subsidiary of Rhône Poulenc S.A. (France), acquired the Mineração São Francisco de Assis tin mine from St. Joe Minerals Corp. for about $7 million.

There were reports of a major new tin ore-body discovery in the Rondônia region. Deposits reportedly contained between 10,000 and 100,000 tons of tin and were in the Alto Paraiso area.

Canada.—The East Kemptville Tin Corp. Ltd. continued tin mining operations at its open pit mine at East Kemptville, Nova Scotia. The firm was owned by a consortium of United States and Canadian banks, with mine operations handled by Rio Algom Ltd., the prior owner. The mine was reported to contain 41 million tons of high-grade ore and 15 million tons of low-grade ore, with an average grade of 0.16% tin. At full capacity, the mill throughput of 9,000 tons daily was projected to yield about 4,800 tons annually of tin-in-concentrate as well as some copper and zinc. During 1987, the mine operated at substantially less than full capacity, the recovery rate was about 63%, and the mine was reportedly profitable. Most of the output of the mine was shipped to the Capper Pass Ltd. tin smelter in North Ferriby, United Kingdom.

China.—Tin resources were concentrated in the southern region, especially in Guangdong, Guangxi, Hunan, Jiangxi, and Yunnan Provinces. The country's largest tin producer is Yunnan Tin Corp., followed by DaChang Tin Mining Bureau in Guangxi. The combined annual output of these two accounted for about 60% of China's production of tin concentrates. In 1987, China reportedly exported about 10,000 tons of refined tin, most of which was shipped to the United States.

India.—Sartin Ltd. announced plans to construct a 300-ton-per-year tin smelter at Chowdwar with the aid of Base Synergy Associates Ltd. (United Kingdom). The new smelter was expected to use domestic tin concentrates from the Koraput District in India as well as imported tin concentrates.

Indonesia.—Tin mining was mostly performed at offshore sites in Indonesia, which is one of the few countries to increase tin mine output in recent years. P.T. Tambang Timah (P.T. Timah), the state-owned mining firm, was the major producer. This firm raised tin production in 1987, accounting for 80% of Indonesia's tin output. P.T. Timah was the world's largest tin-mining company, producing an estimated 22,000 tons annually from 247 mines and 29 dredges.

P.T. Koba Tin was the second largest producer and was jointly owned by Kajaura Mining Corp. (Pty.) Ltd., Australia, and P.T. Timah. Koba closed its Bangka Island tin mining operation. Unlike most major world tin producers, who sell their tin in the United States through independent brokers, Indonesia has for many years sold its tin directly to U.S. users through its own agency.

Malaysia.—Although Malaysia remained the world's leading tin producer, its tin industry continued to restructure. The largest producing firm, Malaysia Mining Corp., undertook a program of either disposing of or reducing its holdings in tin mines that had limited tin reserves. Among those affected were Aokan Tin Dredging, Ayer Hitam Tin Dredging, Kampong Lanjut Tin Dredging, Kamunting Tin Dredging, Tongkah Harbour Tin Dredging, and Tronoh Mines.

Two large tin smelters in Penang, one owned by Datuk Keramat and the other owned by Malaysia Smelting Corp., operated at about 80% capacity. Both smelters operated increasingly on a toll-smelting basis, handling tin concentrates from Australia, Bolivia, and China, because the tin mine output from Malaysia has generally decreased in recent years.

Mexico.—Tin mining occurred in the three adjoining States of Durango, Zacatecas, and San Luis Potosí in north-central Mexico. The country's major tin mine, the El Perro Mine, in San Luis Potosí, was owned by Cía. Minera Pizzuto.

Estãno Electro S.A. de C.V. operated a tin smelter at Tlalnepantla, near Mexico City. Fundidora de Estāno S.A. operated a tin smelter at San Luis Potosí. Metales Potosí S.A. ran a smelter in San Luis Potosí as did Minera de Río S.A. All four smelters mainly treated imported tin concentrates.

Namibia.—The Uis Mine in the Brandberg area produced most of the country's tin. The Uis Mine was owned by Industrial Minerals Mining Corp. (Pty.) Ltd., a wholly owned subsidiary of South African Iron and Steel Industrial Corp. Ltd. (Iscor). The Uis tin deposits occurred as low-grade 0.11% to 0.15% tin cassiterite mineralization. The tin concentrates were shipped directly to the Vanderbijlpark steelworks in the Republic of South Africa, where they provided a large part of Iscor's tin for use in making electrolytic tinplate.

Nigeria.—The five tin-mining companies were Amalgamated Tin Mines of Nigeria (Holdings) Ltd., Bisichi-Jantar Nigeria Ltd., Kaduna Prospecting Nigeria Ltd., Ex-Lands Nigeria Ltd., and Gold & Base Metal Mines of Nigeria Ltd. All tin concentrates were smelted domestically by Makeri Smelting Co. Ltd. at Jos in Plateau State.

Peru.—The sole tin mine was the San Rafael Mine owned by Minsur S.A. near Juliaca. The mine was within the northern extension of the Bolivian tin belt. Tin grades averaged 1.8%. Peru was the main supplier of tin concentrate to the United States.

Minsur announced plans to construct a $10 million tin smelter at Pisco. A new organization, Funsur, was to be formed to build the smelter, with partial funding through Government incentives. Plant construction was expected to start in early 1988, with a 2-year completion goal.

South Africa, Republic of.—Gold Fields of South Africa Ltd. was the parent firm of two moderate-sized tin producers, Rooiberg Tin Ltd. and Union Tin Mines Ltd. Zaaiplaats Tin Mining Co. Ltd. was also a producer.

Spain.—The country's two remaining tin mines announced permanent closure as a result of low tin prices. Minera Adelaide S.A. closed its La Parilla tin-tungsten mine near Caceres after it encountered flooding problems. Minas de San Finx S.A., near La Coruna, also stopped production.

Thailand.—Some major tin-mining firms that had suspended production in 1986 resumed activity. Dutch Chemical Products Holdings Ltd. acquired a 76% interest in the dormant Thai Pioneer Enterprise smelter. The 3,600-ton-per-year tin smelter had been closed since 1982, but there were plans to reopen it by 1988. The smelter was expected to secure tin concentrates from miners in central and northern Thailand.

The Thai Tinplate Manufacturing Co. announced plans to increase its capacity to 270,000 tons annually of tinplate. In 1987, Thailand was a net tinplate importer.

U.S.S.R.—Although the U.S.S.R. ranked as the world's fourth leading producer of tin ore, it was reportedly a net importer of tin metal. Tin mining was centered in the far eastern regions of the country where tin-mining and beneficiation capacities were being expanded. A new automated production line to extract tin from lean ore was commissioned at the Khingan tin complex in the Birobidzhan Autonomous Oblast' in the Soviet Far East. Output at Khingan was expected to double by 2000. Expansion continued at the Deputatskiy tin-mining and beneficiation complex in Yakutia, with a new tin concentrator reportedly near completion. The planned second-stage expansion of Deputatskiy, scheduled for 1995, would increase tin production to the level where the U.S.S.R. would no longer need to import tin. The country imported about 35% of its tin requirements in 1987.

United Kingdom.—Carnon Consolidated Tin Mines Ltd. continued operations, with Government aid to its two tin mines in Cornwall. Operating costs were reduced by selective mining of rich and easily accessible veins, postponement of long-term development projects, staff cutbacks, and a wage freeze. Significant mine and mill improvements were made, especially at South Crofty Mines, where refurbishment of the hoisting shaft more than doubled ore-hoisting capacity. About one-half of Carnon's tin concentrates was sent to Rio Tinto-Zinc Corp. PLC's Capper Pass tin smelter, and the remainder was refined in Europe. The Capper Pass smelter depended on imports, mostly from South America, for most of its feed stock.

Geevor Tin Mines PLC stopped tin mining at midyear after hoisting 40,000 tons of tin ore during the first 6 months at its Pendarves Mine.

Zaire.—The major tin producer was Société Minière et Industrielle de Kivu (Sominki) in Kivu. The firm was 28% Government-owned and 72% owned by Empain-Schneider Group of France. Tin concentrates were shipped to Europe for smelting. The second largest producer was Société Zairetain, with 50% Government ownership and 50% ownership by Geomines Cie. of Belgium.

Table 13.—Tin: World mine production, by country[1]

(Metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
Argentina	291	274	451	379	300
Australia	[2]9,275	7,923	6,374	8,470	9,000
Bolivia	25,278	19,911	16,136	10,479	7,000
Brazil	13,275	19,957	26,514	25,200	[3]28,900
Burma	1,642	2,028	1,751	1,495	[3]939
Cameroon	[e]10	14	9	9	9
Canada	141	217	120	[e]2,450	3,390
China[e]	15,000	15,000	15,000	15,000	15,000
Czechoslovakia[e]	250	250	250	250	250
German Democratic Republic[e]	1,800	1,800	1,800	1,600	1,000
Indonesia	26,553	23,223	21,759	24,049	[3]27,000
Japan	600	485	510	500	[3]86
Korea, Republic of	--	19	21	1	5
Laos	359	430	[e]540	[e]550	550
Malaysia	41,367	41,307	36,884	29,135	[3]30,388
Mexico	[r]334	416	380	585	[3]372
Namibia	[e]1,400	906	984	710	600
Niger	40	76	[e]100	[e]60	110
Nigeria	1,560	1,700	[e]990	[e]1,090	1,100
Peru	2,808	3,314	3,779	4,817	5,000
Portugal	347	[e]300	[e]200	[e]100	100
Rwanda	1,068	1,093	813	29	--
South Africa, Republic of	2,668	2,301	2,153	2,054	[3]1,413
Spain	444	438	637	[e]400	400
Swaziland	5	1	--	--	--
Tanzania	[r]6	[e]4	2	[r][e]2	2
Thailand	19,943	[r]21,960	16,864	17,066	[3]15,006
Uganda	18	[e]18	[e]18	[e]18	10
U.S.S.R.[e]	22,000	23,000	23,000	23,500	24,000
United Kingdom	4,025	5,216	5,204	4,276	4,000
United States	W	W	W	W	W
Vietnam[e]	550	500	600	650	680
Zaire[4]	2,163	2,708	3,100	[e]2,800	1,500
Zambia	[e]22	4	22	3	3
Zimbabwe[e]	1,700	1,670	1,670	1,650	1,600
Total	[r]196,942	[r]198,463	188,635	179,377	179,713

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

[1]Contained tin basis. Data derived in part from the Monthly Statistical Bulletin of the International Tin Council, London. Table includes data available through June 17, 1988.

[2]Excludes tin content of copper-tin concentrates.

[3]Reported figure.

[4]Nonduplicated total of content of concentrates plus smelter production.

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

(Metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
Argentina[2]	254	292	135	365	350
Australia	2,913	2,899	2,683	1,399	600
Bolivia	14,164	15,842	12,859	7,673	2,800
Brazil	12,950	18,887	24,701	24,427	26,400
China[e]	15,000	15,000	15,000	15,000	15,000
Czechoslovakia[2]	307	425	[e]430	[e]430	430
German Democratic Republic[e]	2,000	2,000	2,200	1,600	1,800
Germany, Federal Republic of[e]	[3]417	417	400	350	300
Indonesia	28,390	22,467	20,909	22,080	[3]23,800
Japan	1,260	1,354	1,391	1,280	[3]895
Malaysia[4]	53,338	46,911	45,500	43,788	45,000
Mexico[5]	1,216	1,531	1,492	[e]1,500	1,500
Netherlands	5,398	6,517	6,033	[e]5,000	5,000
Nigeria	1,190	1,400	1,020	[e]1,000	1,000
Portugal	443	432	408	199	130
Rwanda	1,110	[e]1,000	[e]800	--	--
South Africa, Republic of	2,685	1,592	2,069	2,001	[3]1,479
Spain	3,700	4,400	3,900	[e]3,500	3,600
Thailand	18,467	19,729	17,996	19,672	15,300
U.S.S.R.[e]	24,000	[r]25,500	[r]25,500	26,000	26,500
United Kingdom	6,467	7,105	7,548	9,227	12,000

See footnotes at end of table.

Table 14.—Tin: World smelter production, by country[1] —Continued

(Metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
United States[6]	2,500	4,000	[e]3,000	3,213	[3]3,927
Vietnam[e]	[3]520	475	570	[r]620	645
Zaire	201	170	85	(7)	--
Zimbabwe	1,234	1,210	1,207	1,079	1,100
Total	200,124	[r]201,555	197,836	191,403	189,556

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Data derived in part from the Monthly Statistical Bulletin of the International Tin Council, London. Output reported throughout is primary tin only unless otherwise specified. Table includes data available through June 17, 1988.
[2]May include secondary tin.
[3]Reported figure.
[4]Includes small production of tin from smelter in Singapore.
[5]Primarily from imported tin concentrate.
[6]Includes tin content of alloys made directly from ores.
[7]Revised to zero.

TECHNOLOGY

A variety of tin chemical formulations were developed to meet specific requirements in several markets for heat stabilizers. In the market for vinyl siding and window profiles, the Carstab Div. of Morton Thiokol Corp. developed a new compound class, which can be used with organotin mercaptides reportedly to provide excellent processing latitude and superior weathering in earthtone colors. Ciba-Geigy developed a maleate-free tin carboxylate for use in noncoated vinyl siding, with superior weathering reported. The Argus Div. of Witco Corp. developed a low-sulfur butyltin which reportedly improved heat stability and chalking resistance. The Interstab Div. of Akzo Chemie America Co. introduced an estertin-based product with reportedly superior color-retaining properties for the home window frame field. In the market for polyvinyl chloride bottles, Rhone-Poulenc developed a beta diketone for a taste and odor-sensitive application for clear water bottles. M&T Chemical Corp. introduced a new octyl tin liquid for food bottles. In the market for piping, Interstab developed an estertin-based liquid, reportedly offering good whiteness properties.[3]

Weirton Steel Corp. announced development of an easy-open end for steel cans. Although adaptable to both three-piece and two-piece food cans, plans were to use the new ends initially on three-piece containers. Typical applications would be for packaging fruits, vegetables, dry products, and pet foods.[4]

Metal Box Engineering Corp. Ltd. in the United Kingdom, developed a new automated spin-necking and pre-spin-necking technique for tinplate cans. This process reportedly saves considerable material in the canmaking process and thus offers cost reductions and a lighter weight can, two factors that could enable tinplate to increase its share of the beverage can market.[5]

Selective Electronic Inc. developed Laser Pour, a new mold-level-control system for tin and related alloy casting shapes. The closed-loop system was constructed around a laser level sensor and was claimed to offer total system control resulting in maximum casting quality and efficiency. The unit could provide high-quality and lower cost castings of tin and its alloys.[6]

Solarex Corp. announced development of a thin-film, amorphous silicon solar cell deposited on glass coated with a proprietary, textured tin oxide. The solar cell has a conversion efficiency of 11.9%, reportedly the highest efficiency achieved for a single-junction, thin-film solar cell. With further development, the cell could find application in commercial solar cells.[7]

Several firms announced introduction of new tin solders to meet the market needs for the plumbing industry. The recently amended Safe Drinking Water Act prohibited the use of lead in solders in municipal drinking water systems; consequently, solder makers developed alternative solders. Some typical new solders developed for this market were 95% tin, 5% antimony; and 95% tin, 5% silver.

[1]Physical scientist, Branch of Nonferrous Metals.
[2]Can Manufacturer's Institute. Metal Can Shipments Report 1987. Washington, DC, 1987, p. 5.
[3]Modern Plastics. V. 64, No. 9, Sept. 1987, pp. 70-71.
[4]Iron and Steel Engineer. V. 65, No. 9, Sept. 1987, p. 44.
[5]Canning International. V. 2, No. 2, May 1987, pp. 21-22.
[6]Tin International. V. 60, No. 6, June 1987, p. 125.
[7]Chemical & Engineering News. V. 65, No. 21, May 25, 1987, p. 19.

Titanium

By Langtry E. Lynd[1] and Ruth A. Hough[2]

Production and consumption of titanium dioxide (TiO_2) pigments reached new record-high levels for the fifth consecutive year. Increases in U.S. TiO_2 consumption were mainly for use in paper and plastics. Domestic consumption of titanium concentrates increased; a slight drop in ilmenite and rutile production was more than offset by a rise in the quantity of TiO_2 consumed in imported concentrates. U.S. production of titanium sponge metal increased, and demand for mill products improved as a result of increased orders for commercial aircraft and for chemical industry equipment. Prices of concentrates and pigment were steady to slightly higher throughout the year, and metal prices were firming at yearend.

Domestic Data Coverage.—Consumption data for titanium raw materials are developed by the Bureau of Mines from a voluntary domestic survey. Of the 30 operations to which a request was sent, 97% responded, representing 99.99% of the consumption of ilmenite, rutile, and titanium slag shown in tables 1 and 6. Consumption for the one nonrespondent was estimated using reported prior year consumption levels.

Table 1.—Salient titanium statistics

(Short tons unless otherwise specified)

	1983	1984	1985	1986	1987
United States:					
Ilmenite concentrate:					
Mine shipments	W	W	W	W	W
Value thousands	W	W	W	W	W
Imports for consumption	259,328	409,605	506,804	465,617	338,977
Consumption	730,578	783,391	756,071	806,270	813,819
Titanium slag:					
Imports for consumption	138,708	209,839	291,828	361,872	450,608
Consumption	166,401	200,858	252,027	276,324	277,214
Rutile concentrate, natural and synthetic:					
Imports for consumption	111,578	180,508	179,663	174,820	218,188
Consumption	265,558	317,902	305,278	329,151	353,296
Sponge metal:					
Production	13,966	24,326	23,257	17,402	19,675
Imports for consumption	1,199	[1]2,667	[1]1,717	1,626	1,018
Consumption[e]	16,072	24,713	21,606	19,489	19,812
Price, Dec. 31, per pound	$5.55	$5.55	$3.50-$4.00	$3.90-$4.30	$4.00-$4.20
Titanium dioxide pigment:					
Production	760,385	834,889	[r]863,543	[r]930,653	951,685
Imports for consumption	174,857	193,501	196,213	202,674	192,043
Consumption, apparent[2]	853,008	916,198	[r]984,579	[r]1,000,960	1,048,259
Price, Dec. 31, cents per pound:					
Anatase	69.0	69.0	72.0	77.0	77.0
Rutile	75.0	75.0	78.0	82.0	82.0
World: Production:					
Ilmenite concentrate[3]	[r]2,948,089	[r]3,831,103	3,891,119	[p]3,735,466	[e]4,060,636
Rutile concentrate, natural[3]	[r]347,766	375,684	411,839	[p]433,430	[e]496,442
Titaniferous slag	1,160,000	1,260,000	1,410,000	[p]1,417,000	[e]1,707,000

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Excludes sponge imported by the General Services Administration (GSA) for the national stockpile.
[2]Production plus imports minus exports plus stock decrease or minus stock increase.
[3]Excludes U.S. production data to avoid disclosing company proprietary data.

Legislation and Government Programs.—The Government's National Defense Stockpile (NDS) goal for titanium sponge metal remained at 195,000 short tons. The Government stockpile inventory in December contained 25,965 tons of specification metal and 10,866 tons of nonspecification material. The Government stockpile goal for rutile was unchanged at 106,000 tons. The total rutile stockpile inventory at yearend was 39,186 tons, including 56 tons of nonspecification material.

The International Trade Administration (ITA), U.S. Department of Commerce, ruled in February 1987 that Japanese producers did not dump their sponge in the United States between November 1, 1984, and October 31, 1985, and that Japanese sponge would no longer be subject to antidumping duties, confirming a preliminary ITA finding made in November 1986.

In March, Commerce ruled that antidumping duties reflecting a dumping margin of 83.96% would be assessed on titanium sponge imports from the U.S.S.R. This action was based on a review of shipments from the U.S.S.R. between August 1, 1983, and July 31, 1985, and reaffirmed a preliminary ruling announced in late 1986. The same dumping margin had previously been determined on sponge imported from the U.S.S.R. between August 1, 1982, and July 31, 1983.

Rutile (including titanium slag) was included in a list of strategic minerals, certified to the Congress under the authority of the President, as qualifying for exemption from the import restrictions of the Comprehensive Anti-Apartheid Act of 1986. Under the act, such materials may be excepted from prohibition of imports from parastatal organizations of the Republic of South Africa only if the quantities essential for the economy or defense of the United States are unavailable from reliable and secure sources.

DOMESTIC PRODUCTION

Concentrates.—U.S. producers of ilmenite were Associated Minerals (USA) Ltd. Inc. (AMU) at Green Cove Springs, FL, and E. I. du Pont de Nemours & Co. Inc. at Starke and Highland, FL. AMU is a subsidiary of Renison Goldfields Consolidated Ltd. of Australia.

As in 1986, AMU was the only domestic producer of natural rutile concentrate. Kerr-McGee Chemical Corp. was the sole producer of synthetic rutile, at Mobile, AL.

P. W. Gillibrand Co. continued to separate and stockpile heavy minerals containing ilmenite at its rock, sand, and gravel operation in the Soledad Canyon area, Los Angeles County, CA.

Ferrotitanium.—Ferrotitanium was produced by Ashland Chemical Co., Columbus, OH; Reactive Metals and Alloys Corp., West Pittsburg, PA; and Shieldalloy-GFE Corp., Newfield, NJ. Most of the production consisted of the 70% titanium grades.

Metal.—Wyman-Gordon Co. announced plans to install a plasma-refining system at its Millbury, MA, plant to produce nickel-base alloy powders and titanium alloy electrodes. The installation was expected to cost $11.7 million and to be completed in late 1988. The new system, which will have the capacity to produce 4 million pounds of titanium electrodes per year, will enable Wyman-Gordon to produce, rather than buy, key materials used to make turbine engine and airframe structural components.

The Timet Div. of Titanium Metals Corp. of America was carrying out a transition from laboratory output of titanium aluminide products to manufacture on a mill production scale, including sheet, bar, plate, billet, strip, and foil. Titanium aluminide, with a basic formula of Ti_3Al, has high-temperature capability up to 1,400° F, compared with about 1,000° F for Ti-6Al-2Sn-4Zr-2Mo, the best high-temperature titanium alloy now available in commercial quantities. Titanium aluminide was being produced mainly in two alloy compositions: alpha-2 (Ti-21Cb-14Al) and super-alpha-2 (Ti-20Cb-14Al-3.2V-2.0Mo). The columbium, vanadium, and molybdenum provide improved workability.

Engineers at Rohr Industries Inc., Chula Vista, CA, reported that they had developed the first honeycomb structure made from titanium aluminide. The honeycomb structure is thought to offer one of the best strength-to-weight ratios available for aerospace applications. Because of its resistance to high temperature, titanium aluminide could be competitive with superalloys, and the titanium aluminide structure is about one-half the weight of a superalloy material. Titanium aluminide may be used to make structural aircraft components and gas turbine engine parts.

The General Electric Co. (GE) announced plans to redesign titanium compressor blades that were involved in several fires in engines used in the Navy's F-18 fighter planes. The fires in the GE 404 engines were believed to have started when titanium compressor blades broke as a result of engine vibration and metal fatigue. GE said it will still make the blades from titanium. In addition to redesigning the first-and third-stage compressor blades in the engines, GE said it planned to coat the compressor casings with a material that would contain a fire if one started. GE agreed to replace the compressor blades in about 320 Navy F-18 engines.

McDonnell Aircraft Co. reportedly awarded orders for 425 tons of titanium plate for one year's production of *Eagle* and *Hornet* fighters to RMI Co., Niles, OH; Timet Div., Pittsburgh, PA; and Oregon Metallurgical Corp. (Oremet), Albany, OR. In 1986, McDonnell contracted with five titanium producers for a larger order. Industry sources stated that prices for aerospace-quality plate were lower than those of 1986, indicating the competitive nature of the bidding. However, prices on various titanium plate products were reportedly being raised by midyear.

On December 14, 1987, Oremet completed the purchase of Owens-Corning Fiberglas Corp's 80% share in the company. As part of the transaction, Oremet sold most of Owens-Corning's share to Oremet's employees. The sale ended 10 months of negotiations between Oremet and Owens-Corning, which had been trying to sell its share in Oremet for almost 2 years. As a result of the agreement, Oremet's employees owned 67% of the company and minority stockholders' interest in Oremet increased to about 33% from about 20%.

Table 2.—U.S. titanium metal production capacity in 1987

Company	Ownership	Plant location	Capacity (short tons)	
			Sponge	Ingot[1]
Howmet Corp., Titanium Ingot Div.	Pechiney, France	Whitehall, MI	--	7,000
International Light Metals Corp	Martin Marietta Corp., 60%; Nippon Kokan K.K., 40%.	Torrance, CA	--	5,500
A. Johnson Metals Corp	Axel Johnson Group, Stockholm, Sweden.	Lionville, PA	--	[2]2,000
Lawrence Aviation Industries Inc.	Self	Port Jefferson, NY	--	1,500
Oregon Metallurgical Corp. (Oremet).	Oremet employees, 67%; public, 33%.	Albany, OR	4,500	11,000
RMI Co	USX Corp., 50%; National Distillers & Chemical Corp., 50%.	Ashtabula, OH	9,500	--
	do	Niles, OH	--	18,000
Teledyne Allvac	Teledyne Inc	Monroe, NC	--	4,000
Teledyne Wah Chang Albany	do	Albany, OR	--	1,000
Titanium Metals Corp. of America.	NL Industries Inc., 50%; Allegheny International Inc., 50%.	Henderson, NV	14,000	17,500
Viking Metallurgical Corp	Quanex Corp	Verdi, NV	--	[2]3,500
Wyman-Gordon Co	Self	Worcester, MA	--	2,500
Total			28,000	73,500

[1]Based on 7 days per week full production. Includes 68,000 tons vacuum arc double/triple melt, of which triple melt generally ranged from 10% to 30%. The remaining 5,500 tons was single melt electron-beam capacity for remelt electrodes and commercially pure ingot and slab.

[2]Single melt only.

Pigment.—Production of TiO_2 pigment increased for the fifth consecutive year and was 99% of nominal capacity. Kerr-McGee announced that it would increase the annual capacity of its Hamilton, MS, TiO_2 pigment plant from 85,000 tons to 106,000 tons, the expansion to be completed by the first quarter of 1989. SCM Chemicals Inc. planned to expand capacity at one of its two TiO_2 plants in Ashtabula, OH, by 18,000 tons per year, at a cost of $18 million, bringing SCM's total capacity at Ashtabula to 118,000 tons per year. The expansion was expected to be completed by October 1988.

Table 3.—Components of U.S. titanium metal supply and demand

(Short tons)

Component	1983	1984	1985	1986	1987
Production:					
Sponge	13,966	24,326	23,257	17,402	19,675
Ingot	26,439	39,964	35,387	35,093	37,216
Exports:					
Sponge	39	171	51	69	94
Other unwrought	258	204	181	207	225
Scrap	5,379	4,109	6,760	6,403	5,603
Ingot, slab, sheet bar, etc	1,371	2,071	2,248	2,119	2,719
Other wrought	783	778	1,147	1,132	1,985
Total	7,830	7,333	10,387	9,930	10,626
Imports:					
Sponge	1,199	[1]2,667	[1]1,717	1,626	1,018
Scrap	1,572	1,850	2,134	2,375	2,445
Ingot and billet	81	176	179	106	75
Mill products	[r]935	840	1,449	1,239	983
Total[2]	3,788	5,533	[r]5,478	5,346	4,521
Stocks, Dec.31					
Government: Sponge (total inventory)	32,331	32,470	36,831	36,831	36,831
Industry:					
Sponge	3,136	3,147	4,755	3,180	2,504
Scrap	12,635	12,489	11,686	11,558	10,155
Ingot	3,273	4,526	4,000	4,100	4,458
Other	22	18	34	33	15
Total industry	19,066	20,180	20,475	18,871	17,132
Reported consumption:					
Sponge	16,072	24,713	21,606	19,489	19,812
Scrap	10,467	15,549	14,720	16,487	18,037
Ingot	26,232	39,062	35,020	33,801	35,561
Mill products (net shipments)[3]	15,949	22,808	22,760	20,842	22,286
Castings (shipments)[3]	240	268	411	[r]435	475

[r]Revised.
[1]Excludes sponge imported by GSA for the national stockpile.
[2]Data may not add to totals shown because of independent rounding.
[3]Bureau of the Census, Current Industrial Reports, Ser. ITA-991.

Table 4.—Capacities of U.S. titanium dioxide pigment plants on December 31, 1987[1]

Company and plant location	Pigment capacity (short tons per year)	
	Sulfate process	Chloride process
E. I. du Pont de Nemours & Co. Inc.:		
Antioch, CA	--	37,000
De Lisle, MS	--	150,000
Edge Moor, DE	--	114,000
New Johnsonville, TN	--	252,000
Kemira Inc., Savannah, GA	60,000	45,000
Kerr-McGee Chemical Corp., Hamilton, MS	--	85,000
SCM Chemicals Inc., Hanson Industries U.S.A.:		
Ashtabula, OH	--	100,000
Baltimore, MD	66,000	50,000
Total	126,000	833,000

[1]The table does not include Hitox Corp.'s Corpus Christi, TX, production capacity of about 10,000 tons per year of buff TiO_2, which is made by refining and fine-grinding of synthetic rutile.

Table 5.—Components of U.S. titanium dioxide pigment supply and demand

(Short tons unless otherwise specified)

Component	1984		1985		1986[1]		1987[1]	
	Gross weight	TiO_2 content	Gross weight	TiO_2 content	Gross weight	TiO_2 content	Gross weight	TiO_2 content
Production	834,889	777,031	r863,543	r802,827	r930,653	r865,182	951,685	889,131
Shipments:[2]								
Quantity	905,383	844,901	950,637	884,758	1,085,084	1,013,079	1,149,853	1,077,425
Value thousands	$1,106,898	$1,106,898	$1,275,131	$1,275,131	$1,530,225	$1,530,225	$1,700,644	$1,700,644
Exports	106,124	e96,740	101,954	e92,434	112,227	e102,506	120,029	e109,953
Imports for consumption	193,501	e180,091	196,213	r179,912	202,674	e188,416	192,043	e179,420
Stocks, Dec. 31	83,533	e77,744	56,756	52,041	76,896	e71,486	52,336	e48,896
Consumption, apparent[3]	916,198	e854,673	r984,579	916,008	r1,000,960	931,647	1,048,259	e981,188

eEstimated. rRevised.
[1]Data coverage beginning in 1986 was extended to include additional major importers.
[2]Includes interplant transfers.
[3]Production plus imports minus exports plus stock decrease or minus stock increase.

Sources: Bureau of the Census and Bureau of Mines.

CONSUMPTION AND USES

Concentrates.—The total domestic consumption of titanium in concentrates increased slightly, mainly because of the increased production of TiO_2 pigment.

Ferrotitanium.—Consumption of titanium in the form of ferrotitanium and scrap in steel and other alloys increased about 10%, mainly because of higher production of stainless steel and superalloys.

Metal.—Consumption of sponge and ingot increased slightly while net shipments of mill products increased 7%. Consumption of scrap increased 9%, and the proportion of scrap in ingot feedstock rose to 48.5%, continuing a long-term trend toward higher scrap utilization. Castings shipments increased 5%. Mill product shipments were 54% in the form of billet; 31% sheet, strip, plate, tubing, pipe, extrusions, and other; and 15% rod and bar. Bar and billet were the major forms used for aircraft engines and airframes, while the other forms were used mainly for nonaerospace industrial applications. Mill product usage was estimated to be about 78% for aerospace and 22% for other industrial applications.

Current use of titanium in large commercial aircraft represents about 6% of aircraft empty weight. Titanium is utilized where high-strength toughness, heat resistance, and high structural efficiency are required. Typical military aircraft uses are for structural forgings and wing skins for F-14 and F-15 aircraft; rotor parts for helicopter blade systems; B-1B fracture-critical forgings and wing support sections; and rotor discs, blades, and compressor blades on various engines. Major nonaerospace industrial uses are those requiring superior resistance to corrosion, such as surface condensers in powerplants, heat exchangers, and chemical industry equipment. One of the first commercial applications of titanium was in the form of tubing used to carry seawater for cooling in oil refineries and chemical plants.[3] Titanium is being increasingly used in medical implant devices because of its outstanding corrosion resistance and compatibility with body tissues. Automotive uses may be extended beyond race-car applications, as evidence is accumulated showing that higher costs for titanium as valve train materials may be offset by improvements in performance and fuel economy.[4]

Pigment.—Apparent consumption of TiO_2 pigments was about 1,048,000 tons, nearly 5% higher than in 1986. Demand exceeded supply, and consumption probably would have been significantly higher if more production capacity had been available.

Table 6.—U.S. consumption of titanium concentrates

(Short tons)

Year	Ilmenite[1]		Titanium slag		Rutile (natural and synthetic)[2]	
	Gross weight	TiO_2 content[e]	Gross weight	TiO_2 content[e]	Gross weight	TiO_2 content[e]
1983	730,578	474,285	166,401	127,267	265,558	250,418
1984	783,391	498,977	200,858	152,534	317,902	298,639
1985	756,071	481,011	252,027	199,610	305,278	286,488
1986:						
Alloys and carbide	(3)	(3)	(4)	(4)	--	--
Pigments	804,050	511,070	276,324	221,959	259,821	244,178
Welding-rod coatings and fluxes	(3)	(3)	--	--	8,081	7,667
Miscellaneous[5]	2,220	1,655	--	--	61,249	57,539
Total	806,270	512,725	276,324	221,959	329,151	309,384
1987:						
Alloys and carbide	(3)	(3)	(4)	(4)	--	--
Pigments	811,435	504,178	277,214	223,478	288,761	271,658
Welding-rod coatings and fluxes	(3)	(3)	--	--	4,388	4,168
Miscellaneous[5]	2,384	1,912	--	--	60,147	56,558
Total	813,819	506,090	277,214	223,478	353,296	332,384

[e]Estimated.
[1]Includes a mixed product containing rutile, leucoxene, and altered ilmenite.
[2]Includes synthetic rutile made in the United States.
[3]Included with "Miscellaneous" to avoid disclosing company proprietary data.
[4]Included with "Pigments" to avoid disclosing company proprietary data.
[5]Includes ceramics, chemicals, fiber glass, and titanium metal.

Table 7.— Distribution of U.S. domestic titanium pigment shipments, titanium dioxide content, by industry[1]

(Percent)

Industry	1983	1984	1985	1986	1987
Paint, varnish, lacquer	48.9	54.8	54.3	52.6	49.5
Paper	27.3	19.9	20.5	20.7	24.3
Plastics (except floor covering and vinyl-coated fabrics and textiles)	13.2	15.4	16.2	15.8	17.0
Rubber	1.8	2.0	1.7	2.0	1.8
Printing ink	1.1	1.2	1.0	1.4	1.2
Ceramics	1.0	1.0	.7	2.2	.6
Other	6.7	5.7	5.6	5.3	5.6
Total	100.0	100.0	100.0	100.0	100.0

[1]Data coverage beginning in 1986 was extended to include additional major importers.

Table 8.—U.S. consumption of titanium products[1] in steel and other alloys

(Short tons)

	1983	1984	1985	1986	1987
Carbon steel	744	659	483	732	784
Stainless and heat-resisting steel	1,748	1,851	2,104	2,185	2,457
Other alloy steel (includes HSLA)	749	677	491	297	358
Tool steel	W	W	W	W	W
Total steel	3,241	3,187	3,078	3,214	3,599
Cast irons	38	62	23	65	W
Superalloys	535	622	657	630	689
Alloys, other than above	252	473	357	322	320
Miscellaneous and unspecified	12	18	18	35	45
Total consumption	4,078	4,362	4,133	4,266	4,653

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."
[1]Includes ferrotitanium containing 20% to 70% titanium and titanium metal scrap.

STOCKS

The 31% decrease of TiO_2 content of ilmenite stocks at yearend was more than offset by the increase of the TiO_2 content of rutile and slag stocks. Stocks of titanium pigment (TiO_2 content) at yearend were at the lowest level since 1977 when the Bureau began to publish data on titanium pigment stocks.

Table 9.—U.S. stocks of titanium concentrates and pigment, December 31

(Short tons)

	Gross weight	TiO_2 content
Ilmenite:[1]		
1985	237,430	147,357
1986	279,106	169,723
1987	214,449	129,717
Titanium slag:[1]		
1985	106,062	83,821
1986	[r]80,885	[r]65,213
1987	131,735	106,882
Rutile:[1]		
1985	115,973	109,319
1986	[r]113,988	[r]107,491
1987	118,655	110,217
Titanium pigment:[2]		
1985	56,756	[e]52,041
1986	76,896	[e]71,486
1987	52,336	[e]48,896

[e]Estimated. [r]Revised.
[1]Producer, consumer, and dealer stocks.
[2]Bureau of the Census. Producer stocks only.

Table 10.—Published prices of titanium concentrates and products

	1986[1]	1987[1]
Concentrates:		
Ilmenite, f.o.b. eastern U.S. ports per metric ton	(2)	(2)
Ilmenite, f.o.b. Australian ports do	$47.00-$53.00	$46.00-$52.00
Ilmenite, large lots, bulk, f.o.b. U.S. east coast do	50.00- 56.00	50.00- 56.00
Rutile, bagged, f.o.b. Australian ports per short ton	398.00-422.00	398.00-418.00
Rutile, bulk, f.o.b. Australian ports do	374.00-386.00	372.00-392.00
Rutile, large lots, bulk, f.o.b. U.S. east coast do	355.00-375.00	355.00-375.00
Synthetic rutile, f.o.b. Mobile, AL do	350.00	350.00
Titanium slag, 80% TiO_2, f.o.b. Sorel, Quebec[e] per metric ton	210.00-215.00	215.00-225.00
Titanium slag, 85% TiO_2, f.o.b. Richards Bay, Republic of South Africa[e] do	225.00-230.00	235.00-245.00
Metal:		
Sponge, reported sales per pound	3.90- 4.30	4.00- 4.20
Sponge, Japanese, under contract, c.i.f. U.S. ports, including import duty do	No quotation	No quotation
Mill products:		
Bar do	9.25- 10.04	8.50- 9.61
Billet do	7.10- 7.76	6.45- 6.52
Plate do	8.00- 9.53	10.33- 10.74
Sheet do	9.50- 10.00	8.50- 9.50
Strip do	10.10- 10.60	10.10- 10.60
Pigment:		
Titanium dioxide pigment, f.o.b. U.S. plants, anatase do	.75- .77	.75- .77
Titanium dioxide pigment, f.o.b. U.S. plants, rutile do	.80- .82	.80- .82

[e]Estimated.
[1]Yearend.
[2]List price suspended effective Jan. 1, 1985.

Sources: American Metal Market, Industrial Minerals (London), Metals Week, and industry contacts.

FOREIGN TRADE

Exports of all titanium metal categories except scrap increased; ingot, billet, and slab exports rose by 28%, and those in the other wrought category were up 75% over the corresponding 1986 levels. Imports for consumption of titanium sponge dropped 37% in 1987, mainly because of the virtual cessation of imports from Japan except to fulfill previous commitments. The withdrawal of Japanese sponge producers from the U.S. market resulted from the steep appreciation of the Japanese yen and low market prices. The drop in availability of Japanese sponge raised a supply problem for nonintegrated U.S. producers of ingot and mill products, but the three U.S. sponge producers reportedly offered to sell sponge to the nonintegrated producers. Although the sponge produced in the United States is higher in volatile impurity content than the Japanese sponge, causing some problems for the nonintegrated producers, U.S. capacity was believed to be ample to supply the U.S. market at anticipated sponge consumption levels.

Exports of TiO_2 were higher and imports for consumption were lower probably because European prices were higher, discouraging U.S. imports and encouraging exports.

Imports for consumption of total TiO_2 in concentrates increased 6% in 1987. A 27% decrease in ilmenite imports was more than offset by increases in imports of slag, rutile, and synthetic rutile.

Table 11.—U.S. exports of titanium products, by class

Class	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)	1987 Quantity (short tons)	1987 Value (thousands)
Concentrates:						
Ilmenite	--	--	r1,951	r$280	--	--
Rutile	27,759	$6,953	r3,364	r1,135	4,435	$1,395
Total[1]	27,759	6,953	5,314	1,414	4,435	1,395
Metal:						
Sponge	51	338	69	461	94	746
Other unwrought	181	2,604	207	1,757	225	2,254
Scrap	6,760	14,533	6,403	10,652	5,603	9,721
Ingots, billets, slabs, etc	2,248	40,942	2,119	38,754	2,719	44,203
Other wrought	1,147	29,481	1,132	31,413	1,985	40,534
Total[1]	10,388	87,898	9,930	83,037	10,626	97,458
Pigment and oxides:						
Titanium dioxide pigments	101,954	108,384	112,227	145,920	120,029	181,707
Titanium compounds, except pigment-grade	1,247	4,486	3,220	10,415	13,028	28,478
Total	103,201	112,870	115,447	156,335	133,057	210,185

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

Source: Bureau of the Census.

Table 12.—U.S. imports for consumption of titanium concentrates, by country

Concentrate and country	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)	1987 Quantity (short tons)	1987 Value (thousands)
Ilmenite:						
Australia	506,539	$14,060	427,453	$13,846	333,523	$10,640
India	--	--	18,783	1,831	5,454	1,341
Indonesia	265	530	--	--	--	--
Sri Lanka	--	--	19,381	1,160	--	--
Total	506,804	14,590	465,617	16,837	338,977	11,981
Titanium slag:						
Canada	195,230	36,350	194,058	35,696	219,364	41,625
South Africa, Republic of	96,598	15,881	167,814	29,030	231,244	41,381
Total	291,828	52,231	361,872	64,726	450,608	83,006
Rutile, natural:						
Australia	66,054	19,062	73,844	25,222	112,749	41,199
Brazil	3,121	481	1,126	214	--	--
Namibia	--	--	11,052	3,852	--	--
Sierra Leone	32,994	10,822	19,439	7,039	19,090	6,668
South Africa, Republic of	44,146	10,094	37,124	9,521	28,885	9,542
Other	286	50	90	16	6	3
Total[1]	146,602	40,509	142,675	45,865	160,730	57,412
Rutile, synthetic:						
Australia	33,061	3,458	32,035	6,315	50,722	12,021
China	--	--	110	34	101	34
India	--	--	--	--	3,227	1,127
Japan	--	--	--	--	3,401	1,497
Netherlands	--	--	--	--	7	22
Total	33,061	3,458	32,145	6,349	57,458	14,701
Titaniferous iron ore:[2]						
Canada	858	38	710	23	13,148	757

[1]Data may not add to totals shown because of independent rounding.
[2]Includes materials consumed for purposes other than production of titanium commodities, principally heavy aggregate and steel furnace flux.

Source: Bureau of the Census.

Table 13.—U.S. imports for consumption of titanium dioxide pigments, by country

Country	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)	1987 Quantity (short tons)	1987 Value (thousands)
Australia	5,285	$5,967	5,271	$6,604	3,923	$5,398
Belgium-Luxembourg	16,459	15,508	18,009	20,649	16,941	19,451
Canada	26,658	30,019	24,509	28,476	17,533	21,352
Finland	5,799	6,200	5,930	6,995	4,293	5,501
France	39,379	42,167	36,818	44,719	26,921	32,325
Germany, Federal Republic of	39,723	38,955	48,867	57,902	47,707	60,630
Italy	1,520	1,855	3,239	4,338	3,167	4,423
Japan	5,378	6,267	5,083	5,586	5,000	6,693
Mexico	3,289	4,050	1,424	1,595	74	206
Netherlands	1,238	1,120	2,760	3,307	623	690
Norway	6,978	5,968	7,495	8,282	9,218	10,519
South Africa, Republic of	551	634	1,708	2,160	2,046	2,571
Spain	21,283	23,659	17,292	20,965	22,616	27,620
United Kingdom	21,242	22,880	21,876	25,885	29,538	36,640
Yugoslavia	516	508	412	631	332	652
Other[1]	913	1,054	1,981	1,964	2,111	2,274
Total[2]	196,213	206,809	202,674	240,058	192,043	236,945

[1]Includes Algeria, Austria, Brazil, China, Denmark, Dominican Republic, Greece, Hong Kong, Jordan, the Republic of Korea, Mali, New Zealand, Panama, Peru, Singapore, Sweden, Switzerland, and Taiwan, in one or more of these years.
[2]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

Table 14.—U.S. imports for consumption of titanium metal, by class and country

Class and country	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)	1987 Quantity (short tons)	1987 Value (thousands)
Unwrought: Sponge:						
China	--	--	20	$77	18	$54
Germany, Federal Republic of[1]	--	--	--	--	([2])	15
Japan	[3]1,689	$10,007	1,606	9,504	1,000	6,252
Korea, Republic of	28	156	--	--	--	--
United Kingdom	([2])	1	--	--	--	--
Total[4]	[3]1,717	10,164	1,626	9,583	1,018	6,321
Ingot and billet:						
Canada	29	247	8	83	2	5
Germany, Federal Republic of	46	844	47	778	14	245
Israel	([2])	6	8	232	12	338
Japan	101	950	40	590	46	436
United Kingdom	2	49	3	56	1	29
Other	([2])	[r]35	([2])	8	([2])	58
Total[4]	179	2,131	106	1,747	75	1,112
Waste and scrap:						
Austria	--	--	236	512	310	673
Belgium-Luxembourg	47	61	52	50	149	206
Canada	117	155	260	461	156	280
China	372	839	54	90	71	112
France	122	498	205	630	234	631
Germany, Federal Republic of	87	316	110	327	213	694
Japan	352	1,175	338	1,112	603	1,893
Sweden	90	311	51	149	20	47
Switzerland	162	318	238	470	99	286
U.S.S.R	78	194	149	311	--	--
United Kingdom	595	2,001	584	1,567	515	1,641
Other	111	207	96	246	75	116
Total[4]	2,134	6,075	2,375	5,927	2,445	6,579

See footnotes at end of table.

Table 14.—U.S. imports for consumption of titanium metal, by class and country —Continued

Class and country	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)	1987 Quantity (short tons)	1987 Value (thousands)
Wrought titanium:						
Canada	390	$6,293	r376	r$5,874	387	$7,112
Germany, Federal Republic of	(2)	18	r25	r454	46	463
Japan	987	13,128	r633	r9,083	480	6,683
United Kingdom	55	1,254	r43	r1,269	43	790
Other	18	345	10	r266	27	698
Total[4]	1,449	21,038	r1,087	r16,946	983	15,747

rRevised.
[1]Country of transshipment rather than country of production.
[2]Less than 1/2 unit.
[3]Excludes sponge imported by GSA for the national stockpile.
[4]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

WORLD REVIEW

World production of TiO_2 in concentrates increased about 12% in 1987. World production and demand for TiO_2 pigments were again at record-high levels, with demand estimated at about 2.8 million tons. Prices of concentrates and pigments increased in response to the high demand. Pigment producers continued to add to existing plant capacity and were building or planning to build new pigment plants in Brazil, the Republic of Korea, Saudi Arabia, Singapore, and Taiwan.

Titanium sponge metal production in the market economy countries decreased 7% to about 32,000 tons mainly because of a substantial decrease in Japanese sponge production.

Australia.—Australia was again the largest producer of titanium minerals, with exports of ilmenite, in order of decreasing quantity, mainly to the United States, Japan, the United Kingdom, and Spain; and exports of rutile, in order of decreasing quantity, mainly to the United States, the United Kingdom, and the Netherlands.

Associated Minerals Consolidated Ltd. (AMC), Mineral Sands Div. of Renison Goldfields, began operation of its new 124,000-ton-per-year synthetic rutile plant at Narngulu, near Geraldton in Western Australia, bringing AMC's total synthetic rutile capacity to 190,000 tons per year.

Westralian Sands Ltd. began production at its 110,000-ton-per-year synthetic rutile plant at Capel, Western Australia. Completion of this plant brings Australia's total synthetic rutile production capacity to 300,000 tons per year.

TiO_2 Corp. completed a feasibility study of its Cooljarloo deposit and concluded that its proposed mineral sands project is economically viable. Initial production was planned for late 1988.

SCM was planning to increase the annual capacity of its TiO_2 pigment plant at Bunbury, Western Australia, from 40,000 tons to 77,000 tons, in conjunction with conversion from the sulfate process to the chloride process. Earlier plans had been for expansion to only 50,000 tons per year. Cost of the expansion was estimated at about $107 million, with completion scheduled for late 1988.

Belgium.—NL Chemicals Inc. announced a project to convert its TiO_2 plant at Landerbrugge, near Ghent, to the chloride process. The 44,000-ton-per-year plant will replace the existing sulfate process facility on the same site at a cost of $60.3 million. All dumping of spent acid wastes in the North Sea will cease, and SO_2 air emissions will be reduced by 90%.[5]

Brazil.—In August 1987, Du Pont's Brazilian subsidiary and Constructora Andrade Gutierrez S.A., one of Brazil's biggest construction firms, submitted a proposal to the Brazilian Government to form a 50-50 joint venture to construct a $180 million, 60,000-ton-per-year TiO_2 pigment plant. The pigment plant is to be near the proposed titanium concentrate plant to be built in the Tapira region, Minas Gerais State, by Cia. Vale do Rio Doce, by 1991, with an initial capacity of 88,000 tons per year of anatase concentrate. Each of the members of the proposed joint venture had previously planned to build separate TiO_2 facilities in the same region.[6]

Canada.—QIT-Fer et Titane Inc., Montreal, decided to expand its capacity for production of 80% TiO_2 slag by 20% to slightly more than 1.1 million tons per year by mid-1988. The project was expected to cost about $100 million, and was to involve the refurbishing and modernization of two furnaces at QIT's smelter in Sorel, Quebec, Canada, to bring their capacity up to that of seven other more modern furnaces at Sorel.

NL Chem Canada Ltd. completed construction and began operation of its new 42,000-ton-per-year chloride process plant at Varennes, Quebec, in mid-1987. NL Chem Canada continued to operate a 40,000-ton-per-year sulfate process TiO_2 plant at the same location.

China.—Production of ilmenite concentrate at the Panzhihua Mine in eastern Sichuan Province was to be increased from the current rate of 20,000 to 50,000 tons per year, with long-term plans to produce 300,000 tons per year. The Panzhihua ore consists mainly of titaniferous magnetite and is an important source of vanadium.

Japan.—The escalating value of the Japanese yen made titanium sponge produced in Japan uncompetitive in the United States, and Japanese producers virtually withdrew from the U.S. sponge market around midyear, except to fulfill previous contracts. Sponge production in Japan was reduced sharply, and production for the year was only 11,105 tons, or 43% of annual production capacity of 26,000 tons. Estimates of annual production capacities by company in 1987 were Osaka Titanium Co. Ltd., 13,200 tons; Toho Titanium Co. Ltd., 10,600 tons; and Showa Titanium Co. Ltd., 2,200 tons.

Table 15.—Titanium: World production of concentrates (ilmenite, leucoxene, rutile, and titaniferous slag), by country[1]

(Short tons)

Concentrate type and country	1983	1984	1985	1986[p]	1987[e]
Ilmenite and leucoxene:[2]					
Australia:					
Ilmenite	987,900	1,645,937	1,564,031	1,364,322	1,521,000
Leucoxene	14,725	35,395	15,222	15,590	13,500
Brazil	33,568	45,134	84,166	83,194	82,500
China[e]	154,000	154,000	154,000	154,000	154,000
Finland	180,669	[e]184,000	140,055	--	--
India[3]	148,234	154,323	157,630	[e]154,000	154,000
Malaysia	[r]245,498	[r]295,959	346,937	457,394	551,000
Norway	612,826	[r]718,522	811,126	885,841	[4]939,523
Portugal	298	181	159	256	240
Sierra Leone	--	--	--	--	[4]6,173
Sri Lanka	90,145	112,489	126,605	[e]110,000	110,000
Thailand	226	[r]163	1,188	14,869	28,700
U.S.S.R.[e]	480,000	485,000	490,000	496,000	500,000
United States	W	W	W	W	W
Total	[r]2,948,089	[r]3,831,103	3,891,119	3,735,466	4,060,636
Rutile:					
Australia	[r]180,089	187,860	233,265	237,850	283,000
Brazil	510	454	786	546	550
India[e] [3]	6,100	6,600	[4]7,496	8,000	8,000
Sierra Leone[5]	79,146	100,641	88,858	107,034	[4]124,892
South Africa, Republic of[e]	62,000	62,000	61,000	61,000	61,000
Sri Lanka	8,921	7,129	9,434	[e]8,000	8,000
U.S.S.R.[e]	11,000	11,000	11,000	11,000	11,000
United States	W	W	W	W	W
Total	[r]347,766	375,684	411,839	433,430	496,442
Titaniferous slag:					
Canada[6]	700,000	800,000	[e]930,000	[e]937,000	992,000
South Africa, Republic of[e] [7]	460,000	460,000	480,000	480,000	715,000
Total	1,160,000	1,260,000	1,410,000	1,417,000	1,707,000

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Table excludes production of unbeneficiated anatase ore in Brazil, in short tons, as follows: 1983—2,610,028; 1984—2,943,538; 1985—3,000,000 (estimated); 1986—3,000,000 (estimated); and 1987—3,307,000 (estimated). This material reportedly contains 20% TiO_2. Table includes data available through June 24, 1988.

[2]Ilmenite is also produced in Canada and in the Republic of South Africa, but this output is not included here because an estimated 90% of it is duplicative of output reported under "Titaniferous slag," and the rest is used for purposes other than production of titanium commodities, principally as steel furnace flux and heavy aggregate.

[3]Data are for fiscal year beginning Apr. 1 of year stated.

[4]Reported figure.

[5]Contains 96% TiO_2.

[6]Contains 80% TiO_2.

[7]Contains 85% TiO_2.

Madagascar.—On behalf of QIT Madagascar Minerals Ltd., a joint-venture partnership owned 51% by the Government of Madagascar and 49% by QIT, QIT completed an initial evaluation of the heavy minerals prospect in southeast Madagascar, confirming and extending previous reserve estimates. The larger reserve estimate led to an increase in the planned mine production capacity to 660,000 tons per year of ilmenite instead of the 330,000 tons originally proposed. Startup of a commercial operation is planned for the second half of 1990. Most of the ilmenite is to be shipped to QIT's smelter in Sorel, Quebec, Canada, for conversion to a 90% TiO_2 slag suitable for chlorination.[7]

Norway.—KSI Ilmenittsmelteverket A/S (KSI) experienced startup difficulties in the operation of its new plant to smelt ilmenite in Tyssedal. Unexpected expenditures incurred in correcting equipment problems were blamed for additional capital requirements, which led to interrupted production, and were unresolved at yearend.

Senegal.—In April, the President of Senegal signed a decree granting exploration rights for titanium minerals to Du Pont.

Sierra Leone.—Sierra Rutile Ltd., owned by Nord Resources Corp., Dayton, OH, completed expansion of its rutile capacity to about 140,000 tons per year. Sierra Rutile was also planning to produce a small quantity of ilmenite, beginning in late 1987.

U.S.S.R.—Production of titanium sponge was estimated to be 49,000 tons. Annual sponge production capacity was estimated to be about 55,000 tons.

United Kingdom.—Deeside Titanium Ltd., Western Europe's only titanium sponge producer, was to reduce its production rate in late 1987 because of lower demand and profitability. Deeside previously cut production in 1985, and reportedly has never reached full-capacity production of 5,500 tons per year since it began operation in 1982. Production in 1987 was estimated at about 1,500 tons.

TECHNOLOGY

The Bureau of Mines published cost-estimation handbooks on mining,[8] mineral processing,[9] and small placer mines.[10] These reports were prepared to assist in the preparation of prefeasibility-type estimates for capital and operating costs of mining and beneficiation of various types of mineral occurrences, including titanium minerals, using current technology.

A study on titanium chlorination solid wastes done under a Bureau of Mines contract was reported. Conceptual designs and the results of tests on processes used to recover titanium from chlorination-process solid waste were described. Recoveries of 80% to 88% of the titanium in the waste as a concentrate of 94% to 95% TiO_2 were achieved, reducing the amount of final waste effluent to less than 40% of current quantities.[11]

With the objective of assessing the feasibility of preparing chlorination-grade titanium concentrate from domestic ilmenite, the Bureau smelted and treated by sulfation and leaching an ilmenite from northern Minnesota. The final product from small-scale testing contained up to 95.5% TiO_2 and met chlorination-charge specifications for critical impurities.[12]

The Bureau made an economic study of selected heavy-mineral placer deposits in the U.S. Exclusive Economic Zone (EEZ). Three placer areas were investigated and evaluated using engineering and cost models.[13]

The U.S. Congress, Office of Technology Assessment, examined the current knowledge about the hard mineral resources within the EEZ, explored the economic and security potential of seabed resources, and assessed the technologies available to explore for and mine those resources, including titanium-bearing sands.[14]

The Bureau reported results of an investigation of a process to produce titanium powder directly from titanium salts. Potassium titanium fluorides and potassium fluoride were reduced with potassium at 650° to 750° C. After leaching, products with low potassium and fluorine content were obtained, but oxygen levels of more than 1% demonstrated the need for further research.[15]

The Bureau also investigated the use of Kroll-type magnesium reduction to produce titanium alloy powder. Chlorides of titanium, aluminum, and vanadium were reduced together simultaneously at 750°, 850°, and 950° C, using various feed rates and crucible diameters. Results of electron microprobe analysis showed that the chemical composition of the products was less homogeneous than desired, so that a homogenizing step such as melting might be required to produce a sufficiently uniform product.[16]

A comprehensive Bureau report of the historical development and status of technology for producing titanium concentrates and metal from U.S. resource materials was published. Commercially feasible processes and investigations of alternate procedures were reviewed. Procedures were described for producing titanium concentrates from a variety of starting materials, producing and purifying titanium tetrachloride, reduction of titanium tetrachloride to metal with magnesium or sodium or by electrowinning, and metal purification, consolidation, and melting.[17]

As part of its research program on developing substitute materials for tungsten, tantalum, and cobalt in cutting tools, to lessen U.S. dependence on foreign sources of these critical materials, the Bureau investigated the effects of composition and processing variables on the transverse rupture strength and hardness of nickel-alloy-bonded titanium carbide to identify compositions that exhibit promising mechanical properties. A number of promising compositions were determined.[18]

The Bureau also investigated the recovery of titanium from domestic perovskite ($CaTiO_3$) deposits. An acid sulfation method was developed that will extract about 97% of the titanium and columbium and up to 90% of the rare-earth oxides from perovskite concentrates. Cost evaluation results indicated that processing perovskite concentrates by acid sulfation can be an economically viable means of producing TiO_2,[19] Cerium and lanthanum were recovered from the perovskite sulfate-leach solutions as a sodium sulfate double salt.[20]

The U.S. Geological Survey published a report on the geology and mineral deposits of the Roseland District of Nelson and Amherst Counties, VA. The district was formerly an important producer of titanium minerals and still contains more than 5% of identified U.S. resources of those minerals.[21]

The perovskite deposits near Powderhorn, CO, were described as containing one-half of the total usable U.S. reserves of titaniferous raw materials. The geology of the deposits was reviewed, and possible methods for recovery and processing of a perovskite concentrate to manufacture TiO_2 pigment were discussed.[22]

The National Aeronautics and Space Administration (NASA) developed an oxygen-barrier coating for titanium that may extend the temperature range over which titanium may be used considerably above the current range of 800° to 1,000° F. At high temperatures, the coating forms titanium aluminide and silicide compounds that are nearly impervious to oxygen, even at temperatures as high as 1,300° F.[23]

A monograph was published containing evaluations of pure titanium and 66 binary titanium alloys. The volume includes crystal structure and lattice parameter tables, thermodynamics, and a complete bibliography through 1985.[24]

Titanium-base materials, particularly titanium aluminides, were described as promising for providing the strength, low density, and temperature resistance that will be needed for development of advanced performance aircraft such as the national aerospace plane.[25] An overview of rapid solidification (RS) indicated that the refinement of microstructure and extended solid solution ranges achievable by RS technology may lead to titanium alloys with improved high-temperature properties.[26]

Precision forging technology for critical aerospace applications was described as on the threshold of a major revolution. Costs of dies for titanium have been substantially reduced, and the availability of the more readily forgeable near-beta alloys, such as Ti-10-2-3, has increased the size of forgings that may be made from titanium.[27]

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[1]Physical scientist, Branch of Nonferrous Metals.

[2]Supervisory mineral data assistant, Branch of Nonferrous Metals.

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Tungsten

By Gerald R. Smith[1]

All U.S. tungsten mines remained closed in 1987 owing to continued low prices. Domestic production of intermediate ammonium paratungstate (APT) for the year was slightly below the 1986 level. However, after the signing of an Orderly Marketing Agreement (OMA) between the United States and China in September, the domestic industry showed some improvement. The OMA regulated the quantities of APT and tungstic acid to be imported from China. APT was produced at a rate 19% higher than the average for the first 9 months of the year and 24% higher than for the last 3 months of 1986.

Domestic Data Coverage.—Domestic production data for tungsten are developed by the Bureau of Mines by means of three separate, voluntary surveys. These surveys are "Tungsten Ore and Concentrate," "Tungsten Concentrate and Tungsten Products," and "Tungsten Concentrate." Of the 47 operations to which survey requests were sent, all responded, representing 100% of the total production shown in table 1.

Table 1.—Salient tungsten statistics

(Metric tons of tungsten content unless otherwise specified)

	1983	1984	1985	1986	1987
United States:					
Concentrate:					
Mine production	980	1,203	996	780	34
Mine shipments	1,016	1,173	983	817	34
Value thousands	$10,528	$13,409	$9,143	$5,774	$216
Consumption	5,181	8,577	6,838	4,804	5,506
Shipments from Government stocks	259	1,368	902	301	708
Exports	1	129	124	34	2
Imports for consumption	2,861	5,807	4,746	2,522	4,435
Stocks, Dec. 31:					
Producer	47	46	60	21	21
Consumer	1,085	959	1,077	502	329
Ammonium paratungstate:					
Production	5,021	7,339	6,527	5,604	5,336
Consumption	5,655	8,808	7,941	6,475	6,363
Stocks, Dec. 31: Producer and consumer	970	1,191	1,056	468	292
Primary products:					
Production	6,020	9,799	8,219	6,408	6,640
Consumption	6,523	10,216	8,096	7,214	7,228
Stocks, Dec. 31:					
Producer	1,433	1,850	1,968	1,484	1,646
Consumer	1,446	1,585	1,206	860	787
World: Concentrate:					
Production	40,925	[r]46,148	46,513	[p]42,656	[e]40,232
Consumption	[r]42,577	[r]49,838	47,785	[p]44,822	[e]41,733

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

Legislation and Government Programs.—In February 1987, the General Services Administration (GSA) sold 7,979 kilograms of nonstockpile grade concentrate acquired under the Defense Production Act of 1950. A low-grade concentrate amounting to 5,309 kilograms still remains in this inventory. Physical disposals of nonstockpile grade concentrate in support of the ferroalloy upgrading program totaled 700,000 kilograms during the year. At yearend only 31,258 kilograms of concentrate, authorized for release under this program, remained unsold.

U.S. House of Representatives and Senate conferees approved an amendment to the Omnibus Trade Bill (House bill 3) in November that would suspend for 3 years the duty of $0.17 per pound of contained tungsten in imported ores and concentrates. The amendment was introduced to provide a step toward free and stable trade in a material upon which the United States relies heavily on imports.

Table 2.—U.S. Government tungsten stockpile material inventories and goals

(Metric tons of tungsten content)

Material	Goals	Inventory by program, Dec. 31, 1987		
		National stockpile	DPA[1] inventory	Total
Tungsten concentrate:				
Stockpile grade	25,152	24,996	72	25,068
Nonstockpile grade	--	10,552	5	10,557
Total	25,152	35,548	77	35,625
Ferrotungsten:				
Stockpile grade	--	381	--	381
Nonstockpile grade	--	537	--	537
Total[2]	--	919	--	919
Tungsten metal powder:				
Stockpile grade	726	711	--	711
Nonstockpile grade	--	150	--	150
Total	726	861	--	861
Tungsten carbide powder:				
Stockpile grade	907	871	--	871
Nonstockpile grade	--	51	--	51
Total	907	922	--	922

[1]Defense Production Act (DPA) of 1950.
[2]Data may not add to totals shown because of independent rounding.

DOMESTIC PRODUCTION

All tungsten mines remained closed throughout 1987 as low prices for concentrate continued to make operations uneconomical. Concentrate was acquired mainly through imports, although GSA stockpile sales contributed about 14% to the total supply. A small quantity of concentrate also was produced from previously mined ore stocks.

Curtis Tungsten Inc., Upland, CA, started development work in the first quarter of the year toward reopening the Andrew scheelite mine in the San Gabriel Mountains east of Los Angeles. The mine had been operated on a limited scale during 1985, but was forced to close owing to declining tungsten prices and to unresolved questions regarding access to the land. During 1987, concentrate prices reached a level that the ownership considered to be a break-even point. In addition, all difficulties relating to access to the mine were resolved.

U.S. Tungsten Corp. continued to operate its APT mill in Bishop, CA, although significantly below its production capacity.

AMAX Inc. suspended operations at its APT mill in Fort Madison, IA, in March.

Table 3.—Tungsten concentrate shipped from mines in the United States

Year	Quantity		Reported value, f.o.b. mine[1]		
	Metric ton units of WO_3[2]	Tungsten content (metric tons)	Total (thousands)	Average per unit of WO_3	Average per kilogram of tungsten
1983	128,130	1,016	$10,528	$82.17	$10.36
1984	147,958	1,173	13,409	90.63	11.43
1985	123,944	983	9,143	73.77	9.30
1986	103,053	817	5,774	56.04	7.07
1987	4,288	34	216	[3]50.34	6.35

[1]Values apply to finished concentrate and are in some instances f.o.b. custom mill.
[2]A metric ton unit equals 10 kilograms of tungsten trioxide (WO_3) and contains 7.93 kilograms of tungsten.
[3]Metals Week, U.S. Spot Quotations-Annual Average.

Table 4.—Major producers of tungsten concentrate and principal tungsten processors in the United States in 1987

Company	Location of mine, mill, or processing plant
Producers of tungsten concentrate:	
U.S. Tungsten Corp., a division of Strategic Minerals Corp	Bishop, CA.
Processors of tungsten:	
General Electric Co	Euclid, OH, and Detroit, MI.
GTE Products Corp	Towanda, PA.
Kennametal Inc	Latrobe, PA, and Fallon, NV.
Teledyne Firth Sterling	La Vergne, TN.
Teledyne Wah Chang Huntsville	Huntsville, AL.
U.S. Tungsten Corp., a division of Strategic Minerals Corp	Bishop, CA.

CONSUMPTION AND USES

Domestic consumption of tungsten in primary products remained essentially unchanged from that of 1986. Tungsten carbide powder, used in cutting and wear-resistant materials, accounted for about 54% of the consumption. Other end uses were mill products; specialty steels; and miscellaneous materials, including superalloys, welding and hard-facing rods, and chemical and ceramic uses. Consumption of tungsten carbide declined by about 9% from 1986 values primarily because of the decrease in the demand for machine tools. The average number of oil drilling rigs operating in the United States also declined slightly from the average 957 recorded in 1986. Countering the decline in the demand for wear-resistant components was an increase in the consumption of tungsten mill products used in lighting, electrical, electronic, welding, and various other specialty industries.

Table 5.—Production, disposition, and stocks of tungsten products in the United States in 1987

(Metric tons of tungsten content)

	Hydrogen-reduced metal powder	Tungsten carbide powder		Chemicals	Other[1]	Total
		Made from metal powder	Crushed and crystal-line			
Gross production during year	6,375	3,519	W	W	3,556	13,450
Used to make other products listed here	3,540	1	W	W	2,485	6,026
Net production	2,835	3,518	W	W	1,071	7,424
Stocks, Dec. 31: Producer	845	432	W	58	311	1,646

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Includes ferrotungsten, scheelite (produced from scrap), nickel-tungsten, and self-reducing oxide pellets.

Table 6.—Consumption and stocks of tungsten products in the United States in 1987, by end use

(Metric tons of tungsten content)

End use	Ferro-tungsten	Tung-sten metal powder	Tung-sten carbide powder	Scheelite (natural, synthetic)	Tung-sten scrap[1]	Other tungsten materi-als[2]	Total
Steel:							
Stainless and heat-resisting	64	--	--	W	4	--	68
Alloy	28	--	--	W	--	W	28
Tool	152	--	--	154	W	W	306
Superalloys	W	W	W	W	212	W	212
Alloys (excludes steels and superalloys):							
Cutting and wear-resistant materials	--	124	3,787	--	W	W	3,911
Other alloys[3]	W	W	W	W	W	W	W
Mill products made from metal powder	--	W	W	--	--	W	W
Chemical and ceramic uses	--	W	--	--	--	41	41
Miscellaneous and unspecified	9	1,951	220	101	210	171	2,662
Total	253	2,075	4,007	255	426	212	7,228
Consumer stocks, Dec. 31, 1987	62	16	570	18	71	50	787

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."
[1]Does not include that used in making primary tungsten products.
[2]Includes melting base, self-reducing tungsten, tungsten chemicals, and others.
[3]Includes welding and hard-facing rods and materials and nonferrous alloys.

PRICES

Scheelite prices quoted in the Metal Bulletin (London) increased steadily throughout the year, reaching the March-April 1986 average level of $61.00 per metric ton unit by yearend. Wolframite prices, although exhibiting some fluctuations during the year, also recovered to attain the April 1986 average level of about $53.00 per metric ton unit.

According to Metals Week quotations, APT prices in the U.S. market rose by about 7% in the final 2 months of the year following the signing of the OMA with China. At yearend, duty-paid prices for APT were $82.00 to $83.00 per metric ton unit. APT prices generally began to rise as early as March. Much of the impetus for this rise was attributed to efforts by the Chinese to institute stringent price and distribution controls on exported tungsten materials. Duty-paid purchases of Chinese APT were quoted as low as $60.00 per metric ton unit at the beginning of 1987.

U.S. prices for hydrogen-reduced metal powder and tungsten carbide powder decreased slightly during the year. After stabilizing in April at $21.00 per kilogram for metal powder and $20.60 for tungsten carbide powder, transaction prices broadened downward to ranges of $20.00 to $21.00 per kilogram and $19.60 to $20.60 per kilogram, respectively.

Table 7.—Monthly price quotations of tungsten concentrate in 1987

Month	Metal Bulletin (London), scheelite, European market, 70% WO_3 basis[1]				Metal Bulletin (London), wolframite, European market, 65% WO_3 basis[2]				Metals Week, U.S. spot quotations, 65% WO_3 basis, c.i.f. U.S. ports[3]				International Tungsten Indicator, weighted average price,[4] 60% to 79% WO_3	
	Dollars per metric ton unit			Dollars per short ton unit	Dollars per metric ton unit			Dollars per short ton unit	Dollars per short ton unit			Dollars per metric ton unit		
	Low	High	Average	Average	Low	High	Average	Average	Low	High	Average	Average	Dollars per metric ton unit	Dollars per short ton unit
January	46.00	55.00	50.50	45.81	35.25	46.00	40.63	36.86	33.50	40.00	36.75	40.51	44.51	40.38
February	46.63	55.63	51.13	46.38	39.13	46.13	42.63	38.67	36.00	40.50	38.25	42.16	44.93	40.76
March	48.78	57.89	53.34	48.39	45.89	50.67	48.28	43.80	43.75	50.00	46.88	51.68	48.16	43.69
April	52.57	60.71	56.64	51.38	49.71	54.86	52.29	47.44	47.00	55.00	51.00	56.22	48.92	44.38
May	53.13	61.00	57.07	51.77	49.50	55.00	52.25	47.40	46.00	55.00	50.50	55.67	53.39	48.43
June	55.00	61.00	58.00	52.62	48.00	55.00	51.50	46.72	45.00	55.00	50.00	55.12	54.86	49.77
July	55.22	61.11	58.17	52.77	48.00	55.44	51.72	46.92	44.50	52.50	48.50	53.46	54.33	49.29
August	57.00	62.00	59.50	53.98	42.75	57.00	49.88	45.25	37.00	48.00	42.50	46.85	54.64	49.57
September	57.00	62.00	59.50	53.98	39.75	56.00	47.88	43.44	35.50	44.00	39.75	43.82	52.11	47.27
October	57.00	63.56	60.28	54.69	39.44	53.00	46.22	41.93	39.25	45.50	42.38	46.72	52.51	47.64
November	57.00	64.22	60.61	54.98	46.44	56.56	51.50	46.72	46.00	53.00	49.50	54.56	53.05	48.13
December	57.00	65.00	61.00	55.34	48.50	58.00	53.25	48.31	48.00	56.00	52.00	57.32	54.96	49.86

[1]Low and high prices are reported semiweekly. Monthly averages are arithmetic averages of semiweekly low and high prices. The average price per metric ton unit of WO_3, which is an average of all semiweekly low and high prices, was $57.15 for 1987. The average equivalent price per short ton unit of WO_3 was $51.84 for 1987.

[2]Low and high prices are reported semiweekly. Monthly averages are arithmetic averages for semiweekly low and high prices. The average price per metric ton unit of WO_3, which is an average of all semiweekly low and high prices, was $49.00 for 1987. The average equivalent price per short ton unit of WO_3 was $44.45 for 1987.

[3]Low and high prices are reported weekly. Monthly averages are arithmetic averages of weekly low and high prices. The average price per short ton unit of WO_3, which is an average of all weekly low and high prices, excluding duty, was $45.67 for 1987. The average equivalent price per metric ton unit of WO_3 was $50.34 for 1987.

[4]Weighted average price per metric ton unit of WO_3 was $51.36 for 1987. The equivalent weighted average price per short ton unit of WO_3 was $46.60 for 1987.

FOREIGN TRADE

Total exports of tungsten in concentrate and primary products were only slightly higher than those of 1986. Decreases in exports of concentrate and metal powder were essentially counterbalanced by increases in exports of APT, tungsten carbide and other compounds, alloys, and assorted unwrought tungsten forms. Imports of all products for consumption increased by approximately 50%, largely owing to the increase in imports of concentrate.

On May 22, 1987, the United States International Trade Commission (ITC) ruled that imports of APT and tungstic acid from China had caused injury to the U.S. tungsten industry. To remedy the market disruption determined to exist, the ITC recommended to the President that, for the next 5 years, the combined volume of imports of APT and tungstic acid from China be limited to the larger of 506 metric tons of tungsten content per year or 7.5% of U.S. consumption of these materials. Subsequently, the President determined to provide relief for the domestic industry in the form of a negotiated OMA. On September 28, 1987, the OMA was signed between the United States and China. Under the terms of the agreement, lasting from October 1, 1987 to September 30, 1991, total Chinese imports of APT and tungstic acid were limited to 193 metric tons of tungsten content in the last quarter of 1987, with progressive increases from 821 metric tons in 1988 to 880 and 930 metric tons for the years 1989 and 1990, respectively. The limit set for the first 9 months of 1991 was 680 metric tons. The agreement also incorporated provisions to ensure that the effectiveness of the limits was not undermined by transshipment or by increased imports of tungsten oxide. It also provided for future adjustments to the quotas should the specified limits be exceeded in any time period.

Table 8.—U.S. exports of tungsten ore and concentrate, by country

	1986		1987	
	Tungsten content (metric tons)	Value (thousands)	Tungsten content (metric tons)	Value (thousands)
Colombia	--	--	(1)	$9
Finland	--	--	1	20
France	28	$187	--	--
Germany, Federal Republic of	6	53	--	--
India	(1)	2	(1)	2
Total	34	242	[2]2	31

[1]Less than 1/2 unit.
[2]Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

Table 9.—U.S. exports of ammonium paratungstate, by country

Country	1986			1987		
	Gross weight (metric tons)	Tungsten content[1] (metric tons)	Value (thousands)	Gross weight (metric tons)	Tungsten content[1] (metric tons)	Value (thousands)
Belgium-Luxembourg	(2)	(2)	$6	237	168	$1,384
Canada	--	--	--	69	49	568
France	3	2	22	1	1	11
Germany, Federal Republic of	2	2	47	2	1	28
Japan	--	--	--	2	1	23
Mexico	4	2	31	2	1	15
Portugal	--	--	--	10	7	61
United Kingdom	1	1	21	80	57	615
Total	10	7	127	403	285	2,705

[1]Tungsten content estimated by multiplying gross weight by 0.7066.
[2]Less than 1/2 unit.

Source: Bureau of the Census.

Table 10.—U.S. exports of tungsten carbide powder, by country

Country	1986 Tungsten content (metric tons)	1986 Value (thousands)	1987 Tungsten content (metric tons)	1987 Value (thousands)
Argentina	([1])	$1	([1])	$14
Australia	1	37	4	160
Austria	18	473	11	263
Belgium-Luxembourg	22	714	--	--
Brazil	15	584	7	272
Canada	54	1,598	69	1,744
Denmark	11	221	1	27
Finland	5	61	6	93
Germany, Federal Republic of	45	1,444	97	2,183
India	4	119	4	82
Ireland	--	--	([1])	30
Israel	([1])	10	([1])	3
Italy	10	400	33	1,050
Japan	10	213	24	704
Mexico	7	158	6	126
Netherlands	19	933	10	594
Peru	([1])	10	2	30
Singapore	1	47	([1])	2
South Africa, Republic of	6	256	--	--
Sweden	2	19	12	87
Switzerland	8	220	3	106
United Kingdom	72	908	62	487
Venezuela	3	86	6	216
Other	36	756	26	790
Total	349	9,268	383	9,063

[1]Less than 1/2 unit.

Source: Bureau of the Census.

Table 11.—U.S. exports of tungsten and tungsten alloy powder, by country

Country	1986 Gross weight (metric tons)	1986 Tungsten content[1] (metric tons)	1986 Value (thousands)	1987 Gross weight (metric tons)	1987 Tungsten content[1] (metric tons)	1987 Value (thousands)
Australia	3	2	$106	20	16	$479
Austria	21	17	431	1	1	17
Belgium-Luxembourg	4	3	95	5	4	100
Brazil	10	8	254	6	5	167
Canada	38	31	1,222	42	34	1,197
Finland	23	18	358	12	10	179
Germany, Federal Republic of	110	88	2,665	84	67	2,147
Ireland	11	9	311	1	([2])	13
Israel	256	205	4,430	36	29	572
Italy	39	31	825	37	28	660
Japan	3	2	138	7	5	178
Mexico	6	4	122	7	6	157
Netherlands	467	374	5,142	360	288	3,682
Singapore	1	1	19	([2])	([2])	8
Switzerland	76	61	1,430	101	81	1,577
United Kingdom	25	20	514	8	7	198
Other	96	77	1,717	110	88	1,988
Total	1,189	951	19,779	837	669	13,319

[1]Tungsten content estimated by multiplying gross weight by 0.80.
[2]Less than 1/2 unit.

Source: Bureau of the Census.

Table 12.—U.S. exports of miscellaneous tungsten-bearing materials

Product and country	1986 Tungsten content (metric tons)	1986 Value (thousands)	1987 Tungsten content (metric tons)	1987 Value (thousands)
Tungsten and tungsten alloy wire:				
Argentina	1	$353	2	$512
Brazil	6	924	9	936
Canada	13	2,871	26	3,226
France	2	246	2	206
Germany, Federal Republic of	9	2,436	9	2,042
Hong Kong	2	179	2	169
India	9	883	6	530
Italy	3	381	5	604
Japan	3	912	3	783
Korea, Republic of	5	649	5	962
Mexico	3	350	6	562
Poland	(1)	31	(1)	18
Taiwan	4	445	8	716
United Kingdom	4	792	6	868
Other	6	2,077	12	2,608
Total	70	13,529	101	14,742
Unwrought tungsten and alloy in crude form, waste, and scrap:				
Australia	(1)	10	1	24
Austria	57	308	31	332
Belgium-Luxembourg	15	88	--	--
Canada	18	329	4	49
Finland	(1)	2	--	--
Germany, Federal Republic of	404	1,478	457	1,504
Israel	--	--	(1)	2
Japan	5	80	(1)	5
Mexico	1	29	--	--
Netherlands	3	19	--	--
South Africa, Republic of	1	15	--	--
Sweden	1	7	1	6
United Kingdom	36	276	73	523
Other	1	13	6	70
Total	542	2,654	573	2,515
Other tungsten metal:				
Australia	2	138	3	184
Austria	8	612	1	31
Canada	27	2,945	19	2,975
France	4	686	6	495
Germany, Federal Republic of	26	1,162	14	679
Italy	2	89	(1)	37
Japan	19	2,779	23	2,751
Mexico	3	256	5	335
Netherlands	1	220	2	542
Singapore	(1)	28	(1)	8
South Africa, Republic of	(1)	7	1	62
Sweden	1	34	(1)	13
Switzerland	4	241	4	285
Taiwan	5	291	7	399
United Kingdom	17	1,299	11	1,053
Venezuela	1	32	(1)	11
Other	10	604	12	769
Total	130	11,423	108	10,629

See footnote at end of table.

Table 12.—U.S. exports of miscellaneous tungsten-bearing materials —Continued

Product and country	1986 Tungsten content (metric tons)	1986 Value (thousands)	1987 Tungsten content (metric tons)	1987 Value (thousands)
Other tungsten compounds:				
Austria	1	$13	(1)	$13
Belgium-Luxembourg	(1)	2	(1)	3
Brazil	4	107	(1)	25
Canada	4	444	1	37
China	(1)	1	(1)	2
France	1	36	13	199
Germany, Federal Republic of	5	222	34	334
Hong Kong	1	33	1	23
Ireland	2	83	(1)	10
Israel	(1)	28	(1)	12
Italy	1	42	1	51
Japan	6	263	5	102
Korea, Republic of	(1)	373	3	119
Mexico	25	237	2	63
Netherlands	1	42	(1)	28
Singapore	2	51	(1)	6
Sweden	1	29	(1)	6
United Kingdom	2	87	10	387
Venezuela	(1)	14	(1)	12
Other	5	127	50	180
Total	61	2,234	120	1,612

[1]Less than 1/2 unit.

Source: Bureau of the Census.

Table 13.—U.S. imports for consumption of tungsten ore and concentrate, by country

Country	1986 Tungsten content (metric tons)	1986 Value (thousands)	1987 Tungsten content (metric tons)	1987 Value (thousands)
Australia	192	$946	65	$343
Bolivia	609	3,231	750	3,476
Brazil	8	44	--	--
Burma	85	470	96	478
Canada	61	425	312	4,283
Chile	104	472	86	268
China	302	1,840	1,139	5,799
Germany, Federal Republic of	(1)	4	69	450
Hong Kong	--	--	46	249
Japan	44	279	--	--
Mexico	173	879	227	853
Netherlands	--	--	11	63
Peru	436	2,029	362	1,790
Portugal	202	1,520	422	2,632
Rwanda	--	--	101	386
Singapore	12	67	--	--
Spain	--	--	16	55
Sweden	--	--	10	36
Thailand	264	1,415	418	2,013
Turkey	30	219	284	790
Total	2,522	13,840	4,414	23,964

[1]Less than 1/2 unit.

Source: Bureau of the Census.

Table 14.—U.S. imports for consumption of ammonium tungstate, by country

Country	1986 Tungsten content (metric tons)	1986 Value (thousands)	1987 Tungsten content (metric tons)	1987 Value (thousands)
China	971	$8,894	1,239	$9,768
Germany, Federal Republic of	131	1,618	65	664
Hong Kong	5	44	--	--
Japan	(1)	2	--	--
Korea, Republic of	48	491	61	491
Switzerland	1	9	--	--
Taiwan	--	--	1	6
United Kingdom	--	--	36	193
Total	1,156	11,058	1,402	11,122

[1]Less than 1/2 unit.

Source: Bureau of the Census.

Table 15.—U.S. imports for consumption of ferrotungsten, by country

Country	1986 Tungsten content (metric tons)	1986 Value (thousands)	1987 Tungsten content (metric tons)	1987 Value (thousands)
Austria	85	$770	40	$316
Brazil	4	22	--	--
Canada	--	--	17	68
China	75	443	220	1,284
Germany, Federal Republic of	(1)	2	--	--
Netherlands	4	21	--	--
Peru	--	--	15	36
Portugal	14	141	--	--
Switzerland	--	--	8	72
United Kingdom	3	19	--	--
Total	185	1,418	300	1,776

[1]Less than 1/2 unit.

Source: Bureau of the Census.

Table 16.—U.S. imports for consumption of miscellaneous tungsten-bearing materials

Product and country	1986 Tungsten content (metric tons)	1986 Value (thousands)	1987 Tungsten content (metric tons)	1987 Value (thousands)
Other metal-bearing materials in chief value of tungsten:				
Austria	13	$104	--	--
Brazil	8	49	--	--
China	43	226	--	--
South Africa, Republic of	7	39	--	--
United Kingdom	--	--	1	$5
Total	71	418	1	5
Waste and scrap containing not over 50% tungsten:				
Canada	1	15	1	6
France	--	--	8	64
Other	35	205	2	11
Total	36	220	11	81
Waste and scrap containing over 50% tungsten:				
Austria	--	--	9	88
Canada	30	864	21	287
China	15	152	148	955
France	5	34	16	82
Germany, Federal Republic of	15	186	34	205
Hong Kong	1	9	3	25

Table 16.—U.S. imports for consumption of miscellaneous tungsten-bearing materials —Continued

Product and country	1986 Tungsten content (metric tons)	1986 Value (thousands)	1987 Tungsten content (metric tons)	1987 Value (thousands)
Waste and scrap containing over 50% tungsten —Continued				
Israel	69	$610	195	$1,133
Italy	1	15	11	25
Japan	16	251	11	112
Mexico	5	46	10	86
Netherlands	228	1,416	270	1,429
Singapore	28	752	16	256
South Africa, Republic of	8	62	15	155
Sweden	--	--	72	327
Switzerland	9	85	8	52
United Kingdom	5	125	121	568
Total	435	4,607	960	5,785
Unwrought tungsten, except alloys, in lumps, grains, and powders:				
Belgium-Luxembourg	3	93	(1)	21
Germany, Federal Republic of	29	609	21	536
Japan	2	109	3	150
Korea, Republic of	17	256	1	25
Other	3	37	1	40
Total	54	1,104	26	772
Unwrought tungsten, ingots, and shot	1	46	2	70
Unwrought tungsten, other[2]	(1)	15	5	236
Unwrought tungsten, alloys:				
Austria	(1)	31	1	57
Canada	3	283	(1)	13
Germany, Federal Republic of	7	158	3	72
Other	4	186	3	94
Total	14	658	7	236
Wrought tungsten:[2]				
Austria	1	43	(1)	29
Belgium-Luxembourg	10	845	5	458
Japan	32	3,337	35	2,662
United Kingdom	3	107	1	27
Other	2	227	1	165
Total	48	4,559	42	3,341
Tungstic acid: China	156	1,167	276	1,560
Calcium tungstate:				
Germany, Federal Republic of	9	328	7	204
Japan	1	29	1	52
Other	--	--	(1)	8
Total	10	357	8	264
Potassium tungstate	--	--	(1)	20
Sodium tungstate:				
China	129	734	--	--
Germany, Federal Republic of	1	17	(1)	5
Total	130	751	(1)	5
Tungsten carbide:				
Austria	2	53	(1)	3
Belgium-Luxembourg	34	1,207	21	626
Canada	--	--	4	111
China	35	657	3	105
Germany, Federal Republic of	238	4,710	422	7,059
Japan	(1)	33	1	52
Korea, Republic of	41	734	12	212
United Kingdom	23	232	5	49
Other	2	63	26	519
Total	375	7,689	494	8,736

See footnotes at end of table.

Table 16.—U.S. imports for consumption of miscellaneous tungsten-bearing materials —Continued

Product and country	1986 Tungsten content (metric tons)	1986 Value (thousands)	1987 Tungsten content (metric tons)	1987 Value (thousands)
Other tungsten compounds:				
Canada	8	$209	(1)	$4
China	(1)	1	15	68
Other	11	125	10	196
Total	19	335	25	268
Mixtures, organic compounds, chief value in tungsten: Other	10	226	8	208

[1]Less than 1/2 unit.
[2]Estimated from reported gross weight.

Source: Bureau of the Census.

Table 17.—U.S. import duties on tungsten

TSUS No.	Item	Rate of duty effective Jan. 1, 1987: Most favored nation (MFN)	Rate of duty effective Jan. 1, 1987: Non-MFN
601.54	Tungsten ore	17 cents per pound on tungsten content.	50 cents per pound on tungsten content.
603.45	Other metal-bearing materials in chief value of tungsten.	10 cents per pound on tungsten content and 4.8% ad valorem.	60 cents per pound on tungsten content and 40% ad valorem.
606.48	Ferrotungsten and ferrosilicon tungsten	5.6% ad valorem	35% ad valorem.
629.25	Waste and scrap containing by weight not over 50% tungsten.	4.9% ad valorem	50% ad valorem.
629.26	Waste and scrap containing by weight over 50% tungsten.	4.2% ad valorem	Do.
629.28	Unwrought tungsten, except alloys, in lumps, grains, and powders.	10.5% ad valorem	58% ad valorem.
629.29	Unwrought tungsten, ingots, and shot	6.0% ad valorem	50% ad valorem.
629.30	Unwrought tungsten, other	6.6% ad valorem	60% ad valorem.
629.32	Unwrought tungsten, alloys, containing by weight not over 50% tungsten.	4.7% ad valorem	35.5% ad valorem.
629.33	Unwrought tungsten, alloys, containing by weight over 50% tungsten.	6.6% ad valorem	60% ad valorem.
629.35	Wrought tungsten	6.5% ad valorem	Do.
416.40	Tungstic acid	10.5% ad valorem	55% ad valorem.
417.40	Ammonium tungstate	10.0% ad valorem	49.5% ad valorem.
418.30	Calcium tungstate	do	43.5% ad valorem.
420.32	Potassium tungstate	do	50.5% ad valorem.
421.56	Sodium tungstate	do	46.5% ad valorem.
422.40	Tungsten carbide	10.5% ad valorem	55.5% ad valorem.
422.42	Other tungsten compounds	10.0% ad valorem	45.5% ad valorem.
423.92	Mixtures of two or more inorganic compounds in chief value of tungsten.	do	Do.

WORLD REVIEW

The Committee on Tungsten (COT) of the United Nations Conference on Trade and Development (UNCTAD) convened its 19th session in Geneva, Switzerland, in November 1987. The general view of the situation in the tungsten market presented by the consuming countries was that economic growth would remain modest, with a possible increase in some cases. Consequently, market demand generated by economic performance would remain limited, at least in the short run. However, the evolution of consumption could vary from one sector to another. Some of the major end-use sectors, including oil and gas drilling, mineral mining, construction, and industrial machinery and equipment production, were unlikely to show any substantial improvement in activity. Better prospects for demand were expected in a number of applications, such as in automobiles, truck and jet engines, and in electronics. These improvements would compensate, at least in part, for the decline in consumption in other sectors. Structural and technological changes in the industry, including increased use of substitutes and more efficient use of tungsten products, were likely to continue having a negative effect on consumption.

Several representatives expressed concern about the depressed prices in the tungsten market and the continued difficulties faced by mining operations in their countries. Mines remained completely shut down in Canada, France, and the United States. Mines had also been closed in many other countries, including Australia, Brazil, Peru, Portugal, the Republic of Korea, and Spain. Fears were expressed that continued low concentrate prices would preclude the reopening of closed down mines. The closing down of mine operations was attributed to the availability of inexpensive imported materials and unremunerative prices. Although there were some price improvements during 1987, there were still considerable quantities of tungsten material overhanging the market. The market outlook, therefore, was expected to depend greatly on supply restraint and other factors, including development of new end uses. The existing idled mine capacities, together with the materials held in various types of stocks, would continue to act as an overhang preventing any rapid price increases.

The UNCTAD secretariat also presented reports on changing market patterns, structural and technological changes, and exchange rate variations in the tungsten industry. Producer and consumer nations continued to disagree on the most acceptable method for resolving current tungsten market problems. China, supported by some other producing countries, proposed the institution of an international price stabilization agreement between consumer and producer nations. Most consumer nations, on the other hand, suggested that stabilization could be enhanced by reinforcing the work of the COT. More information on market conditions could lead to better investment and operating decisions by individual producers and consumers. Several participants suggested that a market-oriented approach to product pricing and trade by China, the major exporting country, would also be beneficial.

On December 31, 1987, the Primary Tungsten Association (PTA) was disbanded and replaced by the International Tungsten Industry Association (ITIA). Financial support to the PTA by the producing countries had eroded significantly as a result of declining market prices for concentrate and subsequent mine closures. The ITIA, with broader membership, will be supported not only by producers, but also by consumers, converters, traders, assayers, and other participants in the tungsten industry.

The European Economic Community (EEC) tungsten producers compiled information supporting their contention that the Chinese were selling upgraded tungsten products at prices well below that considered to be reasonable market values. In order to remedy the situation, the producers were considering either requesting the EEC to conduct a formal antidumping investigation or negotiating an OMA similar to that signed between China and the United States.

Brazil.—Scheelite production decreased by about 23% as a result of continuing depressed prices. Production levels for the year essentially were capable of meeting only Brazil's demand with little remaining for export.

China.—A new trade organization was established by the Chinese in February in an effort to stabilize tungsten prices. The organization, under the unified leadership of China National Nonferrous Metals Import and Export Corp. and China National Metals & Minerals Import and Export Corp., will conclude all contracts with foreign companies for exports of tungsten concentrate and APT. Branch offices will function only to process these contracts. Two other members of the organization, China Metallurgical Import and Export Corp. and China National Chemicals Import and Export Corp., will handle sales of ferrotungsten and other tungsten chemicals, respectively.

Spain.—The La Parrilla Mine was closed in April as a result of flooding problems and continued low market prices, with subsequent mounting debts. In October, efforts were initiated by the Spanish trade union, General Workers Union, representing the miners, to reopen the mine. A request was submitted to the regional government that either additional financing be provided to the private owners of the mine or the mine be operated by the regional government. Prior to its closing, the mine accounted for nearly 80% of Spain's production of tungsten concentrate.

Table 18.—Tungsten: World concentrate production, by country[1]

(Metric tons of tungsten content)

Country	1983	1984	1985	1986[p]	1987[e]
Argentina	41	37	17	[e]25	25
Australia	2,015	[r]1,709	1,971	1,600	[2]1,150
Austria	1,408	1,632	1,481	1,387	1,250
Bolivia	2,449	1,893	1,643	1,095	500
Brazil	1,026	1,037	1,090	875	[2]672
Burma	930	1,096	945	715	425
Canada	328	3,715	3,174	1,416	--
China[e]	12,500	13,500	15,000	15,000	18,000
Czechoslovakia[e]	50	50	50	50	45
France	832	796	735	982	--
Guatemala	--	--	6	9	10
India	15	21	28	23	25
Japan	475	477	568	579	170
Korea, North[e]	500	1,000	1,000	1,000	1,000
Korea, Republic of	2,480	2,702	2,579	2,455	2,500
Malaysia	31	25	[e]20	[e]25	25
Mexico	186	274	282	294	[2]213
Mongolia[e]	1,500	1,500	1,500	1,500	1,500
New Zealand	6	6	5	[e]5	5
Peru	762	699	723	593	600
Portugal	1,183	1,509	1,755	1,637	1,500
Rwanda	231	260	167	13	--
Spain	517	565	458	495	100
Sweden	365	385	402	357	350
Thailand	562	741	586	475	660
Turkey[e]	390	153	100	50	[2]262
Uganda[e]	[2]4	4	4	4	4
U.S.S.R.[e]	9,100	9,100	9,200	9,200	9,200
United States	980	1,203	996	780	[2]34
Zaire	44	30	18	[e]15	5
Zimbabwe	15	29	10	2	2
Total	40,925	[r]46,148	46,513	42,656	40,232

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through May 20, 1988.
[2]Reported figure.

Table 19.—Tungsten: World concentrate consumption, by country[1]

(Metric tons of tungsten content)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Consumption, reported:					
Australia[e 3]	200	175	150	125	95
Austria	1,629	2,096	[e]2,000	[e]2,000	1,800
Canada[e 3]	15	12	12	12	10
France	520	815	808	667	620
Japan	1,977	2,302	2,616	2,145	2,060
Korea, Republic of	1,555	2,070	2,048	1,987	1,950
Mexico	22	77	79	42	50
Portugal	174	159	133	[e]50	80
Sweden	774	765	820	1,020	500
United Kingdom	560	610	600	580	550
United States	5,181	8,577	6,838	4,804	[4]5,506
Consumption, apparent:[5]					
Argentina[e 3]	23	37	17	25	30
Belgium-Luxembourg	[e]10	142	341	30	200
Brazil	450	538	1,048	672	678
Bulgaria[e 3]	100	100	100	100	100
China[e 3]	6,500	7,000	7,500	7,500	5,000
Czechoslovakia[e]	1,300	1,300	1,300	1,300	1,300
German Democratic Republic[e]	250	270	270	270	250
Germany, Federal Republic of	2,030	3,934	2,073	1,720	1,450
Hungary[e]	400	[r]400	400	400	400
India	250	157	250	[e]250	250

See footnotes at end of table.

Table 19.—Tungsten: World concentrate consumption, by country[1] —Continued

(Metric tons of tungsten content)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Consumption, apparent:[5] —Continued					
Italy	27	78	[e]100	[e]100	80
Korea, North[e 3]	1,000	1,000	1,000	1,000	1,000
Netherlands[e]	300	300	400	350	350
Poland	1,073	594	603	1,264	1,000
South Africa, Republic of[e]	250	250	250	250	250
Spain	107	80	29	159	174
U.S.S.R.[e 3]	15,900	16,000	16,000	16,000	16,000
Total	[r]42,577	[r]49,838	47,785	44,822	41,733

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Source, unless otherwise specified, is the Statistical Summaries Update of the UNCTAD Committee on Tungsten; 19th Session, Geneva, Switzerland, Nov. 9-13, 1987.
[2]In addition to the countries listed, 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 the Bureau of Mines.
[4]Reported figure.
[5]Production plus imports minus exports. For a few countries where data were available, variations in stocks were used in determining consumption.

TECHNOLOGY

Several technological advancements were achieved during the year to enhance the use of tungsten-bearing materials. Single crystal castings of nickel-base superalloys containing 10% to 12.5% tungsten were demonstrated to exhibit superior high-temperature capabilities compared with their predecessors, the polycrystal and columnar crystal alloys.[2] These alloys are used as airfoils in modern gas turbine engines and must maintain strength at high temperatures in corrosive environments. Some renewed interest was generated in turbine engine applications for previously developed columbium-based superalloys containing 10% tungsten.[3] Results of earlier studies had shown the practical temperature range for these cast alloys to be nearly 275° C above that of the nickel-base superalloys. Powder metallurgy was suggested as an attractive processing technique for improving the overall metallurgical characteristics of the columbium-based alloys.

High-purity tungsten pipe of structural quality was prepared using a chemical vapor deposition (CVD) process.[4] After deposition of the tungsten on a thin copper cylinder, the copper was dissolved in acid leaving a microcrystalline tungsten pipe. Although pure tungsten metal resists corrosion and high temperatures, its characteristics prevent it from being formed into such a practical shape by standard metalworking techniques. Tungsten pipe is prepared commercially using powder metallurgy processes but is less pure than the CVD type because copper, iron, or nickel, must be added as binder material.

As electronics technology has begun to advance across a broad spectrum, there has been a noticeable increase in the demand for certain oxides of tungsten as dielectric materials and ceramic capacitors.[5] When combined with other refractory metal oxides, these materials exhibit excellent electronic properties well beyond those of the more common metallic oxides used in the electronics industry.

Use of tungsten and molybdenum compounds to kill termites gained interest as a result of a study conducted 6 years ago by a genetic engineering company.[6] In that study, observations were made of certain microbes that resided in the intestines of the termite. Specifically, these microbes used tungsten and molybdenum chemicals as part of a process to supply nitrogen to the termites. After feeding the termites various tungsten and molybdenum chemicals to determine their role in the process, the microbes continued to fix nitrogen, but, for still unknown reasons, the termites died. The obvious commercial significance of this discovery is the fact that these harmless chemicals could replace the banned insecticides that had been used to control termites.

Developments in cutting tools and cutting tool technology captured significant interest during the year. Competition intensified for the market in silicon carbide, whisker-reinforced, alumina cutting inserts used to machine superalloys in aircraft engine-components.[7] Inserts with whisker sizes ranging from 0.3-micrometer to 0.6 to 0.8-micrometer to 1 to 3 micrometers diameter were tested and marketed. Performance results among the various whisker inserts varied, but each was superior to traditional carbide inserts.

Kennametal Inc., Latrobe, PA, introduced a new, partly ceramic, grade of cutting tool that could further reduce the demand for tungsten.[8] The new grade, KT 175, ceramic-metal insert should act as an intermediate between traditional tungsten carbide cutting tools and the harder but more brittle, whisker-reinforced inserts. KT 175 is a titanium carbide, titanium nitride-based ceramic that uses nickel as a binder. Tool life has been demonstrated to be three times that of uncoated cemented tungsten carbides.

A new application being developed for polycrystalline diamond compact (PDC) tools is their use as drill blanks on mining picks for continuous miners, longwall miners, and roadheaders.[9] Results of studies demonstrated that these PDC tools consumed less energy during cutting and were less incendiary than conventional carbide tools.

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[1]Physical scientist, Branch of Ferrous Metals.

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Vanadium

By Henry E. Hilliard[1]

Reported consumption of vanadium (V) increased after more than 2 years of decline. Most of the increase could be attributed to the domestic steel industry, which had a much better year than expected. About 85% of all vanadium was consumed by the steel industry as an alloying agent for steel. Domestic production and shipments of raw steel increased significantly with a corresponding increase in demand and production of vanadium. The increase in demand was met by increased production from fly ash, spent catalysts, and refinery residues. Production from domestic ores declined during this period.

Imports of vanadium raw materials increased due to shortages of domestic ore and petroleum residues. The increase in more expensive imports combined with an increase in the price of aluminum (Al), used in the production of ferrovanadium (FeV) and V-Al masteralloys, resulted in the announcement of price increases by most producers. Overall exports declined despite the lower value of the U.S. dollar but showed signs of improvement in the latter part of the year.

Table 1.—Salient vanadium statistics

(Short tons of contained vanadium unless otherwise specified)

	1983	1984	1985	1986	1987
United States:					
Production:					
Ore and concentrate:					
Recoverable vanadium[1]	2,171	1,617	W	W	W
Value thousands	$30,675	$24,551	W	W	W
Vanadium oxides recovered from ore[2]	2,433	2,620	W	W	W
Vanadium oxides recovered from petroleum residue[3]	893	1,701	2,695	2,330	2,508
Consumption	3,277	4,761	4,883	4,308	4,653
Exports:					
Ferrovanadium (gross weight)	775	469	454	513	436
Ore and concentrate	59	12	3	86	--
Vanadium pentoxide, anhydride (gross weight)	2,648	3,712	1,527	1,544	1,461
Other compounds (gross weight)	95	305	322	343	479
Imports (general):					
Ferrovanadium (gross weight)	846	1,461	977	747	422
Ores, slags, residues	58	633	303	2,013	2,264
Vanadium pentoxide, anhydride	408	149	63	443	357
World: Production from ores, concentrates, slags	30,924	34,291	[4]33,299	p [4]32,530	e [4]34,300

[e]Estimated. [p]Preliminary. W Withheld to avoid disclosing company proprietary data.

[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 ores and ferrophosphorus; includes metavanadates.

[3]Includes vanadium recovered from ashes and spent catalysts.

[4]Excludes U.S. production.

Domestic Data Coverage.—Domestic production data for vanadium are developed by the Bureau of Mines from voluntary surveys of U.S. mills and processing facilities. Of the 10 plants and/or mills canvassed in 1987, 9 responded with complete data, representing more than 95% of total production. Production for the one nonrespondent was estimated using reported prior year production levels adjusted by trends in employment and other guidelines. Supplemental data were provided by two power-generating stations. Data on uranium-vanadium mining operations were obtained from an independent survey conducted by the U.S. Department of Energy (DOE). When efforts to obtain response to a Bureau survey fail, it becomes necessary to use estimation techniques to account for the missing data.

Legislation and Government Programs.—The National Defense Stockpile (NDS) goal of 7,700 tons of vanadium contained in vanadium pentoxide (V_2O_5) and 1,000 tons in FeV was in effect throughout 1987. Actual yearend stockpile inventories, reported by the General Services Administration (GSA), contained only 721 tons of vanadium as V_2O_5. In May, a defense authorization bill advanced in the House and the Senate that contained proposals to give Congress more control over NDS goals. The Senate version of the bill would allow the President to retain authority over stockpile goals, but within narrower limits. The President could increase or decrease stockpile goals for materials by up to 10% without congressional approval, but would first have to identify the changes in the annual materials plan. The plan is the President's official advisory to Congress on anticipated NDS acquisitions and disposals. If the President wanted to eliminate or reduce an inventory goal by more than 10%, the change would have to be approved by Congress in the form of legislation. Under provisions of the House bill, which had already passed the Critical Materials Subcommittee, the President would lose all of his independent stockpile goal setting authority. Congress would set the goals by law, and stockpile management would be shifted from GSA to the U.S. Department of Defense. The House and Senate versions of the bill were not complementary and differences were to be worked out in a joint House-Senate Conference Committee.

In a decision of importance to importers of vanadium materials, the Supreme Court ruled that States may tax imported goods sitting in duty-free customs-bonded warehouses if those goods are slated for domestic sale. The decision paved the way for the imposition of State and local taxes on foreign products. U.S. importers sometimes store imported goods in duty-free customs-bonded warehouses when import quotas for a particular product have been filled for the year. During this period, the goods are not subject to local property taxes. Courts have ruled that such goods are part of "the stream of commerce" and should not be taxed by State and local governments. In this case, evidence indicated that the goods in question were scheduled to be used in products sold in the United States, not abroad. The decision could have a considerable impact on storing such goods in the future. About $7 million in local taxes was at issue in this case alone.

In July, the 10th U.S. Court of Appeals in Denver, CO, ruled that DOE must restrict the enrichment of foreign uranium to protect the domestic uranium industry. The case began when domestic uranium-vanadium mining companies challenged DOE's interpretation of a Federal law intended to protect the United States from becoming dependent on foreign uranium. The litigation was based on a section of the Atomic Energy Act that required the Government to ensure the viability of the U.S. uranium industry. DOE first concluded in 1985 and again in 1986 that the industry wasn't viable, but refused to restrict imports, arguing that to do so would exacerbate trade tension with major trade partners such as Canada and would drive nuclear powerplant operators abroad for uranium enrichment. Annual U.S. production slumped from about 44 million pounds of uranium oxide and 15 million pounds of byproduct V_2O_5 in 1980 to less than one-third of that in 1986.[2] Since annual U.S. consumption was about 39 million pounds, utilities and other users reduced stocks or filled needs from Australia, Canada, and elsewhere. Uranium from the Republic of South Africa has already fallen under restrictions owing to anti-apartheid sanctions. In 1986, imports of South African uranium surged 300% to more than 13 million pounds. Almost 60% of the deliveries took place in December 1986, the last month before the embargo took effect.

DOMESTIC PRODUCTION

Production of V_2O_5 and shipments of finished products saw slight increases in 1987 with most of the increases coming in the fourth quarter. Pentoxide production was more than 6,000 tons compared with less than 5,000 tons in 1986. Production of V_2O_5 was aided by an unexpected good year for the steel industry, where raw steel production was up more than 8%. V_2O_5 is the principal starting material for the manufacture of alloys, chemicals, catalysts, and other vanadium compounds.

Recoverable production, which represents receipts of domestic ore and vanadium-bearing ferrophosphorus slag, continued the decline that began in 1983. Production from ores was closely tied to the uranium industry, which had fallen on hard times in the 1980's because of reduced demand, imports, and excess capacity, resulting in a sharp decline in the price of uranium oxide (U_3O_8). The outlook for the moribund uranium-vanadium mining and milling industry showed signs of improvement in late 1987, particularly after a favorable decision by the 10th U.S. Circuit Court of Appeals restricted the use of DOE enrichment facilities to domestic material. It would not, however, affect enrichment of foreign uranium for reexport, nor the ability of domestic utilities to have their uranium enriched outside the United States. Vanadium production lost from domestic ores was partially offset by increased production from low-cost petroleum residues, utility ash, and spent catalysts.

Shieldalloy Corp., Newfield, NJ, bought Foote Mineral Corp.'s ferrovanadium plant in Cambridge, OH, for $6.8 million in June. Shieldalloy is a producer of ferroalloys, tantalum, aluminum master alloys, and chromium. In December, the parent company of Shieldalloy, the Metallurg Group, announced plans to merge Shieldalloy with Metallurg Alloy Corp., effective January 1, 1988. The new company, Shieldalloy Metallurgical Corp., will maintain its headquarters in New York, NY. Shortly after announcing the merger, Shieldalloy and Affiliated Metals and Minerals Inc., Pittsburgh, PA, signed a letter of intent to develop a joint venture to produce V_2O_5 from a fly ash previously thought to be too low in vanadium content for economical processing. The processing plant was to be in New Castle, PA, where Affiliated operated an FeV unit and had some of the equipment already in place for producing V_2O_5 from vanadium-bearing slags. All output from the plant will be consumed internally in the production of FeV.

The Umetco Minerals Div. of Union Carbide Corp. reopened the LaSalle uranium mine in Utah and hired several miners to fulfill delivery contracts rather than continue to purchase ore as in the past. Ore from the mine was used to supply the White Mesa mill at Blanding, UT. The mill resumed operation in late 1985 after being closed for several months. The mill, with a design capacity of 2,000 tons of ore per day, produced 4.8 million pounds of uranium oxide and 2.8 million pounds of V_2O_5 in 1986.[3] Meanwhile, Atlas Corp. announced a restructuring of its operations to focus on its core business of mining precious metals. The company closed its uranium operations because of the continuing depressed state of the uranium industry. Atlas' uranium-vanadium mill at Moab, UT, had been closed since 1985.

Strategic Minerals Corp. (Stratcor), Danbury, CT, began producing Nitrovan in the United States for the first time. Nitrovan is a nitrogen derivative of vanadium containing 5% to 10% nitrogen. The company previously produced the additive for steel only at its plant in Brits, Republic of South Africa. A new facility was built at an existing vanadium plant in Niagara Falls, NY. Stratcor installed a new furnace, mixing facilities, and other equipment at a cost estimated at about $9 million.

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]
1983	W	2,171
1984	W	1,617
1985	W	W
1986	W	W
1987	W	W

W Withheld to avoid disclosing company proprietary data.

[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.—U.S. production of vanadium oxides[1]

(Short tons)

Year	Gross weight	Oxide content[2]
1983	4,590	4,344
1984	4,688	4,678
1985	W	W
1986	W	W
1987	W	W

W Withheld to avoid disclosing company proprietary data.
[1]Produced directly from all domestic ores and ferrophosphorus; includes metavanadates.
[2]Expressed as equivalent V_2O_5.

CONSUMPTION, USES, AND STOCKS

Reported consumption of vanadium compounds in 1987 was 4,653 tons of contained vanadium. The largest consumers were producers of high-strength low-alloy steels, followed by carbon steel and full alloy steels.

One of the most important uses of vanadium is as an alloying element by the steel industry. The addition of 1% to 5% vanadium-to-steel produces grain refinement and increases the hardenability. Vanadium is a strong carbide former, which causes carbide particles to form in the steel, thus restricting the grain boundaries during heat treatment. This produces a fine grain that exhibits greater toughness and impact resistance than a course-grained steel and is more resistant to cracking during quenching. The carbide dispersion also confers wear resistance, weldability, and good high-temperature strength. Vanadium steels are used in dies and taps because of their wear resistance. They also are used as construction steels in light and heavy sections, for heavy iron and steel castings, forged parts, automobile parts, springs, and ball bearings. Vanadium is an important component of ferrous alloys used in jet aircraft engines and turbine blades, where high-temperature creep resistance is required.

The principal application of vanadium in nonferrous alloys was in the titanium 6Al-4V alloy, which is irreplaceable in supersonic aircraft, where strength-to-weight ratio is a primary consideration. Vanadium imparts high-temperature strength to titanium, a property essential in high-performance jet engines, high-speed air frames, and rocket motor cases. Vanadium foil can be used as bonding material in the cladding of titanium to steel. Vanadium can be used in copper-base alloy production to control gas content and microstructure. Small amounts of vanadium are added to aluminum alloys used in the manufacture of pistons for internal combustion engines. The vanadium enhances the alloy's strength and reduces its coefficient of thermal expansion. Vanadium is a component in several permanent-magnet alloys containing cobalt, iron, and nickel. The most common of these alloys contains 2% to 13% vanadium. Vanadium compounds are also used as catalysts in certain chemical and petrochemical reactions.

Reported consumers' and producers' stocks of vanadium oxides, metal, alloys, and chemicals totaled 2,057 tons of contained vanadium at yearend 1987 compared with 1,842 tons at yearend 1986. Combined producers' and consumers' stocks represented a 3-month supply at the current rate of consumption.

Table 4.—Producers of vanadium alloys or metal in the United States in 1987

Producer	Plant location	Products[1]
Affiliated Metals and Minerals Inc	New Castle, PA	FeV.
KB Alloys Inc	Henderson, KY	VAl, ZrVAl.
Do	Wenatchee, WA	Do.
Reading Alloys Inc	Robesonia, PA	FeV, VAl, V.
Shieldalloy Metallurgical Corp	Newfield, NJ	FeV, Ferovan.[2]
Strategic Minerals Corp	Niagara Falls, NY	FeV, VAl, Nitrovan,[2] Carvan.[2]
Teledyne Wah Chang Albany	Albany, OR	V, VAl.

[1]FeV, ferrovanadium; V, vanadium metal; VAl, vanadium aluminum; ZrVAl, zirconium vanadium aluminum.
[2]Registered trademarks for patented products.

Table 5.—U.S. consumption and consumer stocks of vanadium materials, by type

(Short tons of contained vanadium)

Type	1986		1987	
	Consumption	Ending stocks	Consumption	Ending stocks
Ferrovanadium[1]	3,617	252	3,925	322
Oxide	11	W	17	10
Ammonium metavanadate	W	W	W	W
Other[2]	680	62	711	40
Total	4,308	314	4,653	372

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Includes other vanadium-iron-carbon alloys as well as vanadium oxides added directly to steel.
[2]Consists principally of vanadium-aluminum alloy, plus relatively small quantities of other vanadium alloys and vanadium metal.

Table 6.—U.S. consumption of vanadium in 1987, by end use

(Short tons of contained vanadium)

End use	Quantity
Steel:	
Carbon	1,197
Stainless and heat-resisting	65
Full alloy	816
High-strength low-alloy	1,336
Tool	465
Unspecified	--
Total	3,879
Cast irons	25
Superalloys	10
Alloys (excluding steels and superalloys):	
Cutting and wear-resistant materials	W
Welding and alloy hard-facing rods and materials	7
Nonferrous alloys	684
Other alloys[1]	W
Chemicals and ceramics:	
Catalysts	12
Other[2]	W
Miscellaneous and unspecified	36
Grand total	4,653

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."
[1]Includes magnetic alloys.
[2]Includes pigments.

PRICES

The Metals Week price quotation for domestic 98% fused V_2O_5 (metallurgical-grade) at the beginning of 1987 was $3.65 per pound V_2O_5 content, f.o.b. mill. Domestic FeV producers, Stratcor of Danbury, CT, and Shieldalloy Metallurgical Corp. at Newfield, NJ, raised the prices of their FeV by 25 cents and 30 cents per pound, respectively. Stratcor's price for 80% FeV was raised to $6.75 per pound of contained vanadium. Stratcor's new prices for its patented products, Vanox and Nitrovan, were raised to $5.75 and $7.00 per pound, respectively. Shieldalloy increased the price of its standard 60% FeV and 42% Ferovan to $6.60 per pound. Shieldalloy also raised the price of its ammonium vanadate by 30 cents to $5.00 per pound. Both companies cited rising costs for raw materials and aluminum as the major cause of the price increases. Meanwhile, Reading Alloys, Robesonia, PA, increased the prices of its aluminum master alloys, effective at the end of the fourth quarter. The new prices were $10.35 per pound for the 65% vanadium alloy and $11.85 per pound for the 85% alloy.

The round of price increases began after Highveld Steel and Vanadium Corp. Ltd. of South Africa successfully raised its fourth quarter prices for V_2O_5 by 10% to $2.95 per pound. Also, better-than-expected steel production in the United States increased the demand for vanadium as an alloying agent, which tended to support higher prices.

FOREIGN TRADE

Exports of vanadium products were essentially unchanged from those of 1986, after declining each year since 1984. Canada, the Federal Republic of Germany, Japan, and Mexico were the largest importers of U.S. vanadium products. Other major importers were Taiwan and the Republic of Korea. With the exception of Canada and the Republic of Korea, these countries imported V_2O_5 almost exclusively. Exports of V_2O_5 and catalysts containing V_2O_5 totaled 1,461 tons, slightly less than the 1,500 tons exported in 1986 and considerably less than the 3,712 tons exported in 1984. The average declared value of V_2O_5 exports was about $3.00 per pound; for FeV exports, the average value was $4.68 per pound of contained vanadium. Imports for consumption of major vanadium compounds declined after increasing in 1984 and 1985, while imports of vanadium raw materials increased. Imports for consumption of FeV totaled 422 tons gross weight, down from 747 tons in 1986. The FeV averaged about 81% vanadium with a mean customs value of $5.53 per pound of contained vanadium. Austria was the largest exporter of FeV to the United States, followed by Canada, the Federal Republic of Germany, and the Republic of South Africa. Pentoxide imports totaled 229 tons V content with a mean customs value of $4.83 per pound. The Republic of South Africa was by far the leading source of V_2O_5 imports, with more than 207 tons. Imports of vanadium contained in ores, slags, and residues totaled 2,264 tons V content, a 12% increase over 1986 imports. About 41% of these imports were in the form of vanadiferous iron slags from Highveld's Witbank steelworks in the Republic of South Africa. The remaining 60% consisted of an assortment of petroleum residues, spent catalysts, and utility ash from, in order of decreasing tonnages, Kuwait, Mexico, Venezuela, the Federal Republic of Germany, Canada, and 14 other countries.

Table 7.—U.S. exports of vanadium in 1987, by country

(Thousand pounds and thousand dollars)

Country	Ferrovanadium (gross weight)		Vanadium ore and concentrate (vanadium content)		Vanadium compounds (gross weight)			
					Pentoxide (anhydride)[1]		Other[2]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Argentina	--	--	--	--	5	34	10	15
Australia	--	--	--	--	98	142	--	--
Bangladesh	--	--	--	--	18	27	--	--
Belgium-Luxembourg	--	--	--	--	35	38	22	99
Brazil	--	--	--	--	350	837	557	585
Canada	393	1,964	--	--	482	669	134	353
Chile	--	--	--	--	(3)	6	2	3
Colombia	--	--	--	--	4	6	--	--
Denmark	--	--	--	--	49	59	--	--
Finland	--	--	--	--	--	--	52	62
France	--	--	--	--	--	--	5	32
Germany, Federal Republic of	--	--	--	--	21	102	1	5
Hungary	--	--	--	--	--	--	41	49
India	15	65	--	--	--	--	--	--
Indonesia	--	--	--	--	9	18	--	--
Italy	--	--	--	--	2	15	--	--
Japan	--	--	--	--	385	902	42	77
Korea, Republic of	172	853	--	--	253	352	--	--
Malaysia	2	8	--	--	7	10	(3)	2
Mexico	68	358	--	--	643	1,502	43	135
Netherlands	--	--	--	--	--	--	50	80
Norway	--	--	--	--	48	87	--	--
Pakistan	--	--	--	--	17	35	--	--
Peru	--	--	--	--	3	3	--	--
Philippines	--	--	--	--	62	93	--	--
Singapore	--	--	--	--	74	86	--	--
Switzerland	--	--	--	--	42	83	--	--
Taiwan	--	--	--	--	267	367	--	--
Thailand	--	--	--	--	29	40	--	--
Uruguay	--	--	--	--	11	18	--	--
Venezuela	222	833	--	--	4	34	--	--
Zimbabwe	--	--	--	--	3	3	--	--
Total[4]	872	4,081	--	--	2,922	5,566	958	1,498

[1]May include catalysts containing vanadium pentoxide.
[2]Excludes vanadates.
[3]Less than 1/2 unit.
[4]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

Table 8.—U.S. imports of ferrovanadium, by country

(Thousand pounds and thousand dollars)

Country	1986			1987		
	Gross weight	Vanadium content	Value	Gross weight	Vanadium content	Value
General imports:						
Austria	311	255	1,459	449	367	2,045
Belgium-Luxembourg	37	30	139	--	--	--
Canada	532	430	2,495	275	228	1,202
China	22	18	105	--	--	--
Germany, Federal Republic of	249	194	1,006	86	62	392
South Africa, Republic of	303	248	1,135	34	28	138
United Kingdom	40	32	188	--	--	--
Total[1]	1,494	1,207	6,527	843	685	3,777
Imports for consumption:						
Austria	311	255	1,459	449	367	2,045
Belgium-Luxembourg	37	30	139	--	--	--
Canada	532	430	2,495	275	228	1,202
Germany, Federal Republic of	249	194	1,006	86	62	392
South Africa, Republic of	303	248	1,135	34	28	138
United Kingdom	40	32	188	--	--	--
Total[1]	1,472	1,189	6,423	843	685	3,777

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

Source: Bureau of the Census.

Table 9.—U.S. imports of vanadium pentoxide (anhydride), by country

Country	1986			1987		
	Gross weight (pounds)	Vanadium content (pounds)	Value	Gross weight (pounds)	Vanadium content (pounds)	Value
General imports:						
Belgium-Luxembourg	37,479	20,996	$89,061	--	--	--
China	435,398	243,910	1,042,694	534,379	299,359	$1,349,202
France	2,863	1,604	16,172	--	--	--
Germany, Federal Republic of	22,430	12,565	98,310	1,055	591	6,258
Japan	--	--	--	18	10	1,201
South Africa, Republic of	1,084,566	607,574	2,547,157	740,254	414,690	2,012,907
Total[1]	1,582,736	886,649	3,793,394	1,275,706	714,651	3,369,568
Imports for consumption:						
Belgium-Luxembourg	37,479	20,996	89,061	--	--	--
China	435,398	243,910	1,042,694	74,957	41,991	189,787
France	2,863	1,604	16,172	--	--	--
Germany, Federal Republic of	22,430	12,565	98,310	1,055	591	6,258
Japan	--	--	--	18	10	1,201
South Africa, Republic of	972,132	544,588	2,317,482	740,254	414,690	2,012,907
Total[1]	1,470,302	823,663	3,563,719	816,284	457,282	2,210,153

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

Source: Bureau of the Census.

WORLD REVIEW

Australia.—According to a report released by the Australian Bureau of Mineral Resources, Australia has almost 10 million tons of demonstrated "paramarginal" vanadium resources, in addition to 10,000 tons of demonstrated economic vanadium deposits. About 85% of total identified resources is in oil shale deposits at Julia Creek, Queensland, whose development depends on oil economics. Australia also has substantial resources of vanadium in titaniferous magnetite. Possible development of those deposits, however, most likely would be driven by the titanium market and would require development of economic techniques to recover metal values from the magnetite ores. The magnetites could be used to produce pig iron with titanium- and vanadium-rich slags as a byproduct. Until now, little or no investigative work had been done on the mineralogy of these ores or on their amenability to metallurgical concentration and recovery techniques.

Brazil.—Finland's Rautaruukki began negotiations for the sale of a vanadium plant and process technology to Odobrech of Brazil. Plant capacity was scheduled to be 4,900 tons V_2O_5 per year; 1,700 tons of production will be exported with the remainder converted to FeV for internal consumption. The plant will use feed from ore deposits in Maracus and Campo Alegre de Lordes. The deposits average 1.3% V_2O_5. Production, the first ever in Brazil, is expected to begin in 1990. In 1986, Brazil imported most of its V_2O_5 from the Federal Republic of Germany and the United States.

China.—The Bank of China arranged a $210 million loan for the expansion of the iron and steel complex at Panzhihua, Sichuan. The transaction involved 24 banks in 12 countries, including the First National Bank of Chicago. The loan was part of $810 million allocated by the Government to double annual crude steel output at Panzhihua to 3 million tons. Although China is the world's fourth largest steel producer, the average per capita output is less than 110 pounds, compared with the world average of 353 pounds. The syndicated loan will be used to finance the importation of key equipment and instruments, and the remainder will be used for the construction of a blast furnace, a continuous-casting plant, a cold-rolling mill, and a hot-rolling mill.

Ore used by the steel complex was a titaniferous magnetite with a high vanadium content. The Chinese planned to boost production of titanium to 50,000 tons per year and V_2O_5 to 2,000 tons per year. The Panzhihua Mine, with reserves of 30 million tons and 80% of China's vanadium slag production, was slated to produce 2,000 tons of V_2O_5 per year. However, the Government failed to find a foreign partner to establish a joint venture with an aim to improve the present yields.

China produced V_2O_5 in six locations, four of which could also produce ferrovanadium. The Panzhihua Iron and Steel Co. plant in Sichuan is a steel plant with an annual production of 70,000 tons of vanadium slag (about 12% V_2O_5). It used titaniferous magnetite ore delivered from a nearby mine to produce pig iron. Vanadium-bearing slags from Panzhihua were shipped to the country's vanadium plants for processing into vanadium pentoxide.

The Emei ferroalloy plant in Sichuan is equipped with a rotary kiln with the capacity to produce 1,000 tons of V_2O_5 per year. Export sales were made through the Sichuan branch of China Metallurgical Import and Export Corp. The Chengde plant in Hebei is equipped with a rotary kiln with the capacity to produce 1,500 tons of V_2O_5 per year and also has the technology to produce ferrovanadium. The Shanghai metallurgical plant No. 2 has two 40-meter rotary kilns with the capacity to produce 2,300 tons of V_2O_5 per year. The plant received vanadium slags from the ironworks in Ma'anshan. The Jinzhou ferroalloy plant in Liaoning, with three 40-meter kilns, is capable of producing 6,000 tons of V_2O_5 per year and 4,000 tons of FeV per year. The plant, equipped with a furnace rated at 4,000 tons of FeV capacity per year, also produced chromium metal and ferrotitanium. The Nanjing ferroalloy plant in Jiangsu has the capacity to produce 1,000 tons of V_2O_5 per year. It currently produces about 350 tons of V_2O_5 and about 200 tons of FeV annually, primarily from oil shale.

South Africa, Republic of.—The first stage of the Kennedy's Vale vanadium project, under construction near Steelpoort in eastern Transvaal for Vansa Vanadium S.A. Ltd., was completed in August, and the plant was scheduled for commissioning in June 1988. Capital cost of the plant increased to about $12.6 million compared with earlier estimates of $7.2 million. The first sales of V_2O_5 were expected to take place in July 1988. The plant was to produce 3,300 tons of V_2O_5 and an unspecified amount of ammonium metavanadate for sale in Japan, South America, and the European Community. Initially, sales are expected to be relatively small with little impact on world markets. However, Vansa plans a rapid and aggressive buildup of sales, with vanadium providing the majority of its earnings by 1989.

Vanadium was produced by three companies. The largest of the three, Highveld Steel and Vanadium Corp., operated the Mapochs Mine at Roossenekal in eastern Transvaal. Highveld produced vanadium slags and pentoxide at two plants situated near Witbank. The Vantra Div. extracted V_2O_5 by the roast-leach process; Highveld Steel ironworks smelts the ore in electric furnaces after prereduction in rotary kilns. The other two companies, Transvaal Alloys Pty. Ltd. and Vametco Minerals Co., extracted vanadium by a similar roast-leach process and produced V_2O_5 and other vanadium compounds. Ore was mined from nearby surface deposits.

South African vanadium producers have not revealed production and commercial information since 1985 because of the growing pressure of anti-apartheid sanctions against the country. The last published figures available from the Government-operated Minerals Bureau put vanadium production in 1985 at about 13,000 tons, 40% of world output and 71% of Western World production. Estimates for 1987 varied from a low of 15,700 tons to a high of more than 18,000 tons.

Venezuela.—In December 1987, Venezuela ranked second as an oil exporter to the United States, averaging about 850,000 barrels per day. Venezuelan oil may contain up to 1,500 parts per million of vanadium, which translates to more than 80,000 pounds per day of V_2O_5 entering the United States.[4] In its push to open new markets for its oil, Venezuela had been buying interest in petroleum refineries, particularly in the United States. Among recent investments were 50% interest in refineries at Lake Charles, LA, and Corpus Christi, TX. Through additional joint ventures in the United States, Petróleos de Venezuela S.A. (PDVSA) expected to expand sales by 700,000 barrels of crude per day.

U.S. geological teams visited Venezuela to confirm the country's sharp upward revisions in its estimates of proven oil reserves. Venezuela's recent upgrading more than doubled its own estimates of proven reserves to 55 billion barrels, about twice those of the United States. In addition, PDVSA counted 267 billion barrels of proven reserves of lower quality, extra heavy crude in its Orinoco Oil Belt. Proven reserves are generally defined as those that can be produced with current technology at today's prices.

Table 10.—Vanadium: World production, by country[1]

(Short tons of contained vanadium)

Country	1983	1984	1985	1986[p]	1987[e]
Production from ores, concentrates, slag:[2]					
China (in vanadiferous slag product)[e]	5,000	5,000	5,000	5,000	5,000
Finland (in vanadium pentoxide product)	3,516	3,376	2,350	--	--
South Africa, Republic of:[3]					
Content of pentoxide and vanadate products[e]	4,117	6,633	6,537	[4]6,350	6,600
Content of vanadiferous slag product[e 5]	5,620	7,165	8,912	10,580	12,100
Total	9,737	13,798	15,449	16,930	18,700
U.S.S.R.[e]	10,500	10,500	10,500	10,600	10,600
United States (recoverable vanadium)	2,171	1,617	W	W	W
Total	30,924	34,291	[6]33,299	[6]32,530	[6]34,300
Production from petroleum residues, ashes, spent catalysts:[7]					
Japan (in vanadium pentoxide product)	778	[e]770	[e]840	929	925
United States (in vanadium pentoxide and ferrovanadium products)	893	1,701	2,695	2,330	[4]2,508
Total	1,671	2,471	3,535	3,259	3,433
Grand total	32,595	36,762	36,834	35,789	37,733

[e]Estimated. [p]Preliminary. W Withheld to avoid disclosing company proprietary data; not included in "Total."

[1]In addition to the countries listed, vanadium is also recovered from petroleum residues in the Federal Republic of Germany, the U.S.S.R., and several other European countries, but available information is insufficient to make reliable estimates. Table includes data available through July 15, 1988.

[2]Production in this section is credited to the country that was the origin of the vanadiferous raw material.

[3]Includes production for Bophuthatswana.

[4]Reported figure.

[5]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 14.1% vanadium.

[6]Excludes U.S. production.

[7]Production in this section is credited to the country where the vanadiferous product is extracted; available information is inadequate to permit crediting this output back to the country of origin of the vanadiferous raw material.

TECHNOLOGY

Several occurrences of placer mineral deposits have been identified in Alaska and are being investigated by the Bureau of Mines as part of its program to inventory the State's vast but little-known mineral wealth.[5] Although the deposits are not likely to be economic at current metal prices, more than 40 million tons of mineralized materials have been inferred, and it is likely that additional tonnages could be found with more intensive exploration. Geochemically anomalous values of vanadium and several other metals, including rare earths, were identified in some of the placer concentrates taken in drainages of the White Mountain study area. The presence of anomalous values probably indicates the presence of lode rather than placer mineralization.

Most vanadium is recovered as a byproduct of other processes such as the leaching of carnotite uranium ores. Vanadium recovery from leach solutions is usually done by dialkylphosphoric acid (DAPEX) or by amine (AMEX) solvent extraction processes. The AMEX process requires the oxidation of vanadium to the pentavalent state prior to solvent extraction. Sodium chlorate and, to a lesser extent, hydrogen-peroxide-oxygen systems are used as oxidants. Sodium chlorate has the disadvantage of being slow and requiring high operating temperatures. Hydrogen peroxide is an effective oxidant but may result in waste owing to decomposition and reductive side reactions. Comparative oxidation tests using two actual uranium mill raffinates showed that the use of Caro's acid eliminated these problems.[6] A four-stage countercurrent extraction performed on the raffinates revealed that extraction efficiency and the extraction coefficient were higher when Caro's acid was used as opposed to hydrogen peroxide.

Researchers at the University of New South Wales in Australia demonstrated a rechargeable storage battery employing electrically charged vanadium solutions instead of the conventionally charged plates of lead-acid batteries.[7] The battery is based on National Aeronautics and Space Administration redox flow cell research and uses two vanadium solutions pumped separately through adjacent half cells. Electricity is produced by the exchange of electrons between the solutions. The researchers expected to have a prototype 25-kilowatt-hour battery ready for production in 1989. An international marketing agreement was signed between the university's commercial arm, Unisearch Ltd., and Agnew Clough Ltd. of Western Australia. In related research, a number of vanadium oxides were studied with special regard to their application as the active component in rechargeable lithium cells.[8] Substances with so-called open crystal structures are used as electrochemically active materials for insoluble positive electrodes in secondary lithium cells. The lattices of these substances have cavities that act as open, freely passable channels for lithium ions. Vanadium oxides are of special interest for this particular application because of their comparatively low equivalent weight.

Extensive testing of commercial fluid cracking catalysts (FCC) showed that, when all metals are removed by demineralizing the catalyst, the catalyst is effectively reactivated. Because vanadium is the primary metal associated with catalytic activity, it is important to understand the effect on catalytic activity when only the vanadium is removed. To isolate the vanadium effect on catalysts, researchers at ChemCat Corp. performed tests on various nonzeolitic amorphous catalysts, zeolitic rare-earths (REY) catalysts, and zeolitic ultrastable Y (USY) catalysts, where vanadium was the only metal removed.[9] Results were compared with reactivation by the Demet process, which effectively removes the vanadium as well as the iron, nickel, and sodium. Vanadium was removed from samples of FCC catalyst obtained from two different refineries, and, in each case, their catalytic activity was selectively improved.

An Israeli botanist identified a microscopic fungus that acts as a superabsorbent sponge, soaking up large amounts of the metals that are often found in the wastewater from mining and manufacturing processes. The fungus can extract such heavy metals as mercury, nickel, vanadium, and uranium.[10] Apparently, the fungus works more quickly, can be grown more cheaply, and can be reused more often than other microorganisms under study. When effluent passes through a filter impregnated with the fungus, the fungus separates metals from the water after only a brief contact time. After the fungus is sated with the metals, it can easily be removed from the filter, the metals extracted, and the fungus reused.

A contract for continued research into the use of powder metal aluminum alloys for use at temperatures as high as 600° F to replace titanium aircraft components was awarded to Lockheed Aeronautical Systems Co., Burbank, CA.[11] The new alloys may find applications in the Advanced Tactical Fighter (ATF) under development by the U.S. Air Force. The alloys being tested include FES 0812 and FES 1212 from the research and development centers of Allied-Signal Corp., Morristown, NJ. The alloys are based on an aluminum-iron-vanadium-silicon mix. According to Allied, the alloys can be used at temperatures as high as 800° F.[12]

Most of the technology used industrially to extract vanadium from refinery residues, oil-fired boiler slags, and fly ash include roasting the material at high temperature followed by leaching with aqueous solvents. Japanese researchers developed a process for the extraction of metal values without roasting using the technique of direct leaching with subsequent solvent extraction.[13] Hydrochloric acid leaching showed the best extraction capability for vanadium and other metals. Sodium hydroxide leaching showed the highest selectivity for vanadium. A combination of the two leaching methods hastened the recovery and separation of metals.

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Vermiculite

By Arthur C. Meisinger[1]

U.S. production of vermiculite concentrate declined slightly to 303,000 short tons valued at $33.1 million. Sales of exfoliated vermiculite were slightly lower than that of 1986, but the average value per ton increased. South Carolina replaced Montana as the leading State in vermiculite concentrate production.

Domestic Data Coverage.—Domestic production data for vermiculite are developed by the Bureau of Mines from two separate voluntary surveys, one for domestic mine operations and the other for exfoliation plant operations. Of the five mining operations to which a survey request was sent, four responded. The one nonrespondent's data were estimated using previous years' production levels adjusted by trends in employment and other guidelines. Of the 41 exfoliating plants to which a survey request was sent, 37 responded. Those respondents accounted for 85% of the total exfoliated vermiculite sold and used shown in table 1. The four nonrespondents' data were estimated using previous years' production levels adjusted by trends in employment and other guidelines.

Table 1.—Salient vermiculite statistics

(Thousand short tons and thousand dollars unless otherwise specified)

	1983	1984	1985	1986	1987
United States:					
Sold and used by producers:					
Concentrate	282	315	314	317	303
Value	$27,200	$31,500	$32,400	$34,400	$33,105
Average value[1] dollars per ton	$96.45	$100.00	$103.18	$108.52	$109.24
Exfoliated	224	264	258	253	252
Value	$52,200	$56,500	$47,900	$53,200	$54,600
Average value[1] dollars per ton	$233.04	$214.02	$185.66	$210.28	$216.67
Exports to Canada	19	22	[e]23	[e]25	[e]20
Imports for consumption	[e]24	32	[e]38	[e]35	[e]30
World: Production[2]	490	545	556	[p]579	[e]601

[e]Estimated. [p]Preliminary.
[1]Based on rounded data.
[2]Excludes production by centrally planned economy countries.

DOMESTIC PRODUCTION

Production of vermiculite concentrate declined 4% to 303,000 tons valued at $33.1 million compared with 317,000 tons valued at $34.4 million in 1986.

W. R. Grace & Co. continued as the leading domestic producer with operations at Libby, MT, and Enoree, SC. Vermiculite was also mined in South Carolina by Patterson Vermiculite Co. near Enoree and by Strong-Lite Products Corp. near Woodruff. Increased production by the three South Carolina producers coupled with a decrease in output from the Libby mine in Montana made South Carolina the leading producing State. Virginia Vermiculite Ltd., Louisa County, VA, was the only other producer during the year.

Domestic sales of exfoliated vermiculite by 12 producers declined slightly in quantity and increased slightly in value. Output came from 41 plants in 28 States, of which 29 plants in 24 States were operated by W. R. Grace.

In descending order of output sold and used, the principal exfoliated vermiculite-producing States were California, Ohio, South Carolina, Florida, New Jersey, and Texas.

CONSUMPTION AND USES

Apparent domestic consumption of vermiculite concentrate declined slightly from 327,000 tons to 318,000 tons.

The quantity of exfoliated vermiculite sold and used for agriculture increased slightly, while sales for aggregates, insulation, and other uses decreased slightly compared with 1986 quantities.

Table 2.—Exfoliated vermiculite sold and used in the United States, by end use

(Short tons)

End use	1986	1987
Aggregates:		
Concrete	50,800	49,200
Plaster	2,200	700
Premixes[1]	80,000	81,300
Total	133,000	131,200
Insulation:		
Loose-fill	21,000	19,600
Block	35,900	35,700
Other[2]	2,100	1,700
Total	59,000	57,000
Agricultural:		
Horticultural	19,700	23,100
Soil conditioning	5,300	8,100
Fertilizer carrier	33,500	30,600
Total	58,500	61,800
Other[3]	2,900	2,200
Grand total[4]	253,000	252,000

[1]Includes acoustic, fireproofing, and texturizing uses.
[2]Includes high-temperature and packing insulation and sealants.
[3]Includes various industrial uses not specified.
[4]Data may not add to totals shown because of independent rounding.

Table 3.—Active vermiculite exfoliating plants in the United States in 1986

Company	County	State
A-Tops Corp	Beaver	Pennsylvania.
Brouk Co	St. Louis	Missouri.
	Irondale	Alabama.
	Maricopa	Arizona.
	Pulaski	Arkansas.
	Alameda	California.
	Orange	Do.
	Denver	Colorado.
	Broward	Florida.
	Duval	Do.
	Hillsborough	Do.
	Du Page	Illinois.
	Campbell	Kentucky.
	Orleans	Louisiana.
	Prince Georges	Maryland.
W. R. Grace & Co., Construction Products Div	Hampshire	Massachusetts.
	Wayne	Michigan.
	Hennepin	Minnesota.
	St. Louis	Missouri.
	Douglas	Nebraska.
	Mercer	New Jersey.
	Cayuga	New York.
	Guilford	North Carolina.
	Oklahoma	Oklahoma.
	Multnomah	Oregon.
	Lawrence	Pennsylvania.
	Greenville[1]	South Carolina.
	Davidson	Tennessee.
	Bexar	Texas.
	Dallas	Do.
Intermountain Products Inc	Salt Lake	Utah.
Koos Inc	Kenosha	Wisconsin.
O. M. Scott & Sons	Union	Ohio.
Patterson Vermiculite Co	Laurens	South Carolina.
Robinson Insulation Co	Cascade	Montana.
The Schundler Co	Middlesex	New Jersey.
Strong-Lite Products Corp	Jefferson	Arkansas.
Do	DeKalb	Illinois.
Verlite Co	Hillsborough	Florida.
Vermiculite Products Inc	Harris	Texas.

[1]Two plants in the county.

PRICES

The average value of vermiculite concentrate sold and used by U.S. producers was $109 per ton, f.o.b. plant, the same as in 1986. The average value of exfoliated vermiculite, f.o.b. plant, increased slightly from $210 per ton to $217 per ton.

Engineering and Mining Journal quoted yearend prices for unexfoliated vermiculite as follows, per short ton: Montana and South Carolina, f.o.b. mine, $100 to $150; and the Republic of South Africa, c.i.f. Atlantic ports, $110 to $160.

FOREIGN TRADE

Imports of vermiculite concentrate from the Republic of South Africa were estimated to be 35,000 tons. Exports to Canada were estimated to be 20,000 tons. Exports represented about 7% of total U.S. sales.

[1]Industry economist, Branch of Industrial Minerals.

Table 4.—Vermiculite: World production, by country[1]

(Short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Argentina	4,355	4,906	5,387	5,740	5,500
Brazil	10,888	10,094	10,242	14,482	15,000
Egypt	331	[e]360	538	546	550
India	2,658	2,153	1,990	7,365	4,400
Japan[e]	19,000	19,000	19,000	[r]17,000	17,000
Kenya	[e]1,300	961	1,670	2,804	2,800
Mexico	440	557	474	[e]500	500
South Africa, Republic of	168,691	191,536	202,902	213,470	[3]252,278
United States (sold and used by producers)	282,000	315,000	314,000	317,000	[3]303,000
Total	489,663	544,567	556,203	578,907	601,028

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Excludes production by centrally planned economy countries. Table includes data available through July 15, 1988.
[2]In addition to the countries listed, Tanzania may produce vermiculite, but available information is inadequate to make reliable estimates of output levels, if any.
[3]Reported figure.

Zinc

By James H. Jolly[1]

Domestic zinc mine production increased in 1987, reversing a 6-year downtrend in output. Zinc metal production also increased and was the highest since 1981. Domestic output of zinc oxide improved despite the closure of two plants. However, for the first time since the early 1850's, no American-process zinc oxide was produced from ores or concentrates. New Jersey Zinc and St. Joe, two well-known old-line names of the domestic zinc industry, virtually disappeared from the zinc scene in 1987, when the last descendants of the original companies merged their zinc operations and products under a new company name. Despite improved production, the United States provided only a fraction of the world's zinc output.

Table 1.—Salient zinc statistics

(Metric tons unless otherwise specified)

	1983	1984	1985	1986	1987
United States:					
Production:					
Domestic ores, recoverable content	275,294	252,768	226,545	202,983	216,981
Value thousands	$251,204	$270,833	$201,607	$170,050	$200,529
Slab zinc:					
From domestic ores	210,315	197,912	198,003	191,079	211,633
From foreign ores	25,379	55,220	63,204	62,288	58,377
From scrap	69,390	78,113	72,567	62,914	72,653
Total	305,084	331,245	333,774	316,281	342,663
Secondary zinc[1]	279,237	317,968	274,456	r277,757	309,890
Exports:					
Ores and concentrates (zinc content)	60,168	30,579	23,264	3,269	16,921
Slab zinc	427	760	1,011	1,938	1,082
Imports for consumption:					
Ores and concentrates (zinc content)	63,156	86,172	90,186	75,786	46,464
Slab zinc	617,679	639,228	610,900	665,126	705,985
Stocks of slab zinc, Dec 31:					
Industry	148,139	137,626	119,892	100,723	96,088
Government stockpile	340,577	340,577	340,577	340,577	340,577
Consumption:					
Slab zinc:					
Reported	805,891	848,903	770,671	705,963	788,728
Apparent (rounded)[2]	r933,000	r980,000	r961,000	r999,000	1,052,000
All classes (rounded)[3]	r1,246,300	r1,343,500	r1,279,600	r1,296,000	1,364,000
Price: High Grade, cents per pound (delivered)	41.39	48.60	40.37	38.00	41.92
World:					
Production:					
Mine thousand metric tons	r6,283	r6,524	6,801	p6,829	e7,144
Smelter do	6,249	r6,527	6,852	p6,761	e7,030
Price: London, cents per pound	34.73	40.46	36.23	34.19	36.20

eEstimated. pPreliminary. rRevised.

[1]Excludes secondary slab and remelt zinc.

[2]Domestic production plus net imports plus or minus stock changes.

[3]Based on apparent consumption of slab zinc plus zinc content of ores and concentrates and secondary materials.

U.S. zinc metal consumption rose significantly owing to an improved domestic economy, expanding export markets, and increases mainly in the galvanizing sector. Metal imports were at an alltime high and exceeded 700,000 metric tons for the first time. Imports of zinc oxide were also at an alltime high and accounted for about 29% of the domestic apparent consumption.

World mine and smelter production of zinc were at record-high levels, and both exceeded 7 million tons for the first time. World zinc metal consumption was record setting for the fourth consecutive year, and exceeded 7 million tons also for the first time.

U.S. and world zinc prices trended downward in the first few months, influenced by the settlement of smelter strikes and increasing stocks in the last few months of 1986. Prices rose in the middle of the year, again affected to some extent by a smelter strike, but moderated when the strike was settled.

Domestic Data Coverage.—Domestic data for zinc are developed by the Bureau of Mines from seven separate, voluntary surveys of U.S. operations. Typical of these is the "Slab Zinc" consumption survey. Of the 307 operations to which the survey request was sent, 297 responded, representing an estimated 97% of the total reported slab zinc consumption shown for 1987 in tables 1, 15, 16, and 17. Consumption for the nonrespondents was estimated using prior year consumption levels. Reported consumption represented 75% of the total apparent consumption reported on tables 1 and 14.

Legislation and Government Programs.—The National Defense Stockpile goal for zinc was 1,292,739 tons, unchanged since May 1980. The total zinc inventory held in the stockpile also has been virtually unchanged since 1974, and at yearend, was 343,202 tons including 2,625 tons contained in brass. At yearend, the President and Congress were considering legislation that would transfer management of the stockpile to the U.S. Department of Defense from the current multiagency management structure.

In June, the Environmental Protection Agency (EPA) eliminated 6 metals, including zinc, from the list of 83 contaminants that EPA was required to regulate by 1989 under the 1986 amendment to the Safe Drinking Water Act. EPA stated that zinc was essential to life and that it was not known to cause health problems at the levels found in drinking water.

In August, EPA announced the results of its assessment of zinc and zinc oxide as candidates for regulation under the Clean Air Act (CAA).[2] The agency said it did not have enough health data to determine whether the materials presented any carcinogenic, mutagenic, or teratogenic danger when inhaled. It concluded that no regulations under CAA were currently warranted.

DOMESTIC PRODUCTION

MINE PRODUCTION

Higher mine output of zinc was attributed largely to initial production from the Montana Tunnels Mining Inc.'s gold-silver-zinc-lead mine near Helena, MT, and to a full year's production at mines that closed temporarily in 1986 because of poor market conditions. The 25 leading U.S. zinc-producing mines accounted for 99% of production, with the 10 leading mines accounting for about 82%. Tennessee was the principal zinc-producing State, followed by New York, Missouri, and Colorado. The leading zinc mine producers were ASARCO Incorporated; The Doe Run Co.; Jersey Minière Zinc Co., a subsidiary of the Belgian company Union Minière S.A.; and Zinc Corporation of America (ZCA), a new subsidiary of Horsehead Industries Inc., formed in November 1987 by the merger of Fluor Corp.'s zinc company, St. Joe Resources Co., and Horsehead's New Jersey Zinc Co. Inc. (NJZI). ZCA became a major domestic zinc mine producer via its acquisition of St. Joe Resources' Balmat and Pierrepont Mines in New York. ZCA's only other zinc mine, NJZI's Sterling Mine in New Jersey, was closed all year.

In Tennessee, zinc was produced from zinc ore at six underground mines and from sulfur-copper-zinc ores at an underground mine at Copperhill. Jersey Minière, operator of the Gordonsville-Elmwood Mine in central Tennessee, and Asarco, operator of four eastern Tennessee mines, were the leading producers. The mine at Copperhill, operated by Tennessee Chemical Co., was closed permanently in August owing to economic factors. This closure ended about 140 years of almost continuous mining activity in the Copperhill mining district.

Asarco's zinc production in Tennessee was almost 50% higher than in 1986, largely because the mines operated all year; whereas, in 1986, all four were closed for part of the year owing to poor market conditions. According to the Asarco annual report, the company milled 2.7 million tons of ore producing 65,000 tons of zinc in concentrates at its Tennessee operation in 1987, compared with 1.8 million tons of ore milled yielding 43,300 tons of zinc in 1986. At yearend, ore reserves at the four mines were estimated to be 5.9 million tons averaging 3.23% zinc, representing a drop in ore reserves of about 0.2 million tons of similar grade ore from 1 year earlier.

In Missouri, zinc was produced as a byproduct of lead at eight underground lead mines along the Viburnum Trend in southeastern Missouri. Doe Run, owned 57.5% by St. Joe Minerals Corp. and 42.5% by Homestake Mining Co., was the largest producer, milling 3.6 million tons of ore averaging 5.8% lead, 0.8% zinc, and 0.6% copper from five mines and producing about 18,500 tons of zinc in 36,900 tons of zinc concentrate. At yearend, the ore reserves at Doe Run's Missouri mines were 68 million tons averaging 5.1% lead, 0.9% zinc, and 0.3% copper.

The Magmont Mine, a joint venture of Cominco American Incorporated and Dresser Industries Inc., was the largest zinc-producing mine in Missouri in 1987. According to Cominco Ltd.'s annual report, the company milled 1.0 million tons of Magmont lead-zinc-copper ore yielding 69,200 tons of lead, 12,900 tons of zinc, and 1,800 tons of copper in concentrates. In 1986, comparable production was 0.95 million tons of ore milled yielding 79,500 tons of lead, 11,500 tons of zinc, and 1,600 tons of copper. Ore reserves at yearend were 4.3 million tons averaging 6.4% lead, 1.3% zinc, and 0.3% copper.

Asarco processed lead-zinc ore at two Missouri mines, West Fork and Sweetwater, in 1987. The latter, acquired from Ozark Lead Co. in December 1986, was reopened by Asarco late in the year at about 40% of capacity. Zinc output was minimal; however, about 3,000 tons of zinc in concentrates was expected to be produced in 1988. At the West Fork Mine, metal production in concentrates fell despite a 46% increase in ore milled in 1987. According to the Asarco annual report, the company milled 404,000 tons of ore producing 5,200 tons of zinc, 26,400 tons of lead, and 147,000 ounces of silver in concentrates in 1987 compared with production of 6,500 tons of zinc, 30,500 tons of lead, and 182,000 ounces of silver in 1986. Asarco continued the expansion program at the West Fork Mine, aiming to attain full design capacity by mid-1988, when annual mine-mill capacity was projected to be 60,000 tons of lead and 9,000 tons of zinc in concentrates. Ore reserves at the West Fork Mine were estimated to be 9.8 million tons of ore averaging 1.94% zinc, 7.07% lead, 0.04% copper, and 0.27 ounce of silver per ton at yearend.

In Colorado, zinc production was largely a coproduct of gold-silver operations at the Leadville Mine, managed by Asarco but jointly owned with the Resurrection Mining Co., and at the Sunnyside Mine, owned by Sunnyside Gold Corp., a subsidiary of Echo Bay Mines Ltd. According to the Asarco annual report, the company milled 198,000 tons of ore in 1987 yielding 13,000 tons of zinc, 7,000 tons of lead, 337,000 ounces of silver, and 16,673 ounces of gold in concentrates. Production was about the same in 1986. Ore reserves at yearend were 715,000 tons averaging 8.09% zinc, 3.95% lead, 1.8 ounces of silver per ton, and 0.06 ounce of gold per ton. Sunnyside Gold substantially increased its zinc production owing to a full year's operation and an increase to 640 tons in the daily ore-processing rate. An aggressive exploration program resulted in a net increase in ore reserves of about 110,000 tons despite production of 233,000 tons of ore in 1987. At yearend, proven and probable ore reserves were 530,000 tons averaging 5.4% zinc, 3.8% lead, 0.57% copper, 3.5 ounces of silver per ton, and 0.15 ounce of gold per ton.

Virtually all of Idaho's zinc production was produced by Hecla Mining Co. at its Lucky Friday silver-lead-zinc mine in northern Idaho. The mine, which was closed in April 1986 because of low silver prices, reopened in June because of improved metal prices and a lack of progress in labor negotiations. In July, union workers agreed to wage and benefit cuts, but, over the 3-year contract period, workers were expected to recover some lost wages by a profit-sharing plan to be instituted in the second and third years of the contract. At yearend, Lucky Friday ore reserves were 580,000 tons averaging 12.3% lead, 2.2% zinc, and 15.9 ounces of silver per ton.

In Montana, Pegasus Gold Inc. commenced milling operations at its new Montana Tunnels gold-silver-zinc-lead mine in late March. Ore was mined by open pit methods, followed by crushing, grinding, flotation, and leaching to recover gold and silver. This was followed by additional flotation to produce lead and zinc concentrates. In 1987, production was 31,800 ounces of gold, 529,300 ounces of silver, 3,900 tons of lead, and 6,500 tons of zinc. At yearend, ore reserves were 47 million tons averaging 0.023 ounce of gold per ton, 0.44 ounce of silver per ton, 0.25% lead, and 0.65% zinc. A 15-year operation was envisioned.

In Alaska, Cominco American moved the startup date of its Red Dog zinc-lead-silver project ahead 1 year to 1990. A 54-mile road over the Alaskan tundra from the port site on the Chukchi Sea to the mine site was nearly completed in 1987 and was expected to be fully operational in early 1988. The road, consisting of numerous bridges and a 4.5-foot-high gravel road bed laid over special sheeting to overcome permafrost problems, was constructed at rates up to about 100 feet per hour. Millsite preparation and housing for workers were scheduled for completion in 1988 and the mill in 1989. Concentrate shipments were scheduled to begin in 1990. At capacity, the company planned to produce annually 314,000 tons of zinc and 64,000 tons of lead in concentrates. Ore reserves were 77 million tons averaging 17.1% zinc, 5% lead, and 2.6 ounces of silver per ton.

Greens Creek Mining Co., a wholly owned subsidiary of BP Minerals America Inc., and minority partners, Hecla, who purchased 28% interest in the mine from BP in May; Exalas Resources Corp.; and CSX Oil and Gas Corp. decided to develop the Greens Creek silver-zinc-lead deposit on Admiralty Island, AK. Plans called for Greens Creek Mining, the majority holder in the venture to develop a trackless underground mine and a 910-ton-per-day mill operation yielding annually about 77,000 tons of concentrates containing 6.4 million ounces of silver, 36,000 ounces of gold, 23,000 tons of zinc, and 8,000 tons of lead. Initial production was expected in early 1989. Ore reserves were estimated to be 3.2 million tons averaging 22.0 ounces of silver and 0.16 ounce of gold per ton, 9.7% zinc and 3.9% lead. A 10-year operation was envisioned.

SMELTER AND REFINERY PRODUCTION

Smelter production of zinc improved substantially owing partly to the resumption of production in January at Huron Valley Steel Corp.'s 27,000-ton-per-year secondary zinc plant at Belleville, MI. The Huron Valley plant was closed in June 1986 because of equipment failure.

Slab zinc was produced at four primary smelters by three companies: ZCA, AMAX Zinc Co. Inc., and Jersey Minière. Secondary slab zinc was produced at 10 plants; the leading producers of metal from secondary materials were ZCA, Huron Valley Steel, and Interamerican Zinc Co. Asarco's Corpus Christi, TX, primary zinc refinery remained on standby status in 1987; however, the company was considering a plan at yearend that would turn the facility into a waste-processing center, thereby terminating its status as a primary smelter.

The formation of ZCA created a company with plant capacities to be the largest domestic producer of zinc metal, dust, powder, and oxide. The new Horsehead subsidiary included the former St. Joe Resources primary zinc smelters at Monaca, PA, and Bartlesville, OK; a zinc dust plant at Depue, IL; and zinc oxide, dust, and alloy production facilities at Horsehead's Palmerton, PA, plant.

Horsehead Resource Development Co. (HRD), another Horsehead subsidiary, processed about 180,000 tons of zinc-containing, steelmaking electric arc furnace (EAF) dusts at its Palmerton, PA, Waelz-kiln processing plant in 1987. Most of the impure zinc oxide produced was shipped to ZCA's Monaca, PA, smelter for refinement to zinc metal. HRD planned to open another EAF dust-processing plant at Calumet City, IL, in early 1988. The new plant, also a Waelz-kiln facility, was expected to process about 70,000 tons of EAF dust per year, producing a crude zinc oxide product and an iron-rich slag suitable for highway and construction purposes.

Oxford Energy Co. began zinc recovery at its new 40,000-ton tire-recycling plant at Modesto, CA. Yearly recovery of about 700 tons of zinc in crude zinc oxide material was expected. This material and that from a larger tire-recycling facility under construction at Sterling, CT, were expected to be processed at ZCA's Monaca, PA, zinc plant to reclaim the zinc.

Zinc Oxide.—In the United States, zinc oxide was produced entirely from slab zinc and scrap material, marking the first time that ores or concentrates were not directly used for zinc oxide production since the beginning of the domestic zinc industry in the early 1850's. Zinc oxide was produced at 11 plants in 1987; however, 2 of these plants, ZCA's American-process zinc oxide plant at

Palmerton, PA, and Pacific Smelting Co.'s plant at Torrance, CA, ceased operation in December. With the closure of the ZCA plant, the only domestic producer of oxide by the American process was the Eagle Zinc Co. at Hillsboro, IL.

ZCA was by far the largest producer, having the combined zinc oxide facilities of NJZI and St. Joe Resources. Pacific Smelting consolidated all future zinc oxide production at its 18,000-ton-per-year plant at Memphis, TN. In 1987, Asarco reported zinc oxide production of 8,400 tons at its 20,000-ton-per-year plant at Hillsboro, IL.

Zinc Salts.—Zinc sulfate was produced by 10 companies from secondary zinc materials and waste streams from electrolytic zinc plants. Zinc sulfate was produced in both solid and liquid form, mainly for agricultural purposes. Zinc-chloride-type chemicals were produced at five plants from secondary zinc materials or chemical waste streams.

Byproduct Sulfur.—Production of sulfur in byproduct sulfuric acid at four primary zinc smelters using zinc sulfide concentrate as feed material was 124,000 tons, virtually the same as in 1986.

CONSUMPTION AND USES

Domestic zinc consumption for most end-use categories increased in 1987, continuing the consumption uptrend started in 1986. The construction sector of the economy accounted for an estimated 43% of zinc consumption, followed by transportation, 22%; machinery, 10%; electrical, 10%; and chemical and other industries, 15%. Galvanizing and electrogalvanizing, mainly for sheet and strip, continued to be the principal use of slab zinc, consuming an estimated 52%, followed by zinc-base die-cast alloys, 22%; brass alloys, 13%; rolled zinc, 3%; and other uses, 10%. Special High Grade (SHG) accounted for about one-half of the slab zinc consumed, followed by Prime Western (PW) and High Grade (HG). About 23,400 tons of SHG was used by the U.S. Mint to produce 9.6 billion pennies in 1987.

According to the American Iron and Steel Institute, shipments of galvanized sheet and strip totaled 8.25 million tons, up from 7.06 million tons in 1986. Of the total shipments, electrogalvanized sheet accounted for 16% compared with only 7% in 1986. The substantial increase in electrogalvanized sheet shipments was due largely to strong demand by the automobile industry for increased corrosion protection of body parts. The typical U.S.-built, 1987-model automobile contained an estimated 9 pounds of zinc for corrosion protection, compared with about 8.4 pounds in 1986.

Zinc-base alloy and die and foundry casting shipments, according to the Bureau of the Census, totaled about 228,000 tons in 1987. The estimated distribution by weight was about one-third each for automotive, hardware, and other uses. The typical U.S.-built, 1987-model automobile contained about 20 pounds of zinc die-cast parts, representing a slight increase.

Zinc consumption in copper-base alloys by brass mills, ingot makers, and foundries increased about 11% from that of 1986.[3] According to the Copper Development Association Inc., the brass and bronze industries consumed about 298,000 tons of zinc, the source of which was about equally divided between refined zinc metal and brass and bronze scrap metal. Brass mills accounted for more than 89% of the total zinc consumed as metal and scrap.

According to the International Lead and Zinc Study Group (ILZSG), the principal uses of zinc metal in 1986 in the major market economy countries, including the United States, were galvanizing, 42.7%; brass and bronze, 20.9%; zinc-base alloys, 15.6%; zinc semimanufactures, 8.4%; chemicals, 8.7%; zinc dust and powder, 1.6%; and miscellaneous, 2.1%.

The apparent domestic consumption of zinc oxide was about 198,000 tons, up from 165,000 tons in 1986. Imports were at record-high levels and domestic production and shipments were up substantially. The rubber industry continued to be the principal consumer of zinc oxide. One of the five new electrogalvanizing plants that came on-stream in 1986 was a significant consumer of zinc oxide because the compound was the source of zinc for the process.

The U.S. Library of Congress reportedly began diethyl zinc (DEZ) gas treatments on many of its brittle and disintegrating books to prevent further paper decomposition caused by the breakdown of aluminum sulfate in paper to sulfuric acid, which attacks paper fibers. DEZ, which is composed of 55% zinc, neutralizes the acidity of the paper, leaving a protective residue of zinc oxide and zinc carbonate. Plans called for treating about 1 million books annually, requiring about 50 tons of DEZ.

STOCKS

At yearend 1987, metal stocks held by domestic producers, consumers, and merchants were down 16% from those held at yearend 1986. The decline represented the sixth straight yearly decrease and reflected a continuing trend by holders of zinc stocks to minimize inventories and reduce investment in stocks. The 1987 ending domestic stock levels were only 43% of those held at the end of 1981. Domestic metal stock levels initially fell in the early months of 1987, tended to be stable in the middle months as both demand and prices improved, and declined toward the end of the year, in part because the world supply of metal began to tighten.

Metal stock levels in the market economy countries, according to ILZSG, followed the same basic pattern as in the United States. Stocks, as reported by ILZSG, were highest at the end of January, 678,000 tons; lowest in November, 516,000 tons; and at yearend, 565,000 tons. Stock reductions were, in part, due to labor disputes that sharply reduced metal availability in the second half of the year.

London Metal Exchange (LME) zinc metal stocks remained at relatively low levels, especially at midyear, mainly because the availability of HG metal was in short supply. LME stocks reached a low of 28,100 tons in June and a high of 44,000 tons in December. At yearend, the LME was considering the establishment of a new U.S.-dollar-based, SHG zinc metal contract to replace the HG contract that only was implemented in September 1985. The change was thought necessary because SHG has become the most widely used metal grade. Plans called for the new contract to be in place by mid-1988. The new contract, if implemented, could lead to the demise of the European Producer Price (EPP), the basis used by zinc miners and European smelters for establishing their raw materials contracts, mainly because the LME price better represents the actual price of zinc in Europe rather than the less responsive EPP price.

Inventories of zinc contained in concentrates at domestic primary smelters, according to the American Bureau of Metal Statistics Inc., totaled 38,450 tons at yearend versus 43,800 tons at the end of 1986. Stocks were lowest, 32,100 tons, in July.

PRICES

Zinc prices trended downward during the first 3 months of 1987, continuing a downward trend begun in late 1986 mainly owing to improved world supply of zinc metal. In late April and in May, prices firmed and increased mainly owing to anticipated and subsequent strike action at Cominco Ltd.'s refinery at Trail, British Columbia, Canada. In the summer months, prices remained relatively stable, bouyed by the continuing Cominco Ltd. strike and production problems at the Cajamarquilla zinc smelter in Peru and at the Kidd Creek and Flin Flon zinc smelters in Canada. In September, the Cominco Ltd. strike was settled, bringing about a modest fall in zinc prices. Also contributing to the price decline in this period was the resumption of zinc shipments from the Cajamarquilla smelter and the announcement by major European producers that they again were shelving plans to reduce their zinc-smelting capacity. Zinc prices tended to improve after mid-November, responding mainly to increased Chinese buying and to tightening of zinc supplies in Europe and the United States.

World zinc prices, essentially the EPP and LME price, paralleled U.S. price trends, although the prices, in terms of most other major currencies, experienced fewer fluctuations owing to relative changes in U.S. dollar exchange rates.

Zinc oxide prices, as quoted in American Metal Market, ranged from 52 to 57 cents per pound in 1987. Although this quote range held throughout the year, premiums or discounts were given depending on the price of HG at the time and on the available supply. The average value of imported zinc oxide in 1987 was 36.9 cents per pound compared with 33.8 cents in 1986.

The price quoted in Chemical Marketing Reporter (CMR) for zinc sulfate, monohydrate industrial grade, 36% zinc in bags in carload lots, ranged from $30 to $32 per 100 pounds. Agricultural zinc sulfate in bulk was quoted by CMR at $26.50 per 100 pounds. Standard pigment-grade zinc dust, types 1 and 2 in drums, was quoted at 59 to 67 cents per pound, and technical-grade zinc chloride, 50% solution in tanks, was quoted at $20.20 per 100 pounds.

FOREIGN TRADE

Exports of zinc waste and scrap again reached record-high levels, exceeding those of 1986 by 29% and were double those of 1985. Taiwan was the principal destination, accounting for about 80% of U.S. exports. Increased exports of concentrates came mainly from Western precious metal producers.

Slab zinc imports for consumption exceeded 700,000 tons for the first time. Canada accounted for more than one-half of the total imports, followed by Spain, Mexico, and Australia. Similarly zinc oxide imports, largely from Canada and Mexico, were record highs, exceeding last year's record level by 13,000 tons and capturing about 29% of the domestic market, up from 26% in 1986 and 22% in 1985.

The vast tonnage difference between general imports and imports for consumption of zinc concentrates continued to reflect the high level of reexports of Canadian zinc concentrates to world markets through Skagway, AK, by Curragh Resources Corp., operators of the Faro lead-zinc mine in the Yukon Territory.

The International Trade Commission imposed antidumping and countervailing duties on 1985 imports of brass sheet and strip from companies in seven countries determined to have dealt in unfair trade practices. In 1985, the collective imports accounted for 68% of the brass sheet and strip imports and were valued at $90 million. Duties as high as 49% were to be collected on future imports from the affected companies. The ban on imports of zinc from the Republic of South Africa imposed in 1986 continued.

In October, Canada and the United States signed a preliminary trade liberalization agreement, known as the Canada-U.S. Free Trade Agreement, which includes provision for the mutual elimination of tariffs on most nonferrous metals by 1999. The tariffs on slab zinc, zinc alloys, and zinc dust and powder were scheduled to be eliminated over a 10-year period at 10% per year. At yearend however, the pact was undergoing review and had not been ratified by either country.

WORLD REVIEW

World zinc production and consumption attained record-high levels in 1987. Consumption was record setting for the fourth consecutive year and exceeded 7 million tons for the first time. Also exceeding 7 million tons for the first time was world zinc mine and metal production.

World consumption of metal, led by a substantial rise in U.S. consumption, was about 0.1 million tons higher than the record set in 1986. On a geographical basis, North and South America (the Americas) accounted for virtually all of the consumption increase as both Europe and Asia remained at last year's consumption level. The market economy countries, according to ILZSG, consumed about 5.1 million tons of zinc metal or about 72% of world consumption. The United States, Japan, and Western Europe accounted for about one-half of world consumption and two-thirds of that of the market economy countries. In 1987, galvanizing increased its proportion of world zinc metal consumption to an estimated 45%; other major consuming sectors, brass and bronze alloys and zinc-base alloys, accounted for about 22% and 16%, respectively.

Record-high world mine production, 7.2 million tons, was largely attributed to a strong rise in Canadian production, which exceeded 1986 production by more than 0.2 million tons. Australia, the Republic of South Africa, and Spain also recorded substantial gains in zinc mine production mainly because of full-year and/or new mine operations. Japan was the only major producer having a significant decrease in output because four mines closed, reducing zinc production by more than 50,000 tons from the previous year. Canada continued to be the principal world zinc producer and, together with Australia, Peru, and the U.S.S.R., accounted for about one-half of world output. The Americas produced about 40% of the world mine production, and Europe, including the U.S.S.R., about 30%. World exports of zinc in concentrates exceeded 2 million tons, one-half of which was exported by Canada and Australia. The principal concentrate-importing countries were Belgium, the Federal Republic of Germany, France, Japan, and the Netherlands.

World mine capacity remained about 8.2

million tons, as the capacities of mines opening and closing were more or less in balance in 1987. Seventeen new or expanded mines in the market economy countries added about 280,000 tons to world capacity in 1987; however, the gain was negated by the closure or reduction of capacity by a similar amount at 16 operations. The most significant new mine openings or capacity increases occurred in Australia, Canada, Italy, and the United States. Significant mine capacity reductions or closings occurred in Australia, Canada, the Federal Republic of Germany, and Japan.

Smelter output was up sharply due to generally higher production in a number of countries, including Canada, where strike-related production losses were less severe than in 1986. About one-third of world zinc metal production was produced by three countries: Canada, Japan, and the U.S.S.R. World primary smelter capacity, about 8.2 million tons, was virtually unchanged from that of 1986 despite the permanent closure of a 90,000-ton-per-year zinc smelter at Viviez, France, at yearend. The lost capacity was recaptured by the doubling of capacity at another company smelter at Arby, France, to 200,000 tons.

The world zinc supply-demand position was essentially in balance in 1987, unlike that of 1986, when strikes at production facilities tended to shift supply-demand to the demand side. Metal stocks in the market economy countries fell during the year in response to strong demand and ended the year at about 565,000 tons, 50,000 tons less than at the end of 1986. Unlike previous years, the market economy countries for the first time imported more zinc metal from the centrally planned economy countries than they exported, owing mainly to increased exports by North Korea and China to Western markets, including the LME. World prices, weak during the early months of 1987, rose at midyear largely in response to a strike at Cominco Ltd.'s refinery at Trail, British Columbia, Canada. Prices fell after the strike was settled but tended to recover late in the year because of renewed Chinese buying in Western markets, improved demand, and potential supply problems because of strikes and technical problems at mines and smelters mainly in Peru and Canada.

Australia.—Increased zinc production was attributed to a full year's output at the zinc mines at Broken Hill, New South Wales, the bringing on-stream of Aberfoyle Ltd.'s new Hellyer Mine in Tasmania, and initial mining at the Cadjebut deposit in Western Australia. MIM Holdings Ltd. continued to increase output at its Hilton Mine in Queensland, phasing the production into the company's Mount Isa Mine operations. At midyear, Denehurst Ltd. began underground production at the former Woodlawn, New South Wales, copper-zinc-lead-silver open pit, which was purchased from Australia Mining & Smelting Ltd. Plans call for the mining of 0.5 million tons per year from the remaining ore body, estimated to have 2.5 million tons of recoverable reserves grading 11.8% zinc, 4.8% lead, 1.4% copper, and 3.3 ounces of silver per ton.

Aberfoyle, 46% owned by Cominco Ltd., treated Hellyer zinc-lead ore at its converted Cleveland tin mill in 1987, which provided experience for the new 1.1-million-ton-per-year concentrator under construction at the mine site. Plans call for mill completion and full operation in early 1989. The estimated in situ ore reserves at Hellyer totaled 15 million tons averaging 22.8% zinc, 6.4% lead, and 3.9 ounces of silver per ton.

BHP Minerals Ltd., 58%, and Billiton (Australia) Ltd., 42%, began mining at their Cadjebut Mine in June. Ore was stockpiled awaiting commissioning of the new mill in early 1988. Planned ore throughput was 320,000 tons per year yielding 41,000 tons of zinc and 7,500 tons of lead in concentrates. Minable reserves were estimated to be about 3.3 million tons grading 14% zinc and 4.5% lead.

Murchison Zinc Pty. Ltd., 45%; Esso Australia Ltd., 35%; and Aztec Exploration Ltd., 20%, continued exploration of their Golden Grove Hill deposits in Western Australia. The companies were considering development of an underground mine in 1990 with a potential output of 100,000 tons of zinc per year. Ore reserves were 9.3 million tons grading 15.8% zinc, 1.3% lead, and 0.5 and 0.04 ounce of silver and gold, respectively, per ton.

The Electrolytic Zinc Co. of Australia Ltd. was conducting a feasibility study to increase the capacity at its Risdon, Tasmania, zinc smelter to 320,000 tons per year from the present 220,000 tons by the early 1990's. The new capacity would make the Risdon facility the world's largest zinc smelter.

Canada.—Mine production of zinc, which accounted for about 21% of world output, was up sharply in 1987, mainly due to accelerated ore production at Pine Point

Mines Ltd.'s mine in the Northwest Territories. Although the Pine Point Mine closed in July, milling of stockpiled ore continued through yearend and was not expected to cease until mid-1988. A record high 483,500 tons of 59.5% zinc concentrate, up about 50,000 tons over that of 1986 in zinc contained, was produced in 1987, making the Pine Point Mine the single largest Canadian zinc producer. Brunswick Mining and Smelting Ltd.'s No. 12 Mine in New Brunswick, Falconbridge Ltd.'s Kidd Creek Mine in Ontario, Curragh Resources Corp.'s Faro Mine in the Yukon, and the Pine Point Mine, accounted for about 60% of Canadian mine production and 12% of world output.

In September, Newfoundland Zinc Mines Ltd. reopened its Tecam Mine at Daniel's Harbour, Newfoundland. The company, which closed the mine in April 1986, planned to initially produce about 2,800 tons of zinc in concentrates per month. Several new mines, with annual zinc capacities totaling 160,000 tons, were under development for initial startup in 1988. Noranda's Isle Dieu Mine in Quebec, with an expected capacity to produce 50,000 tons of zinc annually, was essentially replacement capacity for the company's nearby Mattagami Lake and Norita Mines, both of which are nearing ore reserve depletion. The Ruttan copper-zinc mine in Manitoba was acquired by the Hudson Bay Mining and Smelting Co. Ltd. (HBMS) in October. During the year, HBMS closed two small zinc-producing mines in Manitoba, the Ghost Lake and Centennial Mines, and planned to increase annual zinc production capacity at the Ruttan Mine to 13,000 tons in 1988. The increase was planned partially to maintain the feed source for its zinc and copper smelters at Flin Flon, Manitoba.

Curragh Resources Corp. sold one-half of its 92% interest in the Faro Mine and nearby deposits to Giant Resources Ltd. in July. Boliden AB of Sweden owned the remaining 8% share. Curragh and Giant Resources planned to develop and phase in ore production from the nearby Grum and Vangorda lead-zinc deposits as production from the Faro Mine begins to decline in the next few years. Ore reserves at the two nearby deposits were estimated at 46 million tons grading 9% combined lead and zinc.

Germany, Federal Republic of.—Preussag AG Metall planned to close its 70,000-ton-per-year Harlingerode zinc smelter in the second half of 1988 as a result of poor economic results. The smelter, which processed both scrap and concentrate, was the last operating plant in Europe using the vertical retort process developed in 1929 by the New Jersey Zinc Co.

Honduras.—Rosario Resources Inc., a subsidiary of AMAX, closed down its El Mochita lead-zinc-silver mine in April owing to high production cost. In August, an investor group, American Pacific Holdings (APH), bought the El Mochito Mine. Following concessions by the Government on taxes and power rates, APH reopened the mine in October. In 1986, its last full year of production, the El Mochito Mine had an output of 49,000 tons of zinc, 11,500 tons of lead, and 1.2 million ounces of silver.

Peru.—San Ignacio de Morochoca S.A. (SIMSA), the country's largest private zinc mine producer, completed the expansion program at its San Vicente zinc mine to increase daily mine and mill ore capacity from 1,800 tons to 3,000 tons. In 1987, production was about 85,000 tons of contained zinc in concentrate. Ore reserves at the San Vicente Mine were about 5.1 million tons averaging 12.6% zinc and 0.8% lead at yearend. SIMSA also completed a smelter feasibility study late in the year and was considering the construction of a 45,000-ton-per-year electrolytic zinc smelter, which initially would process mostly company concentrates. Plans called for construction to be completed in 5 years at a cost of about $120 million.

Spain.—Cía. Industrial Asua-Erandio S.A. (ASER) began shipments of Waelz oxide briquets from its new secondary zinc plant near Bilbao following startup in April. The plant, which treats hazardous steelmaking dust imported from Denmark and the Federal Republic of Germany, produced about 10,000 tons of oxide briquets containing about 45% zinc and 12% lead in 1987. The briquets were sold to European smelters for refinement to metal. ASER planned to produce 22,000 tons of briquets in 1988.

TECHNOLOGY

The Bureau of Mines completed an appraisal of the availability of 34 mineral commodities, including zinc.[4] The report includes geologic, engineering, and economic evaluations of about 2,900 mines, deposits, and mineral processing plants in the market economy countries.

Aspects of secondary zinc recovery, including trends in recovery, economic and environmental aspects, technological changes, and perspectives in a number of countries were discussed at a special ILZSG meeting.[5] Three thermal processes to recover zinc from steelmaking EAF dusts were also discussed. Particular emphasis was placed on EAF dust treatment in the United States because proposed regulations by EPA may not allow, after August 1988, disposal in landfills, as currently done, without thermal treatment. An estimated 500,000 tons of EAF dust was generated in the United States in 1987.

A comprehensive coverage of zinc-related investigations and an extensive review of current world literature on zinc extraction, alloys, uses, products, and research was available in quarterly issues of Zincscan, published by the Zinc Development Association, London, United Kingdom.

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[1]Physical scientist, Branch of Nonferrous Metals.

[2]Federal Register. Environmental Protection Agency. Assessment of Zinc and Zinc Oxide as Potential Toxic Air Pollutants. V. 52, No. 167, Aug. 28, 1987, pp. 32597-32600.

[3]Copper Development Association Inc. Annual Data 1988, Copper Supply & Consumption 1967-1987. 1987, 20 pp.

[4]U.S. Bureau of Mines. An Appraisal of Minerals Availability for 34 Commodities. B 692, 1987, 300 pp.

[5]International Lead and Zinc Study Group. Secondary Lead and Zinc Final Report of the Recycling Subcommittee. Washington, DC, Sept. 9-11, 1987, 379 pp.; available from International Lead and Zinc Study Group, Metro House, 58 St. James St., London, England SW1A1LD.

Table 2.—Mine production of recoverable zinc in the United States, by month

(Metric tons)

Month	1986	1987
January	20,606	17,800
February	18,617	17,774
March	19,790	19,023
April	15,472	18,015
May	12,358	17,830
June	14,382	18,093
July	16,724	17,806
August	15,510	19,096
September	16,726	18,495
October	19,576	18,514
November	15,355	16,081
December	17,867	18,454
Total	202,983	216,981

Table 3.—Mine production of recoverable zinc in the United States, by State

(Metric tons)

State	1983	1984	1985	1986	1987
Colorado	W	W	W	W	W
Idaho	W	W	W	351	W
Illinois	W	W	W	W	W
Kentucky	W	W	W	--	10
Missouri	57,044	45,458	49,340	37,919	34,956
Montana	--	--	--	--	W
New Jersey	16,475	W	W	W	--
New York	56,748	W	W	W	W
Pennsylvania	16,792	--	--	--	--
Tennessee	109,958	116,526	104,471	102,118	115,699
Utah	--	W	--	--	--
Total	275,294	252,768	226,545	202,983	216,981

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

Table 4.—Twenty-five leading zinc-producing mines in the United States in 1987, in order of output

Rank	Mine	County and State	Operator	Source of zinc
1	Elmwood-Gordonsville	Smith, TN	Jersey Minière Zinc Co	Zinc ore.
2	Pierrepont	St. Lawrence, NY	Zinc Corporation of America	Do.
3	Young	Jefferson, TN	ASARCO Incorporated	Do.
4	Immel	Knox, TN	do	Do.
5	Balmat	St. Lawrence, NY	Zinc Corporation of America	Do.
6	New Market	Jefferson, TN	ASARCO Incorporated	Do.
7	Buick	Iron, MO	The Doe Run Co	Lead ore.
8	Magmont	do	Cominco American Incorporated.	Lead-zinc ore.
9	Zinc Mine Works	Jefferson, TN	USX Corp	Zinc ore.
10	Leadville Unit	Lake, CO	ASARCO Incorporated	Lead-zinc ore.
11	Coy	Jefferson, TN	do	Zinc ore.
12	Montana Tunnels	Jefferson, MT	Montana Tunnels Mining Inc.	Gold ore.
13	Sunnyside	San Juan, CO	Sunnyside Gold Corp	Do.
14	West Fork	Reynolds, MO	ASARCO Incorporated	Lead ore.
15	Rosiclare	Hardin and Pope, IL.	Ozark-Mahoning Co	Flouspar.
16	Viburnum No. 29	Washington, MO	The Doe Run Co	Lead ore.
17	Fletcher	Reynolds, MO	do	Lead-zinc ore.
18	Lucky Friday	Shoshone, ID	Hecla Mining Co	Silver ore.
19	Copperhill	Polk, TN	Tennessee Chemicals Co	Copper-zinc ore.
20	Casteel	Iron, MO	The Doe Run Co	Copper-lead ore.
21	Viburnum No. 28	do	do	Lead ore.
22	Sweetwater	Reynolds, MO	ASARCO Incorporated	Do.
23	Catnip Hill	Jessamine, KY	Lexington Quarry Co	Zinc ore.
24	Clayton	Custer, ID	Clayton Silver Mines Inc	Silver ore.
25	Cross	Boulder, Co	Hendricks Mining Co. Inc	Gold ore.

Table 5.—Primary and secondary slab zinc produced in the United States

(Metric tons)

	1983	1984	1985	1986	1987
Primary:					
From domestic ores	210,315	197,912	198,003	191,079	211,633
From foreign ores	25,379	55,220	63,204	62,288	58,377
Total	235,694	253,132	261,207	253,367	270,010
Secondary:					
At primary smelters	40,545	44,930	39,723	49,852	W
At secondary smelters	28,845	33,183	32,844	13,062	W
Total	69,390	78,113	72,567	62,914	72,653
Grand total (excludes zinc recovered by remelting)	305,084	331,245	333,774	316,281	342,663

W Withheld to avoid disclosing company proprietary data.

Table 6.—Distilled and electrolytic zinc, primary and secondary, produced in the United States, by grade

(Metric tons)

Grade	1983	1984	1985	1986	1987
Special High	95,395	123,325	98,282	78,978	83,740
High	78,511	71,892	98,979	84,738	88,952
Continuous Galvanizing	50,661	48,200	26,139	20,589	38,751
Controlled Lead	10,231	9,384	20,952	18,883	W
Prime Western	70,286	78,444	89,422	113,093	131,220
Total	305,084	331,245	333,774	316,281	342,663

W Withheld to avoid disclosing company proprietary data; included with "Prime Western."

Table 7.—Annual slab zinc capacity of primary zinc plants in the United States, by type of plant and company

Type of plant and company	Slab zinc capacity (metric tons)	
	1986	1987
Electrolytic:		
AMAX Inc., Sauget, IL	76,000	76,000
ASARCO Incorporated,[1] Corpus Christi, TX	104,000	104,000
Jersey Minière Zinc Co., Clarksville, TN	82,000	82,000
Zinc Corporation of America, Bartlesville, OK	51,000	51,000
Electrothermic:		
Zinc Corporation of America, Monaca, PA	91,000	91,000
Total available capacity	404,000	404,000
Total operating capacity	300,000	300,000

[1]Zinc plant closed indefinitely in Apr. 1985.

Table 8.—Secondary slab zinc plant capacity in the United States, by company

Company	Plant location	Capacity (metric tons)	
		1986	1987
Arco Alloys Corp	Detroit, MI	65,000	65,000
W. J. Bullock Inc	Fairfield, AL		
T. L. Diamond & Co. Inc	Spelter, WV		
Gulf Reduction Corp	Houston, TX		
Hugo Neu-Proler Co	Terminal Island, CA		
Huron Valley Steel Corp	Belleville, MI		
Interamerican Zinc Co	Adrian, MI		
New England Smelting Works Inc	West Springfield, MA		
Pacific Smelting Co	Torrance, CA		
Do	Memphis, TN		
Zinc Corporation of America	Palmerton, PA		

Table 9.—Stocks and consumption of new and old zinc scrap in the United States in 1987, by type of scrap

(Metric tons, zinc content)

Type of scrap	Stocks, Jan. 1	Receipts	Consumption			Stocks, Dec. 31
			New scrap	Old scrap	Total	
Diecastings	782	6,072	--	6,157	6,157	697
Flue dust	3,481	50,719	39,456	9,864	49,320	4,880
Fragmentized diecastings	3,692	19,062	--	21,878	21,878	876
Galvanizer's dross	9,231	33,158	34,718	--	34,718	7,671
Old zinc[1]	225	2,241	--	2,270	2,270	196
Remelt die-cast slab	709	13,189	--	13,145	13,145	753
Remelt zinc[2]	48	3,905	3,885	--	3,885	68
Skimmings and ashes[3]	21,034	80,892	80,721	--	80,721	21,205
Other[4]	W	13,871	13,871	--	13,871	W
Total	39,202	223,109	172,651	53,314	225,965	36,346

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1]Includes engraver's plates and rod and die scrap.
[2]Includes new clippings.
[3]Includes sal skimmings and die-cast skimmings.
[4]Includes chemical residues.

Table 10.—Production of zinc products from zinc-base scrap in the United States

(Metric tons)

Product	1983	1984	1985	1986	1987
Redistilled slab zinc	69,390	78,113	72,567	62,914	72,653
Zinc dust	34,773	35,254	27,115	24,295	28,253
Remelt zinc	66	71	--	--	--
Remelt die-cast slab	3,109	3,380	3,059	1,814	825
Zinc die and diecasting alloys	6,535	6,112	5,667	4,184	8,513
Galvanizing stocks	2,801	2,368	W	W	W
Secondary zinc in chemical products	59,085	66,221	56,109	r67,271	93,020

rRevised. W Withheld to avoid disclosing company proprietary data.

Table 11.—Zinc recovered from scrap processed in the United States, by kind of scrap and form of recovery

(Metric tons)

	1986	1987
KIND OF SCRAP		
New scrap:		
Zinc-base	r158,885	181,861
Copper-base	r111,990	124,306
Magnesium-base	41	35
Total	r270,916	306,202
Old scrap:		
Zinc-base	50,193	55,043
Copper-base	r20,363	20,877
Aluminum-base	336	262
Magnesium-base	163	159
Total	r71,055	76,341
Grand total	r341,971	382,543
FORM OF RECOVERY		
Metal:		
Slab zinc[1]	62,914	72,653
Zinc dust	24,295	28,253
By remelting	1,300	--
Total	88,509	100,906
In zinc-base alloys	5,998	9,338
In brass and bronze	r179,639	178,811
In aluminum-base alloys	350	274
In magnesium-base alloys	204	194
In chemical products:		
Zinc oxide (lead free)	38,422	51,408
Zinc sulfate	20,524	19,752
Zinc chloride	r7,690	12,034
Miscellaneous	635	9,826
Total	r253,462	281,637
Grand total	r341,971	382,543

rRevised.
[1]Includes zinc content of slab made from remelt die-cast slab.

Table 12.—U.S. production of zinc dust[1]

Year	Quantity (metric tons)	Value	
		Total (thousands)	Average per pound
1983	40,508	$45,849	$0.513
1984	41,044	59,902	.662
1985	30,813	38,721	.570
1986	27,247	33,039	.550
1987	29,890	36,276	.551

[1]Does not include zinc dust produced for internal plant use.

Table 13.—U.S. consumption of zinc

(Metric tons)

	1983[r]	1984[r]	1985[r]	1986[r]	1987
Slab zinc, apparent (rounded)	933,000	980,000	961,000	999,000	1,052,000
Ores and concentrates (zinc content)[1]	36,912	45,487	39,886	19,236	2,536
Secondary (zinc content)[2]	276,370	318,018	278,710	[r]277,757	309,890
Total (rounded)[3]	1,246,300	1,343,500	1,279,600	1,296,000	1,364,000

[r]Revised.
[1]Includes ore used directly in galvanizing.
[2]Excludes secondary slab and remelt zinc.
[3]Data have been revised based on apparent consumption; previously based on reported consumption.

Table 14.—Apparent consumption[1] of slab zinc, by industry and product

(Metric tons)

Industry and product	1986	1987
Galvanizing:		
Sheet and strip	361,200	382,000
Other	168,000	168,000
Total	529,200	550,000
Brass and bronze	135,100	139,600
Zinc-base alloys:		
Diecastings	216,700	217,200
Other	14,000	11,500
Total	230,700	228,700
Rolled zinc	30,100	36,700
Zinc oxide	43,000	64,000
Light metal alloys	14,500	16,100
Other[2]	16,400	16,900
Grand total	999,000	1,052,000

[1]Based on reported slab zinc consumption.
[2]Includes zinc used in making zinc dust, wet batteries, desilverizing lead, powder, alloys, anodes, chemicals, castings, and miscellaneous uses not elsewhere specified.

Table 15.—U.S. reported consumption of slab zinc in 1987, by industry and grade

(Metric tons)

Industry	Special High Grade	High Grade	Continuous Galvanizing Grade	Controlled Lead Grade	Prime Western	Remelt	Total
Galvanizing	94,530	67,232	53,714	26,053	162,227	1,298	405,054
Zinc-base alloys	176,555	2,068	--	--	4	55	178,682
Brass and bronze	41,334	29,038	54	--	8,951	4,983	84,360
Rolled zinc	22,143	--	--	13,284	--	--	35,427
Zinc oxide	61,428	W	--	--	W	--	61,428
Other	19,325	1,708	--	--	524	2,220	23,777
Total	415,315	100,046	53,768	39,337	171,706	8,556	788,728

W Withheld to avoid disclosing company proprietary data; included with "Special High Grade."

Table 16.—U.S. reported consumption of slab zinc, by industry and product

(Metric tons)

Industry and product	1986	1987
Galvanizing:		
Sheet and strip	241,872	276,737
Wire and wire rope	13,090	13,845
Tubes and pipe	20,745	21,826
Fittings (for tubes and pipe)	3,025	3,826
Tanks and containers	3,537	2,919
Structural shapes	32,484	32,357
Fasteners	4,208	3,742
Pole-line hardware	1,904	2,472
Fencing, wire cloth, netting	10,953	11,169
Other and unspecified uses	34,133	36,161
Total	365,951	405,054
Brass and bronze products:		
Sheet, strip, plate	25,906	29,005
Rod and wire	15,065	24,906
Tubes	2,093	1,755
Castings and billets	15,979	14,471
Copper-base ingots	13,635	13,403
Other copper-base products	1,003	820
Total	73,681	84,360
Zinc-base alloys:		
Diecasting alloys	163,957	169,821
Dies and rod alloys	3,068	3,352
Slush and sand-casting alloys	8,085	5,509
Total	175,110	178,682
Rolled zinc[1]	28,597	35,427
Zinc oxide	40,061	61,428
Other:		
Light-metal alloys	13,007	14,783
Miscellaneous[2]	9,556	8,994
Total	22,563	23,777
Grand total	705,963	788,728

[1]Includes zinc used in penny production.
[2]Includes zinc used in making zinc dust, wet batteries, desilverizing lead, powder, alloys, anodes, chemicals, castings, and miscellaneous uses not elsewhere specified.

Table 17.—U.S. reported consumption of slab zinc in 1987, by State

(Metric tons)

State	Galva-nizers	Brass mills[1]	Die-casters[2]	Other[3]	Total
Alabama	W	W	--	--	11,003
Arkansas	W	--	--	--	W
California	22,452	W	--	W	28,557
Colorado	W	--	W	--	W
Connecticut	2,005	2,761	W	W	9,676
Delaware	W	--	--	--	W
Florida	W	--	--	--	W
Georgia	W	--	W	--	1,804
Hawaii	W	--	--	--	W
Illinois	69,919	W	32,759	W	131,489
Indiana	40,371	W	W	W	47,074
Iowa	--	--	W	W	W
Kentucky	W	--	--	--	W
Louisiana	W	--	W	--	2,491
Maryland	W	--	--	--	W
Massachusetts	2,083	W	--	W	2,866
Michigan	W	18,466	39,354	W	62,531
Minnesota	W	--	--	--	W
Mississippi	W	--	--	--	W
Missouri	W	--	--	W	4,446
Nebraska	W	--	--	W	5,817
New Jersey	1,260	W	--	W	1,935
New York	3,592	W	63,283	W	90,150
North Carolina	W	--	W	W	W

See footnotes at end of table.

Table 17.—U.S. reported consumption of slab zinc in 1987, by State —Continued

(Metric tons)

State	Galvanizers	Brass mills[1]	Die-casters[2]	Other[3]	Total
Ohio	49,273	W	29,919	W	87,730
Oklahoma	W	--	--	W	2,508
Oregon	W	W	--	--	887
Pennsylvania	105,421	W	W	41,308	152,614
South Carolina	W	--	--	--	W
Tennessee	W	--	--	W	41,246
Texas	W	--	--	W	9,756
Utah	W	W	--	--	W
Virginia	W	W	W	--	4,399
Washington	W	--	--	W	1,079
West Virginia	W	--	--	W	25,926
Wisconsin	W	W	W	W	8,318
Undistributed	107,381	58,151	13,313	77,101	45,870
Total[4]	403,757	79,378	178,628	118,409	780,172

W Withheld to avoid disclosing company proprietary data; included with "Total" and "Undistributed."
[1]Includes brass mills, brass ingot makers, and brass foundries.
[2]Includes producers of zinc-base alloys for diecastings, stamping dies, and rods.
[3]Includes slab zinc used in rolled zinc products and in zinc oxide.
[4]Excludes remelt zinc.

Table 18.—Rolled zinc produced and quantity available for consumption in the United States

(Metric tons)

	1986	1987
Production[1]	34,316	42,771
Exports	721	1,723
Imports for consumption	3,811	960
Available for consumption	42,737	40,342

[1]Includes other plate over 0.375 inch thick, and rod and wire.

Table 19.—Production and shipments of zinc pigments and compounds[1] in the United States

(Metric tons)

	1986		1987	
	Production	Shipments	Production	Shipments
Zinc oxide	120,448	121,480	140,595	137,957
Zinc sulfate	55,221	53,796	48,771	44,518
Zinc chloride	16,214	13,216	25,265	21,928

[1]Excludes leaded zinc oxide and lithopone.

Table 20.—Zinc content of zinc pigments[1] and compounds produced by domestic manufacturers, by source

(Metric tons)

	1986				1987			
	Zinc in pigments and compounds produced from—			Total	Zinc in pigments and compounds produced from—			Total
	Ore	Slab zinc	Secondary material		Ore	Slab zinc	Secondary material	
Zinc oxide	17,311	40,585	38,422	96,318	--	61,014	51,408	112,422
Zinc sulfate	W	--	22,363	22,363	W	--	19,752	19,752
Zinc chloride	--	--	7,690	7,690	--	--	12,034	12,034

W Withheld to avoid disclosing company proprietary data; included with "Secondary material."
[1]Excludes leaded zinc oxide, zinc sulfate, and lithopone.

Table 21.—Reported distribution of zinc oxide shipments, by industry[1]

(Metric tons)

Industry	1983	1984	1985	1986	1987
Agriculture	2,569	2,380	2,575	3,910	4,346
Ceramics	5,987	7,472	7,286	5,012	6,126
Chemicals	19,217	23,611	22,477	22,704	28,486
Paint	9,716	8,117	8,215	10,797	10,009
Photocopying	10,239	9,246	8,324	W	W
Rubber	67,971	79,390	71,574	70,307	79,486
Other	19,355	16,702	15,715	8,750	9,504
Total	135,054	146,918	136,166	121,480	137,957

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]In addition, zinc oxide was imported as follows: 1983—31,588; 1984—35,741; 1985—39,375; 1986—43,924; and 1987—57,276. Distribution cannot be distinguished by industry.

Table 22.—Distribution of zinc sulfate shipments

(Metric tons)

Industry	1984	1985	1986	1987
Agriculture	28,162	33,786	45,965	36,875
Other	8,950	8,723	7,831	7,643
Total	37,112	42,509	53,796	44,518

Table 23.—Stocks of slab zinc in the United States, December 31

(Metric tons)

	1983	1984	1985	1986	1987
Primary producers	20,750	42,025	29,030	16,722	13,449
Secondary producers	3,149	4,303	3,389	3,203	3,162
Consumers	89,041	72,506	60,310	54,239	57,125
Merchants	35,199	18,792	27,163	26,559	22,352
Total	148,139	137,626	119,892	100,723	96,088

Table 24.—Average monthly U.S., LME,[1] and European producer prices for equivalent zinc

(Metallic zinc, cents per pound)

Month	1986			1987		
	United States[2]	LME cash	European producer	United States[2]	LME cash	European producer
January	32.87	29.18	31.75	41.40	34.43	37.87
February	30.88	27.58	30.08	38.38	33.56	34.92
March	31.22	28.35	29.48	37.70	33.16	34.92
April	32.13	29.91	31.34	38.19	34.53	34.92
May	32.97	32.06	33.24	42.23	38.01	37.06
June	36.54	36.45	37.24	45.05	39.80	37.65
July	39.55	36.58	38.10	45.67	37.59	39.01
August	40.83	37.01	38.53	44.43	36.44	39.01
September	43.70	39.48	40.95	42.59	34.28	37.19
October	45.98	40.17	41.73	41.75	34.89	37.19
November	45.78	37.17	40.59	42.38	38.42	37.67
December	43.51	36.18	39.46	43.31	39.25	39.01
Average	38.00	34.19	38.04	41.92	36.20	37.20

[1]London Metal Exchange.
[2]Based on High Grade zinc delivered.

Source: Metals Week.

Table 25.—U.S. exports of zinc and zinc alloys, by country

Country	1985 Quantity (metric tons)	1985 Value (thousands)	1986 Quantity (metric tons)	1986 Value (thousands)	1987 Quantity (metric tons)	1987 Value (thousands)
Unwrought zinc and zinc alloys:						
Belgium-Luxembourg	20	$22	5	$18	6	$21
Canada	432	925	1,081	2,550	1,059	2,608
Chile	501	451	(1)	3	--	--
Egypt	255	250	--	--	--	--
Finland	--	--	33	31	--	--
Germany, Federal Republic of	21	18	9	33	120	34
Ghana	26	26	--	--	--	--
India	48	62	34	32	--	--
Israel	25	56	--	--	--	--
Jamaica	--	--	59	50	77	99
Japan	37	73	27	72	27	77
Korea, Republic of	87	98	431	774	4,257	8,603
Malaysia	--	--	11	8	--	--
Mexico	79	207	93	133	44	134
Netherlands	27	67	11	19	2	5
Panama	5	9	32	52	42	54
Salvador	3	4	21	22	1	2
Spain	--	--	6	14	--	--
Switzerland	1	1	21	63	3	7
Taiwan	618	463	1,610	1,074	1,113	775
Trinidad	--	--	17	19	--	--
United Kingdom	12	40	1	11	7	16
Venezuela	20	63	--	--	50	305
Other[2]	37	95	46	205	99	197
Total	2,254	2,930	3,548	5,183	6,907	12,937
Wrought zinc and zinc alloys:						
Argentina	17	47	8	21	1	2
Australia	1	2	10	16	--	--
Bahamas	41	52	10	21	39	33
Brazil	--	--	1	5	--	--
Canada	1,379	2,085	1,300	1,599	1,087	1,744
Chile	11	80	3	7	53	94
Colombia	13	56	10	26	7	25
Costa Rica	1	2	200	90	1	2
Dominican Republic	11	45	1	10	23	50
Ecuador	20	41	13	23	2	7
Egypt	6	17	--	--	--	--
El Salvador	6	18	10	41	23	36
France	23	69	--	--	--	--
Germany, Federal Republic of	2	3	49	84	863	542
Guyana	4	11	1	2	6	11
India	--	--	18	11	2	7
Japan	9	24	47	108	59	126
Korea, Republic of	14	34	2	3	4	7
Leeward and Windward Islands	1	1	34	48	18	19
Mexico	397	821	288	613	521	775
Netherlands Antilles	6	4	6	12	46	55
Pakistan	--	--	6	11	--	--
Panama	20	41	2	12	22	44
Philippines	3	9	24	54	42	116
Saudi Arabia	2	24	--	--	1	5
Singapore	1	1	--	--	--	--
South Africa, Republic of	11	26	8	24	3	5
Spain	--	--	20	11	1	3
Switzerland	17	63	--	--	--	--
Taiwan	34	83	20	42	2	3
Trinidad and Tobago	27	35	1	5	10	10
United Kingdom	48	41	75	158	11	46
Venezuela	33	182	40	56	29	45
Other[3]	52	154	45	106	127	236
Total	2,210	4,071	2,252	3,219	3,003	4,048

[1]Less than 1/2 unit.

[2]Includes Angola, Argentina, Australia, Barbados, Brazil, Costa Rica, Dominican Republic, Ecuador, El Salvador, France, Guatemala, Honduras, Hong Kong, Indonesia, Italy, Kenya, Kuwait, Leeward and Windward Islands, Libya, Netherlands Antilles, New Guinea, New Zealand, Peru, Philippines, Saudia Arabia, Singapore, Thailand, the United Arab Emirates, and Yugoslavia.

[3]Includes Austria, Belgium-Luxembourg, Belize, Bermuda, China, Cyprus, Denmark, Finland, French Guiana, Ghana, Guatemala, Hong Kong, Iran, Ireland, Israel, Italy, Jamaica, Kuwait, Libya, Morocco, Mozambique, the Netherlands, New Zealand, Nicaragua, Norway, Peru, Portugal, Qatar, Somalia, Sri Lanka, Suriname, Turkey, the United Arab Emirates, and Uruguay.

Source: Bureau of the Census.

Table 26.—U.S. exports of zinc

Year	Ores and concentrates		Blocks, pigs, anodes, etc.: Unwrought		Blocks, pigs, anodes, etc.: Unwrought alloys	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1985	23,264	$8,216	1,011	$1,525	1,243	$1,405
1986	3,269	1,590	1,938	3,533	1,610	1,650
1987	16,921	8,304	1,082	2,114	5,825	10,823

Year	Wrought zinc and zinc alloys: Sheets, plates, strips		Wrought zinc and zinc alloys: Angles, bars, pipes, rods, etc.		Waste and scrap (zinc content)		Dust and flakes	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1985	776	$1,973	1,434	$2,098	43,947	$19,600	2,037	$2,480
1986	721	1,513	r1,531	1,706	68,660	32,803	1,551	2,104
1987	1,732	2,337	1,271	1,711	88,277	46,182	1,927	3,300

rRevised.

Source: Bureau of the Census.

Table 27.—U.S. exports of zinc ores and concentrates, by country

(Zinc content)

Country	1986		1987	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Canada	3,265	$1,582	12,972	$7,359
Germany, Federal Republic of	--	--	3,857	881
Mexico	3	7	8	4
Panama	(1)	1	--	--
Taiwan	--	--	83	59
Total[2]	3,269	1,590	16,921	8,304

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

Source: Bureau of the Census.

Table 28.—U.S. general imports of zinc, by country

Country	1985		1986		1987	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
ORES AND CONCENTRATES (zinc content)						
Australia	2,934	$819	1,981	$262	476	$63
Canada	47,200	18,351	150,100	23,512	399,755	61,634
Chile	--	--	68	57	12	2
China	--	--	--	--	223	30
Germany, Federal Republic of	--	--	--	--	5,103	3,044
Honduras	14,302	4,175	14,218	1,756	6,469	869
Mexico	12,988	4,232	6,251	1,693	5,494	1,648
Peru	13,402	4,970	25,118	5,057	7,978	3,001
South Africa, Republic of	473	1,963	--	--	--	--
United Kingdom	92	64	--	--	--	--
Total	91,391	34,574	197,736	32,337	425,510	70,291

Table 28.—U.S. general imports of zinc, by country —Continued

Country	1985 Quantity (metric tons)	1985 Value (thousands)	1986 Quantity (metric tons)	1986 Value (thousands)	1987 Quantity (metric tons)	1987 Value (thousands)
BLOCKS, PIGS, OR SLABS[1]						
Algeria	--	--	--	--	505	$389
Argentina	2,500	$1,741	--	--	--	--
Australia	29,610	26,482	40,686	$28,421	51,435	42,451
Belgium-Luxembourg	1,000	802	--	--	9,769	8,371
Canada	383,618	326,388	349,335	253,110	360,729	301,773
China	--	--	1,342	1,185	4,199	3,474
Colombia	--	--	200	162	--	--
Costa Rica	--	--	147	92	--	--
Finland	19,601	16,832	23,134	18,896	18,336	15,702
France	5,410	4,027	5,756	4,933	10,539	8,575
French Polynesia	--	--	2,938	1,962	--	--
Germany, Federal Republic of	11,991	11,937	9,712	7,236	15,272	13,065
Greece	--	--	1,011	884	--	--
Hong Kong	--	--	40	48	1,289	1,020
Italy	--	--	12,743	9,668	16,388	12,752
Japan	2,700	2,386	1,951	1,283	11,943	9,892
Korea, Republic of	--	--	--	--	3,868	4,184
Mauritius	--	--	430	292	--	--
Mexico	53,846	38,355	49,619	36,372	53,344	42,368
Netherlands	13,053	10,293	20,767	15,538	28,281	23,451
New Zealand	--	--	300	257	500	423
Norway	10,822	8,975	12,809	10,133	17,507	15,440
Panama	13	13	--	--	--	--
Peru	36,326	29,104	43,590	30,720	22,383	17,235
Poland	652	491	1,183	973	250	232
Saudi Arabia	39	25	--	--	--	--
South Africa, Republic of	3,696	2,753	11,730	7,106	--	--
Spain	17,058	13,370	48,948	40,515	55,427	42,256
Taiwan	6	7	22	27	--	--
U.S.S.R.	--	--	812	544	--	--
United Kingdom	6,779	5,320	5,968	3,929	3,570	2,875
Yugoslavia	--	--	3,979	3,398	2,035	1,550
Zaire	12,042	8,597	15,974	9,346	17,338	12,870
Zambia	--	--	--	--	1,078	873
Total	610,762	507,898	665,126	487,030	705,985	581,221

[1]In addition, in 1987, 332 tons of zinc anodes was imported from Australia, Canada, Denmark, the Federal Republic of Germany, Israel, Japan, Mexico, the Netherlands, Norway, Sweden, Taiwan, and the United Kingdom.

Source: Bureau of the Census.

Table 29.—U.S. imports for consumption of zinc, by country

Country	1985 Quantity (metric tons)	1985 Value (thousands)	1986 Quantity (metric tons)	1986 Value (thousands)	1987 Quantity (metric tons)	1987 Value (thousands)
ORES AND CONCENTRATES (zinc content)						
Australia	1,936	$256	1,226	$477	--	--
Canada	50,031	20,017	28,645	10,069	28,960	$7,130
Honduras	14,302	4,175	14,218	1,756	6,469	869
Mexico	12,900	4,149	6,251	1,693	5,422	1,639
Peru	10,452	3,002	25,446	5,101	5,613	2,684
South Africa, Republic of	473	1,963	--	--	--	--
United Kingdom	92	64	--	--	--	--
Total	90,186	33,626	75,786	19,096	46,464	12,322
BLOCKS, PIGS, OR SLABS[1]						
Algeria	--	--	--	--	505	389
Argentina	2,500	1,741	--	--	--	--
Australia	29,610	26,483	40,686	28,421	51,435	42,451
Belgium-Luxembourg	1,000	802	--	--	9,769	8,371
Canada	383,618	326,388	349,335	253,110	360,729	301,773
China	--	--	1,342	1,185	4,199	3,474
Colombia	--	--	200	162	--	--
Costa Rica	--	--	147	92	--	--
Finland	19,601	16,832	23,134	18,896	18,336	15,702
France	5,410	4,027	5,756	4,935	10,539	8,575

See footnote at end of table.

Table 29.—U.S. imports for consumption of zinc, by country —Continued

Country	1985 Quantity (metric tons)	1985 Value (thousands)	1986 Quantity (metric tons)	1986 Value (thousands)	1987 Quantity (metric tons)	1987 Value (thousands)
BLOCKS, PIGS, OR SLABS[1] — Continued						
French Polynesia	--	--	2,938	$1,962	--	--
Germany, Federal Republic of	11,991	$11,937	9,712	7,236	15,272	$13,065
Greece	--	--	1,011	884	--	--
Hong Kong	--	--	40	48	1,289	1,020
Italy	--	--	12,743	9,668	16,388	1,252
Japan	2,700	2,386	1,951	1,283	11,943	9,892
Korea, Republic of	--	--	--	--	3,868	4,184
Mauritius	--	--	430	292	--	--
Mexico	53,984	38,460	49,619	36,372	53,344	42,368
Netherlands	13,053	10,293	20,767	15,537	28,281	23,451
New Zealand	--	--	300	257	500	423
Norway	10,822	8,975	12,809	10,133	17,507	15,440
Panama	13	12	--	--	--	--
Peru	36,326	29,104	43,590	30,720	22,383	17,235
Poland	652	491	1,183	973	250	232
Saudi Arabia	39	25	--	--	--	--
South Africa, Republic of	3,696	2,753	11,730	7,106	--	--
Spain	17,058	13,370	48,948	40,515	55,427	42,256
Taiwan	6	7	22	27	--	--
U.S.S.R.	--	--	812	544	--	--
United Kingdom	6,779	5,320	5,968	3,928	3,570	2,875
Yugoslavia	--	--	3,979	3,398	2,035	1,550
Zaire	12,042	8,597	15,974	9,346	17,338	12,870
Zambia	--	--	--	--	1,078	873
Total	610,900	508,003	665,126	487,030	705,985	581,221

[1]In addition, in 1987, 332 tons of zinc anodes was imported from Australia, Canada, Denmark, the Federal Republic of Germany, Israel, Japan, Mexico, the Netherlands, Norway, Sweden, Taiwan, and the United Kingdom.

Source: Bureau of the Census.

Table 30.—U.S. imports for consumption of zinc

	Ores and concentrates (zinc content)		Blocks, pigs, slabs[1]		Sheets, plates, strips, other forms		Waste and scrap	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1985	90,186	$33,626	610,900	$508,003	3,559	$2,757	3,247	$1,848
1986	75,786	19,096	665,126	487,030	3,811	3,048	4,521	1,937
1987	46,464	12,322	705,985	581,221	960	1,384	4,025	1,928

	Dross and skimmings (zinc content)		Zinc fume (zinc content)		Dust, powder, flakes		Total value[2] (thousands)
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	
1985	4,942	$2,419	--	--	8,681	$10,781	$559,434
1986	6,087	3,098	11	$2	7,446	8,260	522,473
1987	6,711	3,443	16	18	7,001	7,940	608,256

[1]Unwrought alloys of zinc were imported as follows, in metric tons: 1985—1,096 ($841,413); 1986—113 ($107,389); and 1987—60 ($53,687).
[2]In addition, the value of manufactures of zinc imported was as follows: 1985—$713,112; 1986—$1,206,175; and 1987—$1,569,545.

Source: Bureau of the Census.

Table 31.—U.S. imports for consumption of zinc pigments and compounds

	1986		1987	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Zinc oxide	43,924	$32,769	57,276	$46,572
Zinc sulfide	766	1,197	997	1,693
Lithopone	1,204	729	1,282	810
Zinc chloride	1,572	1,278	1,254	1,096
Zinc sulfate	3,311	1,971	3,339	1,964
Zinc cyanide	122	199	229	425
Zinc hydrosulfite	256	462	231	427
Zinc compounds, n.s.p.f.	6,162	8,401	4,064	7,091

Source: Bureau of the Census.

Table 32.—Zinc: World mine production (content of concentrate and direct shipping ore unless noted), by country[1]

(Thousand metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
Algeria	12.1	14.6	13.5	14.0	14.0
Argentina	36.6	34.9	35.7	39.5	37.0
Australia	699.0	676.5	759.1	662.3	733.0
Austria	19.4	20.9	21.7	16.3	15.5
Bolivia	47.1	37.8	37.1	33.5	36.3
Brazil	118.6	[r]113.7	123.8	123.9	119.4
Bulgaria[e]	68.0	68.0	68.0	70.0	70.0
Burma	4.5	5.3	4.4	4.6	[2]2.6
Canada	1,069.7	1,207.1	1,172.2	1,290.8	1,500.2
Chile	6.0	19.2	22.3	10.5	19.6
China[e]	160.0	160.0	300.0	[2]396.0	425.0
Colombia	--	--	2.0	[e]6.0	--
Congo (Brazzaville)	[e]3.0	2.8	2.3	[e]2.3	2.3
Czechoslovakia	9.8	7.2	[e]7.3	6.3	6.5
Ecuador[e]	(3)	(3)	(3)	(3)	(3)
Finland	55.9	60.2	[e]61.0	[e]60.0	55.1
France	34.3	36.2	40.6	39.5	31.3
Germany, Federal Republic of	113.5	113.1	117.6	103.7	[2]102.2
Greece	21.3	22.5	21.5	22.5	[2]21.0
Greenland	79.2	71.3	70.3	62.1	[2]69.2
Honduras	38.0	41.5	44.0	[2]25.4	10.0
Hungary[e]	2.4	2.3	2.2	[2]--	--
India	40.4	44.3	45.3	49.2	[2]53.4
Iran	39.5	47.1	50.0	36.0	36.0
Ireland	186.0	206.1	191.6	181.7	[2]177.0
Italy	42.9	42.3	45.4	26.3	47.0
Japan	255.7	252.7	253.0	222.2	[2]165.8
Korea, North[e]	140.0	140.0	180.0	180.0	225.0
Korea, Republic of	56.0	49.2	45.7	37.3	[2]23.5
Mexico	266.3	303.6	291.9	271.4	304.0
Morocco[e]	7.5	10.7	14.7	13.1	[2]10.3
Namibia	33.5	32.2	30.3	35.4	35.3
Nigeria[e]	(3)	(3)	(3)	--	--
Norway	32.4	28.5	27.8	[e]27.5	22.2
Peru	[r]491.7	[r]465.9	523.4	597.6	[2]592.3
Philippines	2.3	2.2	1.9	1.6	[2]1.1
Poland	189.0	190.7	190.8	190.4	189.6
Romania[e]	45.0	44.0	43.0	43.0	42.0
South Africa, Republic of	110.0	106.1	96.9	101.9	[2]112.7
Spain	167.7	230.4	234.7	223.1	235.0
Sweden	204.2	210.0	216.4	213.9	200.0
Thailand	--	41.4	77.5	97.2	[2]88.7
Tunisia	7.5	6.7	5.6	4.5	4.5
Turkey	31.1	50.4	37.4	41.1	58.0
U.S.S.R.[e]	805.0	810.0	810.0	810.0	810.0
United Kingdom	8.9	7.5	5.3	5.6	5.0
United States	296.7	277.5	251.9	216.0	[2]232.9
Vietnam[e]	7.0	7.0	5.0	5.0	5.0
Yugoslavia[4]	86.8	[r]85.8	89.3	94.6	[2]80.5
Zaire	76.2	74.8	77.5	81.3	81.3
Zambia	55.2	41.1	32.0	33.0	[2]35.4
Total[5]	[r]6,282.9	[r]6,523.5	6,801.3	6,829.1	7,143.9

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through July 15, 1988.
[2]Reported figure.
[3]Less than 1/2 unit.
[4]Content in ore hoisted.
[5]Data may not add to totals shown because of independent rounding.

Table 33.—Zinc: World smelter production, by country[1]

(Thousand metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
Algeria, primary	31.2	35.0	35.7	34.5	35.0
Argentina:					
Primary	30.0	27.7	30.4	29.1	30.0
Secondary	2.0	2.2	2.5	[e]3.0	4.5
Total	32.0	29.9	32.9	[e]32.1	34.5
Australia:					
Primary[2]	298.5	301.9	288.7	305.7	[3]310.2
Secondary[e]	4.5	4.5	4.5	4.5	4.5
Total	303.0	306.4	293.2	310.2	314.7
Austria, primary and secondary	23.0	24.0	25.0	[r] [e]24.0	24.5
Belgium, primary and secondary	275.8	285.3	289.6	285.0	284.5
Brazil:					
Primary	99.9	106.9	116.1	129.7	138.0
Secondary	11.0	7.5	4.6	5.9	6.0
Total[4]	[r]111.0	114.4	120.7	135.6	144.0
Bulgaria, primary and secondary[e]	90.0	90.0	90.0	90.0	[3]92.0
Canada, primary	617.0	683.2	692.4	571.0	610.5
China, primary and secondary[e]	175.0	185.0	275.0	[3]336.0	375.0
Czechoslovakia, undifferentiated[e]	9.1	9.1	9.2	9.0	9.0
Finland, primary	155.3	158.8	160.4	[e]155.4	152.0
France:					
Primary[e]	231.5	238.5	268.6	269.5	249.0
Secondary[e]	18.0	20.0	17.0	[r]18.0	17.0
Total	249.5	258.5	285.6	287.5	266.0
German Democratic Republic, primary and secondary[e]	16.5	17.0	[r]17.0	[r]17.0	19.0
Germany, Federal Republic of:					
Primary	328.7	325.6	339.9	344.3	348.3
Secondary	27.8	30.8	27.9	26.6	[3]29.3
Total	356.5	356.4	367.8	370.9	[3]377.6
Hungary, secondary[e]	.6	.6	.6	.6	.6
India:					
Primary	53.3	55.8	70.9	72.0	[3]61.0
Secondary[e]	.2	.2	.2	.2	.2
Total	53.5	56.0	[e]71.1	[e]72.2	61.2
Italy, primary and secondary	155.9	169.7	215.6	229.4	256.0
Japan:					
Primary	579.0	644.4	629.5	626.5	[3]591.5
Secondary	122.3	110.1	110.1	81.5	[3]74.1
Total	701.3	754.5	739.6	708.0	[3]665.6
Korea, North, primary[e]	120.0	120.0	180.0	180.0	210.0
Korea, Republic of, primary	108.0	108.5	111.7	127.4	[3]186.1
Mexico, primary	175.7	167.0	175.4	173.7	180.0
Netherlands, primary and secondary	187.5	209.7	201.7	196.2	207.0
Norway, primary	90.7	94.2	92.7	90.4	[3]116.5
Peru, primary	154.0	148.4	169.7	155.9	145.1
Poland, primary and secondary	170.3	176.0	180.0	179.0	[3]177.0
Portugal, primary	3.8	6.4	5.9	[e]6.5	6.0
Romania, primary and secondary[e]	42.0	41.0	40.0	39.0	39.0
South Africa, Republic of, primary	84.4	88.4	93.7	80.8	[3]96.1
Spain, primary	189.9	207.4	213.3	202.0	213.0
Thailand, primary	--	--	62.1	58.9	[3]66.9
Turkey, primary	14.3	19.9	22.2	15.4	20.2
U.S.S.R.:[e]					
Primary	870.0	900.0	900.0	900.0	905.0
Secondary	95.0	95.0	100.0	105.0	110.0
Total	965.0	995.0	1,000.0	1,005.0	1,015.0
United Kingdom, primary and secondary	87.7	85.6	74.3	85.9	81.0

See footnotes at end of table.

Table 33.—Zinc: World smelter production, by country[1] —Continued

(Thousand metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
United States:					
Primary	235.7	253.1	261.2	253.4	[3]270.0
Secondary	69.4	78.1	72.6	62.9	[3]72.7
Total	305.1	331.2	333.8	316.3	[3]342.7
Vietnam, primary[e]	6.0	6.0	4.2	4.2	4.2
Yugoslavia:					
Primary[e]	77.0	81.6	71.4	77.0	93.5
Secondary[e]	11.0	11.0	12.0	12.3	24.6
Total	88.0	92.6	83.4	89.3	118.1
Zaire, primary	62.5	66.1	64.0	63.9	[3]63.3
Zambia, primary	37.9	29.2	22.8	22.5	[3]21.0
Grand total[4]	[r]6,249.0	[r]6,526.5	6,852.4	6,760.6	7,029.7
Of which:					
Primary	4,654.3	[r]4,874.1	5,082.9	4,949.6	5,122.2
Secondary	[r]361.9	[r]360.1	352.0	320.6	343.4
Undifferentiated	1,232.8	[r]1,292.3	1,417.5	1,490.5	1,564.0

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

[1]Wherever possible, detailed information on raw material source of output (primary—directly from ores, and secondary—from scrap) has been provided. In cases where raw material source is unreported and insufficient data are available to estimate the distribution of the total, that total has been left undifferentiated (primary and secondary). To the extent possible, this table reflects metal production at the first measurable stage of metal output. Table includes data available through July 15, 1988.

[2]Excludes zinc dust.

[3]Reported figure.

[4]Detail may not add to totals shown because of independent rounding.

Zirconium and Hafnium[1]

By James B. Hedrick[2]

Mine production of zircon, the principal ore mineral of zirconium and hafnium, increased in 1987. Three domestic companies produced zircon from three heavy-mineral sands deposits in Florida, and from one operation in New Jersey. Zircon was mined in Florida as a coproduct of the titanium minerals, ilmenite and rutile, and in New Jersey from tailings previously produced as a byproduct of processing ilmenite. World demand for zircon was strong from the ceramic, foundry, and refractory industries, resulting in limited availability.

Major nonenergy uses for zirconium were in foundry sands, refractories, ceramics, abrasives, chemical manufacture, and metallurgical applications. Hafnium was used in metallurgical applications, refractory alloys, and in ceramic cutting tools.

Advanced technology applications of zirconium included stabilized zirconia used in extrusion dies in the nonferrous metals industry and in ceramic parts and coatings in high-temperature applications. Also, zirconium fluoride and hafnium fluoride glasses were being developed as replacements for silicon dioxide glasses in fiber optics.

Domestic Data Coverage.—Domestic mine production data for zircon are developed by the Bureau of Mines from a voluntary survey of U.S. operations entitled the "Production of Zircon." Of the three mining companies to which the form was sent all responded, representing 100% of mine production. Zircon production data are withheld to avoid disclosing company proprietary data.

Table 1.—Salient U.S. zirconium statistics

(Metric tons)

	1983	1984	1985	1986	1987
Zircon:					
Production	W	W	W	W	W
Exports	11,995	8,644	15,291	15,852	20,054
Imports for consumption	40,358	60,270	39,723	68,764	67,917
Consumption, apparent[1]	90,718	117,934	117,934	143,335	132,800
Stocks, Dec. 31: Dealers and consumers[2]	33,110	29,811	26,570	r28,074	39,218
Zirconium oxide:					
Production[e 3]	3,736	6,689	8,322	7,148	5,226
Exports	633	383	951	1,648	1,206
Imports for consumption	409	719	1,332	464	1,274
Consumption, apparent	3,084	5,262	6,804	6,078	3,800
Stocks, Dec. 31: Producers'[e 3]	812	1,073	1,383	2,002	1,213

eEstimated. rRevised. W Withheld to avoid disclosing company proprietary data.
1Includes insignificant amounts of baddeleyite.
2Excludes foundries.
3Excludes oxide produced by zirconium metal producers.

Environmental Impact.—A February ruling by the Oregon Energy Facility Siting Council stated that Teledyne Wah Chang Albany's (TWCA) sludge ponds, created as a waste during the pre-1980 processing of zircon, did not require regulation by the Council. The sludge contains radioactive materials, including radon, thorium, and uranium, that naturally occur in zircon. The Council determined that Teledyne's ponds did not contain significant levels of radioactivity to come under their jurisdiction. Significant expenditures have been made by TWCA in its effort to meet environmental requirements.[3]

DOMESTIC PRODUCTION

Zircon was mined, along with titanium minerals, by E. I. du Pont de Nemours & Co. Inc. at Starke and Trail Ridge, FL, and by Associated Minerals (USA) Ltd. Inc. at Green Cove Springs, FL. The combined capacity of these three operations was estimated to be 113,000 metric tons per year.

A new company, Mineral Recovery Inc., began production of zircon from tailings in Lakehurst, NJ, at yearend 1986. Mineral Recovery defaulted on its option to renew its lease from Heritage Minerals Inc., which acquired control of the operation in August 1987. Tailings at the mine were created prior to March 1982 when ASARCO Incorporated closed its ilmenite operation. An estimated 1.5 million tons of tailings was on-site prior to the start of zircon recovery. Heritage planned to continue recovery of zircon through 1990, when tailings are expected to be depleted. Future plans may include the installation of a dredging operation to recover zircon and other heavy minerals.

Five processors produced 42,394 tons of milled (ground) zircon from domestic and imported zircon, and five companies, excluding those that produce the oxide as an intermediate product in making zirconium sponge metal, produced 5,226 tons of zirconium oxide. Two companies produced zirconium sponge, ingot, and alloys, as well as hafnium sponge and crystal bar. Three companies produced cubic zirconia for use as diamond and other gem stone simulants.

A new company, The Applegate Group, was formed in Newark, NJ, to market the zirconium ore, baddeleyite, and other mineral-related products, including rare-earth alloys and compounds.

Table 2.—Producers of zirconium and hafnium materials in 1987

Company	Location	Materials
ZIRCONIUM MATERIALS		
American Minerals Inc	Camden, NJ	Milled zircon.
Associated Minerals (USA) Ltd. Inc	Green Cove Springs, FL	Zircon.
Ciba-Geigy Corp., Drakenfeld Colors	Washington, PA	Ceramic colors and milled.
Continental Mineral Processing Corp	Sharonville, OH	Milled zircon.
Corhart Refractories Corp	Buckhannon, WV	Refractories.
Do	Corning, NY	Do.
Do	Louisville, KY	Do.
Didier-Taylor Refractories Corp	Cincinnati, OH	Do.
Do	South Shore, KY	Do.
E. I. du Pont de Nemours & Co. Inc	Starke, FL and Trail Ridge, FL.	Zircon and foundry mixes.
Elkem Metals Co	Alloy, WV	Alloys.
Harshaw Chemical Co	Elyria, OH	Oxide and other compounds.
Heritage Minerals Inc.	Lakehurst, NJ	Zircon.
Leco Corp., Ceramics Div	St. Joseph, MI	Refractories and milled zircon.
Lincoln Electric Co. Inc	Cleveland, OH	Welding rods.
M & T Chemicals Inc	Andrews, SC	Ultrox and milled zircon.
Magnesium Elektron Inc	Flemington, NJ	Compounds.
Norton Co	Huntsville, AL	Oxide.
Shieldalloy Corp	Newfield, NJ	Welding rods and alloys.
Do[1]	Cambridge, OH	Alloys.
Sola Basic Industries, Engineered Ceramics Div	Gilberts, IL	Ceramics.
Standard Oil Engineered Materials Co	Falconer, NY	Refractories.
TAM Ceramics	Niagara Falls, NY	Milled zircon, oxide, compounds.
Teledyne Wah Chang Albany	Albany, OR	Oxide, sponge, ingot, mill products.
Thiokol Corp., Ventron Chemicals Div	Beverly, MA	Oxide.
Transelco, a division of Ferro Corp	Penn Yan, NY	Do.
Western Zirconium Inc	Ogden, UT	Oxide, sponge, ingot, mill products.
Z-Tech Corp	Bow, NH	Oxide.
Zedmark Inc	Dover, OH	Refractories.
Zicar Products Inc	Florida, NY	Fibrous ceramics.
ZIRCOA Products, Ceramic Products	Solon, OH	Oxide and ceramics.
HAFNIUM MATERIALS		
Teledyne Wah Chang Albany	Albany, OR	Oxide, sponge, ingot, crystal bar.
Western Zirconium Inc	Ogden, UT	Do.

[1]Formerly Foote Mineral Co.

CONSUMPTION AND USES

Of the domestic zircon produced in 1987, 36% was used in proprietary mixtures as foundry sand, and the remainder was used in refractory sand blends with kyanite, sillimanite, and staurolite; in chemicals; in refractories; in weighing agents; in ceramic glazes and enamels; in zircon-titanium dioxide welding rod coatings; for sandblasting abrasive; and for the production of zirconium and hafnium metal.

Baddeleyite, another zirconium mineral, was used primarily in the manufacture of alumina-zirconia abrasives and also for ceramic colors, refractories, and other miscellaneous uses.

Research on calcia-, magnesia-, and yttria-stabilized zirconia continued. These materials were considered to have considerable potential for use in ceramic coatings in jet aircraft engines and in other applications where high-strength and high-temperature oxidation resistance are required. Yttria-stabilized zirconia ceramics were also used in automobiles in oxygen sensors in the exhaust system to supply microprocessor data for adjusting the air-fuel ratio to improve fuel efficiency and reduce pollution emissions.

Most of the hafnium and zirconium metals were consumed by the nuclear power industry. Zirconium metal was used in reactors as fuel cladding and structural components owing to its low thermal neutron cross section and excellent corrosion resistance. Nuclear-grade zirconium was alloyed with chromium, iron, nickel, and tin to further improve its corrosion resistance at high temperatures and high pressures. Zirconium's corrosion resistance was attributed to its ability to form a very thin, dense oxide layer that is impervious to the diffusion of ions.[4] Most of the remainder of the zirconium metal was used by the chemical and textile industry in other corrosive acidic and caustic environments for piping, heat exchangers, tank coils, thermosiphon evaporators, and bayonet heaters.[5] The electronic industry also used small amounts of zirconium metal, including lead lanthanum zirconium titanates, for optical arrays and electro-optic devices. CB 103, a columbium-hafnium alloy, was used in F-15 and F-16 fighter jet aircraft engines.

Table 3.—Estimated consumption[1] of zircon[2] in the United States, by end use

(Metric tons)

End use	1986	1987
Zircon refractories[3]	21,772	20,000
AZS refractories[4]	13,245	11,800
Zirconia[5] and AZ abrasives[6]	14,878	15,000
Alloys[7]	5,443	5,000
Foundry applications	50,802	47,000
Other[8]	37,195	34,000
Total	143,335	132,800

[1]Based on total apparent consumption.
[2]Includes insignificant amounts of baddeleyite.
[3]Dense and pressed zircon brick and shapes.
[4]Fused cast and bonded alumina-zirconia-silica-based refractories.
[5]Excludes oxide produced by zirconium metal producers.
[6]Alumina-zirconia-based abrasives.
[7]Excludes alloys above 90% zirconium.
[8]Includes chemicals, metallurgical-grade zirconium tetrachloride, sandblasting, welding rods, and miscellaneous uses.

Table 4.—Estimated consumption[1] of zirconium oxide[2] in the United States, by end use

(Metric tons)

End use	1986	1987
AZ abrasives	W	W
AZS refractories[3]	635	600
Other refractories	2,812	1,300
Chemicals	1,451	1,200
Glazes, opacifiers, colors	1,180	700
Total	6,078	3,800

W Withheld to avoid disclosing company proprietary data, not included in "Total."
[1]Based on total apparent consumption.
[2]Excludes oxide produced by zirconium metal producers. Includes baddeleyite.
[3]Fused cast and bonded.

Table 5.—Yearend stocks of zirconium and hafnium materials in the United States

(Metric tons)

Item	1986	1987
Zircon concentrate held by dealers and consumers excluding foundries	r22,792	36,251
Milled zircon held by dealers and consumers excluding foundries	r5,282	2,967
Zirconium:[1]		
Oxide[e]	2,002	1,213
Sponge, ingot, scrap, alloys	445	489
Refractories	7,783	4,380
Hafnium: Sponge and crystal bar[e]	27	27

[e]Estimated. [r]Revised.
[1]Excludes material held by zirconium sponge metal producers.

Table 6.—Published prices of Australian zircon

(U.S. dollars per ton)

Date of publication	Standard grade	Intermediate grade	Premium grade
December 1986	114-120	126-138	138-144
December 1987	138-151	157-177	183-203

Source: Industrial Minerals (London). No. 231, Dec. 1986, p. 87; and No. 243, Dec. 1987, p. 103.

Table 7.—Published yearend prices of zirconium and hafnium materials

Specification of material	1986	1987
Zircon:		
Domestic, standard-grade, f.o.b. Starke, FL, bulk, per short ton[1]	$190.00	$202.00
Domestic, 75% minimum quantity zircon and aluminum silicates, Starke, FL, bulk, per short ton[1]	99.00	121.00
Imported sand, containing 65% ZrO_2, f.o.b., bulk, per metric ton[2]	$126.00- 133.00	$163.00- 172.00
Domestic, granular, bags, bulk rail, from works, per short ton[3]	165.00- 177.00	165.00- 177.00
Domestic, milled, 200- and 325-mesh, rail, from works, bags, per short ton[3]	225.00	225.00
Baddeleyite, imported concentrate:[4]		
96% to 98% ZrO_2, minus 100-mesh, c.i.f. Atlantic ports, per pound	.50	.50
99%+ ZrO_2, minus 325-mesh, c.i.f. Atlantic ports, per pound	.97	1.02
Zirconium oxide:[3]		
Powder, commercial-grade, drums, 2,000-pound minimum, per pound	4.25	4.25
Electronic, same basis, per pound	7.25	7.25
Insulating, stabilized, 325° F, same basis, per pound	3.31- 3.82	3.31- 3.82
Insulating, unstabilized, 325° F, same basis, per pound	3.55- 3.75	3.55- 3.75
Dense, stabilized, 30° F, same basis, per pound	2.82	2.82
Zirconium oxychloride: Crystal, cartons, 5-ton lots, from works, per pound[3]	.91- 1.04	.91- 1.04
Zirconium acetate solution:[3]		
25% ZrO_2, drums, carlots, 15-ton minimum, from works, per pound	.97	.97
22% ZrO_2, same basis, per pound	.78	.78
Zirconium hydride: Electronic-grade, powder, drums, 100-pound lots, from works, per pound[3]	[r].31- .75	.31- .75
Zirconium:[5]		
Powder, per pound	75.00- 150.00	60.00- 150.00
Sponge, per pound	12.00- 17.00	12.00- 17.00
Sheets, strip, bars, per pound	20.00- 40.00	16.00- 45.00
Hafnium: Sponge, per pound[5]	80.00- 130.00	75.00- 135.00

[r]Revised.
[1]E. I. du Pont de Nemours & Co. Inc. price lists. Dec. 1986 (effective Jan. 1, 1987); and Dec. 1987 (effective Jan. 1, 1988).
[2]Industrial Minerals (London). No. 231, Dec. 1986, p. 87; and No. 243, Dec. 1987, p. 103.
[3]Chemical Marketing Reporter. V. 230, No. 26, Dec. 31, 1986 (effective Dec. 26, 1986), p. 32; and v. 231, No. 25, Dec. 21, 1987, p. 49.
[4]The Applegate Group Inc., Newark, NJ. Baddeleyite price lists. Jan. 1, 1987, and Jan. 1, 1988.
[5]American Metal Market. V. 94, No. 252, Dec. 31, 1986, p. 15; and v. 95, No. 245, Dec. 18, 1987, p. 6.

Table 8.—U.S. exports of zirconium ore and concentrate, by country

Country	1986		1987	
	Metric tons	Value	Metric tons	Value
Algeria	9	$5,157	--	--
Argentina	768	272,789	242	$125,540
Australia	117	106,567	--	--
Belgium-Luxembourg	127	93,896	340	206,128
Brazil	162	68,000	--	--
Canada	226	66,964	848	339,726
Colombia	725	358,600	1,552	728,565
Ecuador	193	91,911	461	212,720
France	--	--	91	44,080
Germany, Federal Republic of	7,706	1,439,411	4,868	1,542,716
India	--	--	19	7,810
Ireland	44	23,550	18	3,600
Italy	21	14,789	3,303	809,333
Japan	3	3,660	18	11,437
Korea, Republic of	14	8,514	148	75,287
Mexico	4,543	1,372,807	6,048	1,798,707
United Kingdom	190	43,563	732	219,315
Venezuela	864	513,590	1,042	520,051
Other	140	83,276	324	157,276
Total	15,852	4,567,044	20,054	6,802,291

Source: Bureau of the Census.

Table 9.—U.S. exports of zirconium, by class and country

Class and country	1986		1987	
	Metric tons	Value	Metric tons	Value
Zirconium and zirconium alloys, wrought:				
Belgium-Luxembourg	11	$1,272,400	5	$355,807
Canada	148	8,016,468	207	10,896,627
Finland	17	722,611	9	384,285
France	25	1,007,609	70	2,562,785
Germany, Federal Republic of	191	11,851,377	87	6,657,124
Italy	22	3,002,167	(1)	2,332
Japan	330	20,016,720	361	25,074,231
Korea, Republic of	--	--	8	404,706
Spain	24	6,798,024	10	2,011,195
Sweden	63	2,357,298	80	2,681,434
Switzerland	(1)	5,552	--	--
Taiwan	(1)	5,665	16	959,682
United Kingdom	69	3,320,340	104	3,897,200
Other	3	86,757	26	701,785
Total	903	58,462,988	983	56,589,193
Zirconium and zirconium alloys, unwrought and waste and scrap:				
Canada	3	54,668	5	76,441
France	33	359,080	35	365,969
Germany, Federal Republic of	7	87,676	6	226,604
Japan	82	3,324,723	71	3,569,960
Netherlands	7	43,315	20	62,445
Peru	--	--	32	670,250
Sweden	11	267,784	38	935,252
United Kingdom	28	376,689	30	324,967
Other	5	156,672	5	71,140
Total	176	4,670,607	242	6,303,028

[1]Less than 1/2 unit.

Source: Bureau of the Census.

Table 10.—U.S. exports of zirconium oxide, by country

Country	1986		1987	
	Metric tons	Value	Metric tons	Value
Argentina	17	$83,153	15	$79,635
Australia	3	11,397	47	49,519
Belgium-Luxembourg	82	94,920	(1)	3,465
Brazil	7	37,070	8	63,867
Canada	425	556,051	226	649,447
Ecuador	72	36,580	(1)	2,521
France	3	29,330	4	18,205
Germany, Federal Republic of	12	105,103	30	229,152
Hong Kong	4	29,473	1	7,035
Italy	(1)	29,123	21	81,001
Japan	63	224,848	55	265,764
Korea, Republic of	5	17,536	(1)	10,899
Mexico	r45	158,715	105	175,508
Netherlands	14	44,675	5	33,494
Singapore	9	15,960	5	15,208
Sweden	16	64,642	1	24,779
Taiwan	54	152,645	14	85,757
United Kingdom	801	2,247,335	646	2,073,739
Other	15	71,387	19	79,360
Total[2]	1,648	4,009,943	1,206	3,948,355

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

Source: Bureau of the Census.

Table 11.—U.S. imports for consumption of zirconium ores, by country

Country	1985 Quantity (metric tons)	1985 Value (thousands)	1986 Quantity (metric tons)	1986 Value (thousands)	1987 Quantity (metric tons)	1987 Value (thousands)
Argentina	5,261	$520	8,104	$847	--	--
Australia	22,088	2,272	37,255	4,233	50,641	$6,917
Canada[1]	2,093	225	669	81	207	20
Hong Kong	302	28	--	--	--	--
Italy	58	25	120	46	20	13
Netherlands	--	--	28	4	--	--
Philippines	79	407	--	--	--	--
South Africa, Republic of[2]	9,842	1,120	22,588	2,625	16,964	3,266
Other	([3])	2	--	--	85	27
Total	39,723	4,599	68,764	7,836	67,917	10,243

[1]Believed to be country of shipment rather than country of origin.
[2]In addition, very small quantities of baddeleyite were imported.
[3]Less than 1/2 unit.

Source: Bureau of the Census.

Table 12.—U.S. imports for consumption of zirconium and hafnium in 1987, by class and country

Class and country	Metric tons	Value thousands
Zirconium, wrought:		
Canada	11	$905
France	261	12,980
Germany, Federal Republic of	8	85
Other	2	97
Total	282	14,067
Zirconium, unwrought and waste and scrap:		
Canada	9	65
France	9	34
Germany, Federal Republic of	20	215
Japan	9	68
United Kingdom	28	189
Total	75	571
Zirconium alloys, unwrought:		
France	1	38
Germany, Federal Republic of	1	38
U.S.S.R	1	14
United Kingdom	([1])	2
Total	3	92
Zirconium oxide:		
Belgium-Luxembourg	32	34
Canada	97	66
China	1	91
France	96	251
Germany, Federal Republic of	10	182
Japan	108	1,189
South Africa, Republic of	287	545
United Kingdom	643	2,497
Total	1,274	4,855
Zirconium compounds:		
France	172	589
Germany, Federal Republic of	14	352
Japan	40	395
South Africa, Republic of	1,590	3,085
United Kingdom	773	1,518
Other	9	68
Total	[2]2,599	6,007
Hafnium, unwrought and waste and scrap: France	1	180

[1]Less than 1/2 unit.
[2]Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

WORLD REVIEW

Australia.—The Mineral Sands Div. of Renison Goldfields Consolidated Ltd. (RGC) announced that exploration west of its Allied Eneabba Mine, Western Australia, was successful in locating mineral sands resources of 150 million tons grading 3.5% heavy minerals. Further exploration in the area was planned. To optimize mining at its Eneabba properties, RGC will reportedly mine selected areas by dredging instead of its present dry mining method. RGC also completed redesign of its mineral sands processing plant at Eneabba, which allowed increased recovery of all minerals, including zircon.[6]

RGC continued exploration on Moreton Island, Queensland.[7] The Queensland government adopted the recommendation of a report that would allow mining on 1,200 hectares (6.4%) of the island as short-term use.[8]

Mineral Deposits Ltd., a subsidiary of The Broken Hill Pty. Co. Ltd. (BHP), announced the opening of a heavy-mineral sands mining operation at Viney Creek, New South Wales, in mid-1987. Mineral Deposits recovered heavy-mineral sands, including zircon, using twin dredges connected to a floating wet concentrator. Zircon and other heavy-mineral concentrates were produced at Mineral Deposits' nearby Hawks Nest dry concentrator plant.[9]

TiO_2 Corp. completed feasibility studies of its heavy-mineral sands deposit at Cooljarloo, Western Australia, and declared the project viable. The deposit reportedly contains 12 million tons of ore, with a cutoff grade of 2% heavy minerals.[10]

West Coast Holdings Ltd. announced plans to install a pilot plant at its Brockman multimineral deposit in Western Australia. The deposit reportedly contains zirconium, hafnium, rare earths, yttrium, thorium, gallium, tantalum, and columbium (niobium). The Brockman deposit, 15 kilometers southeast of Halls Creek, is a joint venture of West Coast Holdings and Greater Pacific Investments Ltd. If additional feasibility studies prove out, a $115 million plant to process 200,000 tons of ore per year was planned. Estimated plant output of zirconium and hafnium was 1,500 tons and 40 tons per year, respectively.[11]

ICI Australia Operations Pty. Ltd announced plans to build a high-purity zirconia plant at Rockingham, Western Australia. The plant was planned to supply the increasing demands of the advanced ceramic industry, especially for electronic and engineering applications. Planned capacity of the new plant was 450 tons per year of high-purity zirconia and 250 tons per year of zirconium chemicals. Construction was planned to commence in May 1987 and be completed in mid-1988. A variety of products, including stabilized and partially stabilized zirconia, was scheduled for production. Products from the plant will be marketed worldwide by Z-Tech Pty. Ltd.[12]

Brazil.—Production of zircon concentrates in 1985 was 9,462 tons from the State of Amazonas, 435 tons from the State of Espírito Santo, 354 tons from the State of Minas Gerais, 53 tons from the State of Paraná, and 10,735 tons from the State of Rio de Janerio.[13]

Deposits containing zirconium were discovered in the vicinity of the Pitinga tin mine in the State of Amazonas, tripling Brazil's zirconium reserves.[14] Measured reserves of zircon ore were 60.4 million tons with a zirconium content of 1.1 million tons. Zircon reserves were in the States of Amazonas, Bahia, Espírito Santo, Minas Gerais, Paraíba, Paraná, Rio de Janeiro, and São Paulo.[15]

Madagascar.—QIT-Fer et Titane Inc. (QIT) of Canada announced it had completed initial feasibility studies of a heavy-mineral sands deposit in southeast Madagascar. The joint venture project was 51% owned by the Government of Madagascar and 49% by QIT. The drilling program reportedly confirmed the existence of an ore body containing mineral sands, including zircon. Ilmenite will reportedly be mined as the principal product with monazite, rutile, and zircon recovered as byproducts. Further drilling and the construction of a pilot plant at the site were planned.[16]

Table 13.—Zirconium concentrate: World production, by country[1]

(Metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
Australia	[r]382,005	[r]457,599	501,440	451,824	439,000
Brazil	7,431	[r]6,375	21,039	13,351	15,000
China[e]	15,000	15,000	15,000	15,000	15,000
India[2]	11,395	[e]12,000	14,800	[e]16,000	16,000
Malaysia (exports)	2,548	[r]7,993	11,652	12,633	12,000
South Africa, Republic of	162,281	153,123	160,533	[e]160,000	160,000
Sri Lanka	5,721	3,708	4,061	[e]4,000	3,500
Thailand	199	290	1,292	1,705	1,500
U.S.S.R.[e]	80,000	80,000	85,000	85,000	85,000
United States	W	W	W	W	W
Total	[r]666,580	[r]736,088	814,817	759,513	747,000

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."
[1]Includes data available through May 20, 1988.
[2]Data are for fiscal year beginning Apr. 1 of that stated.

TECHNOLOGY

A new magnesium alloy containing zirconium, yttrium, and other rare earths was developed by researchers at Magnesium Elektron Ltd. in the United Kingdom. Designated WE54, the new alloy had high-temperature stability up to 300° C, reportedly higher than any magnesium alloy now available. The alloy contained 0.5% zirconium, 5.5% yttrium, and 3.5% other rare earths.[17]

Zirconium tetrafluoride was studied as a possible optical fiber to transmit infrared laserbeams for medical applications. The zirconium fluoride fiber transmits light energy in the 1- to 4-micrometer range, with good transmission at 2.94 micrometers, the lasing wavelength of a Q-switched erbium: yttrium-aluminum garnet (Er:YAG) laser. Research to strengthen the fiber was said to be needed because in its present form, although bendable, it is still brittle and crushable.[18]

Aerojet TechSystems, an aerospace company, developed concepts for a space-based interceptor (SBI) using hafnium in its design. SBI's would be used to intercept and impact intercontinental ballistic missiles during the boost phase. Carbon-carbon composite, infiltrated with hafnium carbide, was proposed for use in the SBI's engine to withstand the high combustion temperatures of oxygendifluoride-diborane propellant. An experimental engine using the hafnium carbide material was tested using chloropentafluoride-hydrazine propellant, which reportedly could be used in the SBI's second-stage booster.[19]

Researchers at Fansteel Inc. reportedly produced several experimental parts for engines of the Advanced Tactical Fighter (ATF), including one using columbium alloyed with zirconium, titanium, and tungsten (CB 782). Although CB 782 had been in existence for years, the alloy was not currently used in aircraft engines. As a result of higher operating temperatures, the columbium alloy presently used in the F-15 and F-16, CB 103, was reportedly not being considered as seriously as other columbium-based alloys for the ATF engines.[20]

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[1]Zirconium and hafnium are nearly identical in chemical properties and atomic volume and are associated in the principal ore mineral zircon, in a ratio of about 50 to 1. The two elements are separated for nuclear power applications but not for other uses.
[2]Physical scientist, Branch of Nonferrous Metals.
[3]Montgomery, M. Siting Council Stays Out of Wah Chang. Salem (Oregon) Statesman J. Feb. 28, 1987.
[4]Kane, R., and W. Boyd. Use of Titanium and Zirconium in Chemical Environments. Ch. in Industrial Applications of Titanium and Zirconium, ASTM STP 728, ASTM, 1981, pp. 3-8.
[5]Bowen, L. Use of Zirconium Heat Exchangers in Viscase Rayon Process. Ch. in Industrial Applications of Titanium and Zirconium, ASTM STP 728, ASTM, 1981, pp. 119-125.
[6]Renison Goldfields Consolidated Ltd. Annual Report 1987. 44 pp.
[7]Work cited in footnote 5.
[8]Industrial Minerals (London). More on Moreton Island Minsands. No. 237, June 1987, p. 8.
[9]———. Mineral Deposits Up and Running. No. 237, June 1987, p. 8.
[10]———. TiO_2 Corp. Declares Cooljarloo Minsands Viable. No. 237, June 1987, p. 8.
[11]Australian Mining. Rare Earth Plant Under Study for Western Australia. Sept. 1987, p. 47.
[12]Industrial Minerals (London). ICI Plans High Purity Zirconia Plant. No. 232, Feb. 1987, p. 8.
[13]Anuario Mineral Brasileiro 1986. Zirconio, pp. 356-358.
[14]Mining Journal (London). Brazilian Zirconium/Uranium. V. 308, No. 7918, May 22, 1987.
[15]Work cited in footnote 8.
[16]Industrial Minerals (London). QIT Expanding Heavy Minerals Project. No. 236, May 1987, p. 15.
[17]Gschneidner, K. (ed.). Rare-Earth Information Center News. Elektron WE54, v. 22, No. 2, p. 4.
[18]Lasers & Applications. Medical-Updating Fiber Delivery Systems. Apr. 1987, p. 40.
[19]Aviation Week & Space Technology. Firm Develops Concepts for Interceptor Propulsion. V. 127, No. 15, Oct. 12, 1987, pp. 30-31.
[20]American Metal Market. Fighter Test Set for Fansteel Columbium Alloy Parts. V. 95, No. 107, June 4, 1987. p. 5.

Other Industrial Minerals

By Staff, Branch of Industrial Minerals

CONTENTS

INTRODUCTION

Effective in the 1987 Minerals Yearbook, the following changes have been made: "Asphalt" has been deleted; "Greensand" is included in the "Potash" chapter; "Meerschaum" is included in the "Clays" chapter; and "Staurolite" is included in the "Abrasive Materials" chapter.

QUARTZ CRYSTAL[1]

Cultured quartz crystal production increased significantly in 1987, following 2 years of reduced production. Consumption of domestic lascas as feedstock for cultured quartz crystal increased. Imports of lascas from Brazil also increased. Although no lascas was mined in the United States during the year, the domestic producer supplied material to consumers from company stockpiles. Specimen-quality natural quartz was very much in demand; quartz crystal for this application is discussed in the Gem Stone chapter.

Domestic Data Coverage.—Domestic production and consumption data for quartz crystal are developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the seven companies canvassed for production of cultured quartz crystal, all responded, and the six active operations represented 100% of total production shown in table 1. Of the 36 operations that were canvassed concerning consumption of quartz crystal, 33 responded and 28 were active in 1987, representing approximately 95% of total consumption, also shown in table 1. Consumption for the remaining respondents was estimated using reported prior-year consumption levels.

Table 1.—Salient U.S. electronic- and optical-grade quartz crystal statistics

(Thousand pounds and thousand dollars)

	1983	1984	1985	1986	1987
Production:					
Mine[e] [1]	600	2,500	1,000	1,200	--
Cultured	426	1,027	568	524	840
Exports:					
Natural:[2]					
Quantity	28	42	60	74	139
Value	$156	$234	$290	$411	$708
Cultured:[2]					
Quantity	80	277	185	324	448
Value	$3,258	$11,021	$3,723	$5,686	$6,954
Lascas:					
Quantity	[3]339	[e]1,600	[e]800	--	--
Imports of Brazilian lascas:[4]					
Quantity	153	569	173	52	146
Value	$121	$373	$99	$51	$157
Consumption:					
Natural (electronic- and optical-grade)	13	7	7	2	([5])
Cultured (lumbered)	112	77	44	43	55
Cultured (as grown)	312	391	224	428	552
Total	437	475	275	473	607

[e]Estimated.
[1]Excludes lascas produced for specimen and jewelry material uses.
[2]Bureau of the Census.
[3]Journal of Commerce Port Import/Export Reporting Service.
[4]Bureau of the Census as adjusted by the Bureau of Mines.
[5]Less than 1/2 unit.

Legislation and Government Programs.—The National Defense Stockpile contained 1.8 million pounds of natural quartz crystal, valued at $11 million, throughout the year. This quantity represented an excess of 1.2 million pounds above the goal set for the stockpile although no authority existed for disposal of this excess.

DOMESTIC PRODUCTION

Coleman Quartz Inc., the only domestic company known to produce lascas, supplied consumers with the feed material for cultured quartz crystal from company stocks.

Production of cultured quartz crystal increased 60% in 1987, the first increase since 1984. Six companies were active producers of cultured quartz crystal. The two largest producers, Sawyer Research Products Inc. of Eastlake, OH, and Thermo Dynamics Corp. of Merriam, KS, were independent growers that produced crystal bars for domestic and foreign consumers in the crystal device fabrication industry. Motorola Inc. of Chicago, IL, and Electro Dynamics Corp. of Overland Park, KS, produced quartz crystal for internal consumption and the domestic device fabrication industry. P. R. Hoffman Material Processing Co. of Carlisle, PA, also reported outside sales. Bliley Electric Co. of Erie, PA, produced only for internal consumption.

CONSUMPTION AND USES

Consumption of lascas by the six domestic quartz crystal producers increased from 610,000 pounds to 1.1 million pounds in 1987. The 28 active companies in 12 States consumed 28% more quartz crystal in 1987 than was consumed in 1986. Of these companies, 25 consumed only cultured quartz crystal and 3 consumed both natural and cultured crystal. No companies exclusively consumed natural quartz crystal.

Imported natural quartz crystal continued to be required as seed material for growing cultured quartz. Cultured quartz crystal was the primary material used as resonators in electronic applications. Applications included timing signals for watches and clocks; microprocessors in industrial, automotive, and consumer products; and military-aerospace and commercial bandpass filters and oscillators that require very high selectivity and stability.

STOCKS

Crystal growers stocks of as-grown cultured quartz crystal were reported as 154,000 pounds at the beginning of 1987. At yearend, these stocks had increased to 180,000 pounds.

PRICES

The average price for domestic lascas reported by consumers was $0.45 per pound. The customs value of Brazilian lascas decreased slightly to $0.95 per pound. The average value of as-grown cultured quartz, based on reported sales of about 509,000 pounds, was $12.71 per pound, a decrease of 6% compared with that of 1986. Sales volume increased 23%. The average value of lumbered quartz, as-grown quartz that has been processed by sawing and grinding, decreased 8% to $58.29 per pound, based on reported sales of 119,000 pounds. Sales volume increased 61%.

FOREIGN TRADE

Cultured quartz crystal exports, as reported by the Bureau of the Census, increased 38% in 1987 to 447,904 pounds. The average f.a.s. value was $15.52 per pound, a 12% decrease compared with exports in 1986. Most of these exports, 239,334 pounds, went to Japan. The Republic of Korea received 158,580 pounds of cultured quartz crystal from U.S. producers.

Imports of Brazilian lascas, designated as "Crude Brazilian Pebble," increased 181% to 146,381 pounds with a customs value of $138,604.

STRONTIUM[2]

Demand for strontium minerals and compounds increased as U.S. television manufacturers expanded domestic production. Imports of celestite, a strontium ore consisting of at least 90% strontium sulfate, increased, indicating expanded domestic production of strontium compounds. Imports of most strontium compounds also grew. Chemical Products Corp. (CPC) of Cartersville, GA, was the only U.S. producer of strontium compounds from the ore celestite. CPC produced compounds from imported material because there were no active celestite mines in the United States.

Domestic production data for strontium are developed by the Bureau of Mines from a voluntary survey of U.S. operations. The one operation to which the survey request was sent responded, representing 100% of total production. However, production and stock data were withheld from publication to avoid disclosing company proprietary data.

The strontium survey is also used to calculate the distribution of strontium compounds by end use. Of the 12 operations to which a survey request was sent, 10 responded, 1 did not respond, and 1 was no longer active. The information collected from this survey represents nearly 100% of the end-use data shown in table 2. Consumption for the nonrespondent was estimated using reported prior-year consumption levels.

DOMESTIC PRODUCTION

CPC was the only producer of strontium carbonate from imported celestite. CPC was also the only major domestic strontium nitrate producer. Mallinkrodt Inc. of St. Louis, MO, produced strontium chloride and Mineral Pigments Corp. of Beltsville, MD, produced strontium chromate. A few other companies produced downstream strontium compounds, but on a very small scale.

CONSUMPTION AND USES

The largest end use for strontium was in the manufacture of faceplate glass for color television picture tubes. Strontium, which is supplied as strontium carbonate and converted to strontium oxide during the manufacturing process, blocks X-ray emissions from the picture tube during operation of the television set. A number of domestic television manufacturers announced a return to domestic production because unfavorable currency exchange rates with Japan have caused the price of imported sets to increase significantly. Additional domestic production of televisions increased demand for strontium carbonate.

Another end use for strontium expected to continue to grow is strontium ferrites, formed by heating a mixture of strontium carbonate and iron oxide. The resulting material is formed into permanent ceramic magnets, which are used in fractional horsepower motors for automobile accessories, loudspeakers, computers, and other electronic equipment.

Use of strontium nitrate in pyrotechnics and signals, the second largest market for strontium, was considered to be a mature market. Strontium nitrate is used in this application because of the brilliant red flame created when it burns.

Smaller amounts of strontium compounds are used in a variety of applications. Strontium carbonate was used to remove lead from electrolytically refined zinc. Strontium chromate was used as a corrosion inhibitor in pigments and paint, strontium phosphate was used in fluorescent lights, and strontium chloride was an active ingredient in toothpaste for sensitive teeth.

Demand for strontium metal, used to improve castability of aluminum, continued to increase owing to the demand for aluminum castings in the automobile industry. Strontium oxide was one of the materials used in high-temperature superconductor research.

Table 2.—U.S. estimated distribution of primary strontium compounds, by end use

(Percent)

End use	1985	1986	1987
Electrolytic production of zinc	6	6	5
Ferrite ceramic magnets	12	r11	11
Pigments and fillers	8	7	5
Pyrotechnics and signals	15	r12	13
Television picture tubes	52	r60	63
Other	7	r4	3
Total	100	100	100

rRevised.

PRICES

The average customs value for celestite imported from Mexico was about $86 per short ton. A small quantity of ore was imported from China at about $114 per ton. The weighted average value for all imported strontium minerals was about $86 per ton. This value represented a decrease of almost 16% from customs value reported in 1986. Values of imported strontium compounds varied according to the type of compound.

FOREIGN TRADE

The Federal Republic of Germany remained the most important source of imported strontium compounds, with Mexico the second most important source. Imports of strontium carbonate, precipitated and not precipitated, increased 21%. Imports of strontium nitrate decreased about 49%. Canada was once again the major supplier of strontium metal, with imports increasing 62%.

Late in the year, the U.S. Department of Commerce completed reviewing an allegation of dumping of Italian strontium nitrate from June 1, 1985, through May 31, 1986. The review found no evidence of dumping, and so the antidumping duty on strontium nitrate from Italy was revoked.[3]

According to the Port Import/Export Reporting Service of the Journal of Commerce, U.S. exports of strontium compounds were about 3,500 tons, an increase of 133% over the exports reported from the same source in 1986. Of these exports, 97% of the total was strontium carbonate that went to Japan, the world's leading consumer of strontium compounds. Other strontium compounds exported were the chromate, ferrite, nitrate, oxalate, and phosphate, all in relatively small quantities.

Table 3.—U.S. imports for consumption of strontium minerals,[1] by country

Country	1986 Quantity (short tons)	1986 Value[2] (thousands)	1987 Quantity (short tons)	1987 Value[2] (thousands)
China	348	$64	297	$34
Mexico	30,904	2,991	42,172	3,636
Spain	1,983	342	--	--
Total[3]	33,236	3,396	42,469	3,670

[1]Celestite (strontium sulfate).
[2]Customs value.
[3]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

Table 4.—U.S. imports for consumption of strontium compounds and metal, by country

Country	1986 Pounds	1986 Value[1]	1987 Pounds	1987 Value[1]
Strontium carbonate, not precipitated:				
Germany, Federal Republic of	39,682	$11,663	--	--
Mexico	--	--	44,092	$10,948
Spain	--	--	34,172	1,875
Total	39,682	11,663	78,264	12,823
Strontium carbonate, precipitated:				
Germany, Federal Republic of	8,208,672	2,247,425	10,120,618	2,771,119
Japan	--	--	11,670	7,822
Mexico	3,739,467	931,557	4,263,566	1,139,916
United Kingdom	27	2,536	41,798	24,693
Total	11,948,166	3,181,518	14,437,652	3,943,550

See footnote at end of table.

Table 4.—U.S. imports for consumption of strontium compounds and metal, by country —Continued

Country	1986 Pounds	1986 Value[1]	1987 Pounds	1987 Value[1]
Strontium chromate:[2]				
Belgium	101,853	266,510	21,826	23,760
Canada	--	--	29,765	41,509
France	41,005	49,275	160,932	186,625
Germany, Federal Republic of	59,524	53,017	39,684	44,843
Spain	46,297	53,592	--	--
United Kingdom	453	2,432	10,400	10,776
Total	249,132	424,826	262,607	307,513
Strontium nitrate:				
Germany, Federal Republic of	1,320	6,389	1,357	8,220
Italy	975,865	398,385	1,183,671	455,589
Mexico	--	--	2,205	2,000
Spain	2,103,227	816,793	481,708	206,218
Switzerland	88,184	41,762	--	--
United Kingdom	79,971	35,841	--	--
Total	3,248,567	1,299,170	1,668,941	672,027
Strontium compounds, other:				
Canada	--	--	3,489	31,956
Germany, Federal Republic of	46,295	32,433	6,614	8,129
Japan	247,486	180,311	546,742	1,206,432
Netherlands	66	1,237	148,546	150,299
United Kingdom	6,324	14,857	31,838	53,800
Total	300,171	228,838	737,229	1,450,616
Strontium salts, potassium oxalate and other:				
China	--	--	37,478	1,253
Germany, Federal Republic of	115,985	21,986	6,614	7,891
Total	115,985	21,986	44,092	9,144
Strontium sulfate, other than celestite:				
Belgium	407,407	43,698	--	--
Denmark	--	1	1	4,000
France	110	1,439	--	--
Germany, Federal Republic of	630,302	189,948	2,696,297	157,939
Total	1,037,819	235,085	2,696,298	161,939
Strontium metal, unwrought:				
Canada	50,928	467,759	82,724	747,805
United Kingdom	--	--	11	1,131
Total	50,928	467,759	82,735	748,936

[1]Customs value.
[2]Imported as strontium chromate pigment (TSUS 473.19).

Source: Bureau of the Census.

WORLD REVIEW

Australia.—Status Minerals NL discovered a celestite deposit in the desert region of the South Australian Great Artesian Basin. Areas of ore grading 90% to 96.6% were identified, and more complete evaluation of the deposit was being conducted. Mineral concentrate and chemical production studies were planned following the completion of the evaluation.[4]

Canada.—Timminco Ltd., with headquarters in Toronto, Ontario, began production of strontium metal at its new facilities at Westmeath, Ontario. The new facilities are operated by the Timminco Metals Div., (formerly known as the Chromasco Div. of Timminco Ltd.), the world's largest producer of strontium metal. The company was also upgrading its operations for secondary processing of strontium at the Westmeath site.[5]

Korea, Republic of.—Two separate plants were announced for the production of barium and strontium carbonates to supply the growing demand for these chemicals by the television-manufacturing industry in the Far East. Kofran Chemical Co. was formed by Rhône-Poulenc S.A. of France and Oriental Chemical Industry Ltd. of Korea to build a 22,000-ton-per-year facility at Inchon.[6] Kali-Chemie AG of the Federal Republic of Germany, the world's largest producer of barium and strontium carbonates joined with Samsung Corning Co. of Korea to create Daehan Specialty Chemicals Co. Ltd. This company was formed to build a plant for barium and strontium carbonates with an annual capacity of 33,000 to 44,000 tons at an undisclosed location on the northwestern coast.[7]

Table 5.—Strontium minerals: World production, by country[1]

(Short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Algeria[e]	6,000	6,000	6,000	6,000	6,000
Argentina	742	[r]441	1,084	1,249	1,100
Cyprus	--	--	1,543	8,119	8,000
Iran[3]	[r]24,251	[r]23,149	27,558	24,251	24,250
Italy	456	2,866	5,083	5,144	[4]195
Mexico (celestite)	41,343	35,264	33,601	26,774	[4]68,597
Pakistan	149	622	791	1,099	1,100
Spain	38,000	29,760	46,848	38,030	38,000
Turkey[e]	[4]42,808	38,600	38,600	38,600	38,600
United Kingdom	13,340	17,750	25,353	15,543	16,500
Total	[r]167,089	[r]154,452	186,461	164,809	202,342

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

[1]Table includes data available through June 10, 1988.

[2]In addition to the countries listed, China, Poland, and the U.S.S.R. produce strontium minerals, but output is not reported quantitatively, and available information is inadequate to make reliable estimates of output levels.

[3]Data are for year beginning Mar. 21 of that stated.

[4]Reported figure.

Mexico.—Cía. Minera La Valenciana S.A. made its first shipment of strontium carbonate from its new plant at Torreon in the Coahuila State. The production equipment was purchased from FMC Corp. when that company closed its strontium carbonate facilities in Modesto, CA, in 1984. Cía. Minera La Valenciana produced strontium carbonate from celestite from its San Augustine Mine. This mine also provides celestite for CPC. The Mexican carbonate is targeted for the expanding market in the Far East, and the celestite exports will continue to supply U.S. demand.[8]

Pakistan.—Tawakkal Mineral Exports Corp. expanded production of celestite, containing 94% strontium sulfate, from 11 tons per day to 55 tons per day by 1989. The company was also conducting a study to evaluate the potential for producing strontium chemicals.[9]

WOLLASTONITE[10]

Wollastonite is natural calcium silicate and has a theoretical composition of $CaO \bullet SiO_2$.

The tonnage of wollastonite sold or used by U.S. producers in 1987 increased slightly. Specific data were withheld to avoid disclosing company proprietary data. The three producers, in descending order of output, were NYCO, a division of Processed Minerals Inc., Essex County, NY; R. T. Vanderbilt Co. Inc., Lewis County, NY; and Pfizer Inc., San Bernardino County, CA. NYCO announced plans for the construction of a new plant for the production of chemically modified minerals, including wollastonite. Completion of the new facility was scheduled for 1988.[11]

Some of the uses of wollastonite are as a filler in ceramic tile, marine wallboard, paint, plastics, and refractory liners in steel mills, and as a partial replacement for short-fibered asbestos in certain applications such as brake linings.

Technical improvements in filler properties in plastics and rubber have been made in recent years with better compatibility between the polymer and the filler. This is achieved by chemical surface treatment of the mineral fillers. Wollastonite, when treated in such a manner, results in improved flexural modulus in polypropylene and improved reinforcement in nylon.[12]

Chemical Marketing Reporter, at yearend 1987, quoted prices for wollastonite, truckloads, f.o.b. plant, as $200 per ton for general grade, $140 per ton for 325 mesh, $160 per ton for 400 mesh, and $500 per ton for 1,250 mesh.

Plantinova Resources Ltd. and its joint-venture partner Cominco Ltd. carried out test work on their wollastonite deposit near Tweed, Ontario, Canada. The next stage of development, scheduled to be completed in March 1988, includes detailed core drilling to obtain cylindrical core samples of the deposit, a pilot-plant-scale flotation run, and economic evaluation. Future markets could include Europe and Japan.[13]

Samples from a deposit in the Republic of South Africa containing approximately 69% wollastonite, with quartz, calcite, and iron-bearing minerals as the main impurities, were investigated for possible beneficiation. Iron content of the ore was reduced by magnetic separation from 1.5% to less than 0.3% after grinding to smaller than 70 mesh. Flotation of the wollastonite was less successful, with high grades of wollastonite being achieved at the expense of recovery.[14]

In the United Kingdom, Blue Circle Industrial Ltd. produced surface modified grades of wollastonite treated with aminosilane and methacryloxy-silanes. The product is an effective reinforcing filler in polyamide compounds, polyurethane, phenolics, melamine, polyvinyl chloride, and other plastics. Tests carried out by the company showed that treated wollastonite, when compared with other fillers, gave increased stiffness and strength, improved heat distortion temperature, and low coefficient of expansion.[15]

Competition in the tile market and increasing production costs have resulted in the introduction of highly automated production processes with a one-fire, fast-fire cycle. To meet the requirements of the production process, improved material compositions were investigated. A wall tile body containing, by weight, 65% coarse wollastonite, 30% kaolin, and 5% minus 400-mesh nepheline syenite showed good flexural strength, low shrinkage, good resistance to moisture expansion, and water absorption in the desired range.[16]

ZEOLITES[17]

Six companies mined or sold chabazite and clinoptilolite from deposits in six States. Natural zeolites were used for aquaculture, catalysts, cat litter, odor control, and removing radioactive ions from nuclear plant effluent.

Steelhead Resources Ltd. purchased Tenneco Specialty Minerals, a subsidiary of Tenneco Minerals Co. Tenneco owned natural zeolite deposits in California, Nevada, and Oregon.[18] Steelhead Resources will continue to mine the Barstow, California, deposit and will operate as Steelhead Specialty Minerals.

A new company, ZChem Inc., was formed to supply natural zeolite products to the paper industry. The company was established following successful testing of bleached and unbleached clinoptilolite by several paper companies. ZChem is wholly owned by Teague Mineral Products Inc. and has deposits with substantial reserves of white, high-purity clinoptilolite.[19]

Lawrence Livermore National Laboratory began testing clinoptilolite as a soil additive on Bikini Atoll in the South Pacific. The study will determine if cesium uptake by food crops can be reduced by adding natural zeolites to the soil.[20] The soil was contaminated with cesium during nuclear testing during the 1940's and 1950's.

The University of Mississippi received a grant to investigate the use of natural zeolites for removing ammonia and other contaminants from catfish ponds. Natural zeolites already are used in fish hatcheries for removing ammonia from the water. The application of this technology to catfish farming may increase the yield of catfish per acre of pond.[21]

The ion-exchange capacities of clinoptilolite, ferrierite, and mordenite for lead were investigated. Clinoptilolite had a higher maximum exchange capacity for lead than did ferrierite and mordenite. Ammonium-treated clinoptilolite exchanged more lead than sodium-treated clinoptilolite. The reversibility of the exchange reactions also were investigated. The exchange reactions were reversible for mordenite and ammonium-treated ferrierite but not for clinoptilolite and sodium-treated ferrierite. The maximum exchange capacity and the reversibility of the exchange reaction determine the usefulness of a natural zeolite for removing lead from effluents.[22]

The crystal structure of a large-pore zeolite, recently developed by Exxon Corp., was proposed. The zeolite consists of alternating layers of mordenite and mazzite structures. Researchers believe that by changing the sequence of the mordenite and mazzite structures, a family of synthetic zeolites can be developed.[23] The large pore size of the new synthetic zeolite could permit large organic molecules to enter the zeolite structure and undergo catalysis. Currently employed synthetic zeolites have small pore sizes that prevent large molecules from entering the structure. The ability to change the stacking sequence of the mazzite and mordenite structures may allow researchers to synthesize zeolites with slightly different catalytic properties.

A large-pore molecular sieve, based on an aluminum phosphate structure, was developed by Virginia Polytechnic Institute and State University in cooperation with Dow Chemical USA. Unlike current zeolite sieves, which have pore sizes less than 7 angstroms in diameter, the aluminum phosphate sieve has pore sizes up to 14 angstroms in diameter. The molecular sieve could improve the efficiency of the catalysis process because large organic molecules could enter the zeolite structure through the large pore openings to undergo catalysis.[24]

The oxide forms of aluminum, calcium, potassium, silicon, and sodium are the common starting materials for synthesizing zeolites. The potential use of low-cost perlite, pumice, and volcanic tuff as a starting material was evaluated. Under identical conditions, zeolites were more readily synthesized from pumice than from perlite or volcanic tuff. In a pilot plant operation, zeolites such as hydrosodalite, faujasite, and phillipsite, were synthesized. Iron present in the perlite and pumice was incorporated into the synthetic zeolites. The iron-bearing zeolites could be used only where iron did not interfere with their commercial applications. Higher value zeolites such as zeolite A, X, and Y could be synthesized from the residual pilot plant solutions, which contained no iron.[25]

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Other Metals

By Staff, Branches of Nonferrous and Ferrous Metals

CONTENTS

ARSENIC[1]

ASARCO Incorporated, the only domestic arsenic producer, terminated copper-smelting operations and the associated recovery of byproduct arsenic trioxide at Tacoma, WA, in 1985. It still shipped small quantities of trioxide from its remaining stocks in 1987. Imports for consumption of arsenic trioxide were slightly higher than in 1986.

Domestic Data Coverage.—Shipments of small amounts of arsenic trioxide from remaining stocks by Asarco were reported voluntarily to the Bureau of Mines.

Legislation and Government Programs.—The Environmental Protection Agency (EPA) issued its preliminary position to cancel most of the nonwood pesticide uses for inorganic arsenicals. Included in the list were lead arsenate, calcium arsenate, sodium arsenite, sodium arsenate, and arsenic trioxide. Exceptions to the list were turf herbicidal use of the flowable formulation of calcium arsenate, the grapefruit growth regulator use of lead arsenate, and the grape fungicidal use of sodium arsenite. These three uses and the desiccant use of arsenic acid were still under special review by EPA. All copper acetoarsenite and arsenic acid herbicide registrations had already been voluntarily canceled. The EPA invited comments on the proposal.[2]

Life Systems Inc., under contract for the U.S. Public Health Service, published a toxicological profile for arsenic, which was made available for public comment. Toxicological data and the regulatory status of arsenic were discussed.[3]

DOMESTIC PRODUCTION

Asarco shipped small quantities of arsenic trioxide to customers from the remaining stocks at its closed copper smelter in Tacoma, WA. Koppers Co. Inc. in Conley, GA, a major producer of arsenical wood preservatives, produced arsenic trioxide, which it converted to arsenic acid. The acid was marketed or consumed internally in the production of chromated copper arsenate wood preservatives. The Applied Research Group, Charlotte, NC, and Hickory Grove Industries, Hickory Grove, SC, both owned by Hickson Inc., United Kingdom, produced arsenic acid for use in the wood industry. In addition, Mineral Research Development Corp., Harrisburg, NC, and Chemical Specialties Inc., Valdosta, GA, both owned by LaPorte Industries PLC, United Kingdom, also produced arsenic acid for use in the wood industry. W. R. Metals Inc. in Wheat Ridge, CO, produced arsenic acid in Wyoming from arsenic-bearing lead smelter flue dusts containing about 50% arsenic.

CONSUMPTION AND USES

Arsenic compounds, principally arsenic trioxide, accounted for 98% of the arsenic consumed in 1987. Demand for arsenic was about the same level in 1987 as it was in 1986. The wood industry continued to be the dominant industry using trioxide. The estimated end-use distribution of arsenic (metal content) was 69% in wood preservatives, 23% in agricultural products (principally herbicides and desiccants), 4% in glass, 2% in metallic form in nonferrous alloys and electronics, and 2% in other uses (animal feed additives, pharmaceuticals, etc.).

The bulk of metallic arsenic was used in lead- and copper-base alloys as a minor additive (about 0.01% to 0.5%) to increase strength in the posts and grids of lead-acid storage batteries and to improve corrosion resistance and tensile strength in copper alloys. A relatively small amount of high-purity arsenic metal, about 15 metric tons, was used in the electronics industry. Gallium arsenide and its alloys have been used in products such as light-emitting diodes and displays, room-temperature lasers, microwave devices, solar cells, and photoemissive surfaces. Gallium arsenide integrated circuits are currently undergoing commercial development, and, compared with silicon circuits, have higher operating frequencies, lower power consumption, lower noise, and superior resistance to radiation damage. Because of these superior properties, they are expected to have extensive military and commercial applications.

PRICES

Prices for imported refined arsenic trioxide from Mexico remained constant throughout the year at $0.44 per pound. This was the only price quoted by Metals Week.

Table 1.—Arsenic price quotations

(Cents per pound, yearend)

	1985	1986	1987
Trioxide, domestic, 95% As_2O_3, f.o.b. Tacoma, WA[1]	33	33	([2])
Trioxide, Mexican, 99.13% As_2O_3, f.o.b. Laredo, TX[3]	42	44	44
Metal, domestic, 99% As[1]	210	185	([2])

[1]Producers' quote.
[2]Price suspended.
[3]Metals Week.

Table 2.—U.S. imports for consumption of arsenicals, by class and country

Class and country	1985 Quantity (metric tons)	1985 Value (thousands)	1986 Quantity (metric tons)	1986 Value (thousands)	1987 Quantity (metric tons)	1987 Value (thousands)
Arsenic trioxide:						
Australia	30	$3	--	--	--	--
Belgium-Luxembourg	1,498	1,074	1,255	$967	1,643	$1,325
Bolivia	98	67	--	--	16	10
Canada	3,669	4,059	1,924	310	2,012	703
Chile	191	101	1,659	727	4,800	1,935
China	105	46	39	25	233	136
France	3,608	2,264	6,274	4,072	5,341	3,180
Germany, Federal Republic of	--	--	200	169	--	--
Hong Kong	--	--	--	--	36	18
Iran	--	--	--	--	241	87
Japan	371	184	141	74	48	33
Korea, Republic of	--	--	--	--	102	70
Mexico	3,399	2,946	4,408	3,471	4,457	3,550
Namibia	--	--	354	224	93	60
Netherlands	236	149	--	--	--	--
Philippines	23	10	936	335	1,280	436
Portugal	18	12	36	24	--	--
Saudi Arabia	--	--	96	53	--	--
South Africa, Republic of	113	72	1,210	475	1,380	848
Sweden	2,996	3,014	7,069	5,341	4,824	4,140
Switzerland	--	--	--	--	307	248
United Kingdom	116	58	128	80	30	22
Total[1]	16,472	14,059	25,728	16,347	26,843	16,800

See footnotes at end of table.

Table 2.—U.S. imports for consumption of arsenicals, by class and country —Continued

Class and country	1985 Quantity (metric tons)	1985 Value (thousands)	1986 Quantity (metric tons)	1986 Value (thousands)	1987 Quantity (metric tons)	1987 Value (thousands)
Arsenic acid:						
Australia	--	--	--	--	16	$28
Germany, Federal Republic of	--	--	(2)	$1	--	--
United Kingdom	1,993	$1,360	1,381	999	1,038	824
Total	1,993	1,360	1,381	1,000	1,054	852
Arsenic sulfide:						
Germany, Federal Republic of	--	--	--	--	15	10
Philippines	2	2	--	--	--	--
Sweden	--	--	16	2	--	--
United Kingdom	--	--	(2)	12	--	--
Total	2	2	16	14	15	10
Arsenic metal:						
Belgium-Luxembourg	--	--	--	--	2	18
Canada	23	644	8	731	16	1,054
China	136	311	295	951	463	972
Dominica	--	--	--	--	(2)	1
Germany, Federal Republic of	2	195	7	272	2	174
Hong Kong	47	158	34	115	139	291
Japan	22	171	2	382	9	951
Netherlands	--	--	(2)	4	--	--
Sweden	171	642	34	124	(2)	1
Switzerland	--	--	10	53	--	--
Taiwan	5	17	--	--	--	--
United Kingdom	(2)	12	5	17	(2)	8
Total[1]	407	2,150	395	2,649	631	3,471
Lead arsenate:						
Canada	29	13				
Germany, Federal Republic of	--	--	6	56	--	--
Japan	(2)	1	--	--	--	--
Netherlands	66	128	--	--	--	--
Peru	68	144	--	--	--	--
United Kingdom	--	--	60	114	50	95
Total[1]	162	287	66	170	50	95
Sodium arsenate:						
France	20	7	--	--	--	--
Israel	--	--	--	--	421	72
Other	(2)	3	--	--	--	--
Total	20	10	--	--	421	72
Arsenic compounds, n.s.p.f.:						
Brazil	--	--	9	482	--	--
Canada	--	--	(2)	1	--	--
Mexico	23	52	--	--	--	--
United Kingdom	(2)	66	(2)	175	(2)	41
Other	(2)	13	(2)	13	(2)	42
Total[1]	23	131	10	671	(2)	83

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

Source: Bureau of the Census.

WORLD REVIEW

Arsenic is recovered as arsenic trioxide in about 20 countries from the smelting or roasting of nonferrous metal ores or concentrates. Arsenic metal, which accounts for only 3% of world demand for arsenic, is produced by the reduction of arsenic trioxide. Commercial-grade arsenic metal, which is 99%-pure arsenic, is produced in only a few countries. This grade accounts for the majority of arsenic metal production. High-purity arsenic, which is 99.99% pure or greater and is used in the semiconductor industry, is produced by about 10 companies. Furukawa Co. Ltd. in Japan and Preussag AG in the Federal Republic of Germany are believed to be the world's largest producers, with reported metal production capacities of 30 tons and 15 tons per year, respectively. Other high-purity arsenic producers include Cominco Ltd. in Canada; Mitsubishi Metal Corp. and Rasa Industries Co. Ltd. in Japan; and Johnson Matthey PLC and MCP Electronic Materials Ltd. in the United Kingdom.

Table 3.—Arsenic trioxide:[1] World production, by country[2]

(Metric tons)

Country[3]	1983	1984	1985	1986[p]	1987[e]
Belgium[e]	3,000	3,000	3,000	3,000	3,500
Bolivia	107	144	361	241	130
Canada[e 4]	2,000	3,000	3,000	3,000	3,000
Chile[e 5]	--	3,500	4,000	6,000	5,000
France	4,727	3,828	[e]8,000	[e]10,000	9,000
Germany, Federal Republic of[e]	360	360	360	360	360
Japan[e]	300	500	500	500	500
Korea, Republic of	560	NA	NA	NA	100
Mexico	4,557	5,496	6,312	7,016	7,000
Namibia[6]	1,126	2,504	2,471	1,936	1,800
Peru[7]	1,009	1,090	1,257	[e]1,210	1,200
Philippines[e 8]	--	--	5,000	5,000	5,000
Portugal[e]	180	180	170	150	150
Sweden[e 9]	9,000	10,000	10,000	10,000	10,000
U.S.S.R.[e]	7,900	8,000	8,100	8,100	8,100
United States	7,300	6,800	2,200	--	--
Total	42,126	48,402	54,731	56,513	54,840

[e]Estimated. [p]Preliminary. NA Not available.

[1]Including calculated arsenic trioxide equivalent of output of elemental arsenic and arsenic compounds other than arsenic trioxide where inclusion of such materials would not duplicate reported arsenic trioxide production.

[2]Table includes data available through June 10, 1988.

[3]Austria, China, Czechoslovakia, the German Democratic Republic, Hungary, Spain, 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, if any.

[4]Figures include estimated production of low-grade dusts that were exported to the United States for further refining.

[5]Chile began producing arsenic trioxide during 1983 from the El Indio gold-copper ores; however, it was not of marketable quality and required further refining by foreign producers. It has not been listed separately to avoid double counting.

[6]Output of Tsumeb Corp. Ltd. only.

[7]Output of Empresa Minera del Centro del Perú (Centromín Perú) as reported by the Ministerio de Energia y Mines.

[8]The Philippines may have had some arsenic output in 1984 from the Philippine Smelting and Refining Corp. (PASAR) copper smelter, but available information is inadequate to make reliable estimates of output levels, if any.

[9]Based on arsenic trioxide exported plus the arsenic trioxide equivalent of the output of metallic arsenic exported.

CESIUM AND RUBIDIUM[4]

Domestic data for cesium and rubidium are developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the four operations to which a survey request was sent, two companies responded; production data are withheld to avoid disclosing company proprietary data. Cesium and rubidium metals and compounds were produced from pollucite and lepidolite ores imported from Canada. The metals were produced by the Electronic Materials and Refractory Metals Div. of Cabot Corp., Revere, PA. Cabot also produced cesium and rubidium compounds. The Special Products Div. of Carus Chemical Co., LaSalle, IL, produced cesium compounds. Cabot's prices for cesium and rubidium materials in quantities under 50 pounds remained unchanged from its 1986 prices. Per pound quotes to the nearest dollar for technical grades and high-purity grades, the latter in parentheses, were as follows: cesium metal $275 ($325), rubidium metal $300 ($375), common cesium compounds $36 to $44 ($73 to $79), and common rubidium compounds $104 to $112 ($155 to $170).

Japan's Matsushita Electric Co. reportedly developed a new paper-thin rubidium-containing electrolyte suitable for use in devices such as batteries, chemical sensors, and pacemakers; it is light, and operates over a relatively wide range of temperatures, -60° C to 100° C.[5]

Table 4.—U.S. imports for consumption of cesium compounds, by class and country

Class and country	1985		1986		1987	
	Quantity (pounds)	Value	Quantity (pounds)	Value	Quantity (pounds)	Value
Cesium chloride:						
Canada	--	--	--	--	31,445	$2,667,401
Germany, Federal Republic of	20,452	$630,635	27,924	$952,998	29,098	1,078,217
Netherlands	33	1,887	44	2,639	--	--
Norway	362	11,335	210	12,187	345	14,986
Sweden	115	7,367	124	9,096	8	1,110
United Kingdom	192	5,464	--	--	352	12,557
Total	21,154	656,688	28,302	976,920	61,248	3,774,271
Cesium compounds, n.s.p.f.:						
German Democratic Republic	119	2,625	--	--	--	--
Germany, Federal Republic of	28,358	735,785	7,140	165,717	12,500	241,659
Greece	110	2,726	--	--	--	--
Italy	--	--	--	82	4,783	
Japan	170	32,250	1,984	5,821	--	--
Netherlands	--	--	58	11,390	62	12,214
United Kingdom	626	164,468	3	1,076	--	--
Total	29,383	937,854	9,185	184,004	12,644	258,656

Source: Bureau of the Census.

GERMANIUM[6]

The estimated domestic production and consumption of germanium increased compared with that of 1986. Infrared systems and fiber optics continued to be the major end uses. The domestic fiber-optic market decreased for the second successive year, and germanium consumption for fiber optics also declined. The National Defense Stockpile (NDS) goal for germanium was increased substantially. Germanium is a strategic material that is vital to the manufacture of infrared systems needed by advanced aircraft and other defense applications.

Domestic Data Coverage.—Domestic refinery production and consumption data for germanium are estimated by the Bureau of Mines based on discussions with domestic producers.

Legislation and Government Programs.—Pursuant to section 3 of the Strategic and Critical Materials Stock Piling Act (50 U.S.C. 98 and following) and Executive Order 12155, the Federal Emergency Management Agency determined that, effective July 24, 1987, the NDS goal for germanium was increased from 30,000 kilograms to 146,000 kilograms, where it remained at yearend.[7]

The General Services Administration (GSA) began the purchase of zone-refined germanium metal for the NDS. During the two initial rounds that took place in May and August, the GSA was successful in the purchase of 7,000 kilograms of metal. The first-round puchase price was at $666 per kilogram, and the second was at $731 per kilogram. In September, the GSA contracted to purchase 23,000 kilograms of germanium during the third round of bidding to meet the previous 30,000-kilogram goal for the NDS. Tightening of supplies, probably owing in part to the GSA purchases, led to prices of $740 to $784 per kilogram for this round. In an effort not to disrupt the market, delivery times were stretched out to August 1989. The free-market price increased from a range of $700 to $800 per kilogram to about $825 per kilogram when GSA began awarding the contracts. All of the contract prices were considerably below the U.S. published price. Germanium was expected to come from Belgium, France, and the United States to satisfy these contracts.

Although metal transactions were conducted during the year, deliveries were not made, and no stocks of germanium were reported by GSA at yearend.

DOMESTIC PRODUCTION

Domestic refinery production from both primary and secondary materials was estimated to be 25,000 kilograms. Refined germanium products were produced by Eagle-Picher Industries Inc., Quapaw, OK; KBI Div. of Cabot, Revere, PA; and Atomergic Chemetals Corp., Plainview, NY.

The Jersey Minière Zinc Co. in Clarksville, TN, continued to produce germanium-rich residues as a byproduct of processing zinc ores from its Gordonsville and Elmwood Mines. These residues reportedly were shipped to Métallurgie Hoboken-Overpelt S.A. (MHO) in Belgium for germanium recovery and refining.

Lack of working capital and technical problems with its leach extraction unit reportedly caused Musto Exploration Ltd. to temporarily close its Apex Mine and refinery operation at St. George, UT, as of September 1987. Company officials indicated that the facilities would remain closed for more than 4 months. During the closure, the company planned to make required equipment repairs and to continue its metallurgical test work to increase overall recoveries for both germanium and gallium. Musto Exploration was the only company in the world to recover germanium and gallium as principal products.

CONSUMPTION AND USES

The consumption of germanium was estimated at 40,000 kilograms, a slight increase compared with that of 1986. The estimated consumption pattern by end use of germanium in 1987 was as follows: infrared systems, 65%; fiber optics, 10%; gamma-ray, X-ray, and infrared detectors, 6%; semiconductors, 5%; and other, 14%.

The largest end use for germanium continued to be in infrared optics, mainly for military use in guidance and weapon-sighting systems. Germanium-containing lenses and windows transmit thermal radiation similar to visible light transmission by optical glass. Germanium glass was also used for nonmilitary surveillance and monitoring systems in fields such as satellite systems and fire alarms.

The U.S. fiber-optic market continued the downward trend started in 1986. Consumption of germanium in this application decreased about 17% compared with that of 1986. Many of the long-distance fiber-optic telecommunication systems have been completed and others are planned for installation in the future. However, fiber-optic applications for local-area-network systems were becoming a reality and reportedly offered the most effective means of transmitting voice and data with immunity to electromagnetic and noise interference. Optical signals cannot be intercepted easily, and they provide a more secure system. These attributes and the light weight of fibers compared with conventional communication systems make fiber optics an ideal system for military and civilian applications.

PRICES

The domestic producer prices, published by Metals Week, for germanium metal and germanium dioxide remained at $1,060 and $660 per kilogram, respectively.

The Belgian producer prices, published by Metal Bulletin (London), for germanium metal and germanium dioxide began the year at $1,116 and $676 per kilogram, respectively.[8] On February 11, the prices decreased to $795 per kilogram for germanium metal and $455 per kilogram for germanium dioxide. The Belgian producer prices remained at these levels through yearend.

FOREIGN TRADE

A comparison of the value per kilogram of imported germanium material with the published foreign producer price for germanium metal, before estimated processing charges, was used to estimate the germanium content of imported scrap. In 1987, the estimated germanium content of total imports was calculated to be approximately 13,000 kilograms.

Table 5.—U.S. imports for consumption of germanium, by class and country

Class and country	1986		1987	
	Gross weight (kilograms)	Value	Gross weight (kilograms)	Value
Unwrought and waste and scrap:				
Belgium-Luxembourg	833	$850,804	1,401	$1,455,925
Canada	21	17,058	35	22,903
China	6,296	2,746,121	5,168	2,402,457
France	19	16,590	5,448	2,737,307
Germany, Federal Republic of	137	197,860	1,121	755,366
Hong Kong	489	209,186	549	240,630
India	85	13,337	--	--

Table 5.—U.S. imports for consumption of germanium, by class and country —Continued

Class and country	1986 Gross weight (kilograms)	1986 Value	1987 Gross weight (kilograms)	1987 Value
Unwrought and waste and scrap —Continued				
Israel	195	$38,948	195	$5,985
Italy	542	30,063	--	--
Japan	--	--	15	23,415
Netherlands	889	85,757	--	--
Sweden	179	127,806	--	--
Switzerland	45	10,490	391	46,588
Taiwan	213	89,329	--	--
United Kingdom	--	--	686	296,238
Total	9,943	4,433,349	15,009	7,986,814
Wrought:				
Belgium-Luxembourg	2,347	2,726,407	1,340	1,348,383
China	198	73,856	--	--
France	8	1,315	--	--
Germany, Federal Republic of	415	290,640	584	652,902
Israel	--	--	549	499,518
Netherlands	--	--	16	3,496
Total	2,968	3,092,218	2,489	2,504,299

Source: Bureau of the Census.

WORLD REVIEW

Australia.—The Overseas Telecommunications Commission called for vendors to submit bids for the installation of an underwater fiber-optic cable system. This long-distance network system is the first phase of the previously announced Tasman II fiber-optic system, which will link Australia to New Zealand by 1991, North America by 1993, and Asia by 1995.[9]

Japan.—Germanium metal production decreased dramatically from 8,810 kilograms to 4,637 kilograms. Germanium dioxide production was 13,358 kilograms, which was equivalent to that of 1986.[10]

Spain.—Asturiana de Zinc S.A. sold its first lot of 1,200 kilograms of germanium concentrates derived from processing zinc concentrates from the La Troya Mine, Guipézcoa, Spain. The mine is owned by Exminesa, a consortium including Asturiana, Banco Urquijo, Cominco, and Union Corp. It was expected to produce 40,000 tons of zinc and 6,000 kilograms of germanium per year.

U.S.S.R.—Unlike market economy countries, which produce germanium as a byproduct of the refining of base metal ores, the U.S.S.R. reportedly recovered germanium from coal tar and coking residues generated by coking coal from the Donetsk Basin in the Ukraine. Also under consideration was the recovery of germanium from fly ash generated in powerplants, possibly using an extraction technique similar to that used in the United Kingdom prior to the mid-1970's.

TECHNOLOGY

The Bureau of Mines investigated pressure-leaching techniques for recovering gallium and germanium from low-grade ores and zinc-processing residue samples. Detailed studies were made on an ore sample obtained from the Apex Mine, St. George, UT, which contained 0.033% gallium and 0.096% germanium. Pressure leaching of this ore sample at 200° C for 3 hours, coextracted 93% of the gallium and 96% of the germanium when the sulfur dioxide used in the reactor was greater than 2,200 pounds per short ton of treated ore. Selective extraction of 91% to 96% germanium was obtained using less than 1,500 pounds of sulfur dioxide per short ton of treated ore.[11]

Development of high-strength optical fibers and related components for wide-bandwidth two-way telecommunications have paved the way for fiber-optic guided missile systems. In these systems, many miles of spooled fiber, carried aboard a missile, are played out to maintain two-way communication between the missile and the launcher during the flight time. Numerous flights of this type of weapon system successfully demonstrated its target accuracy against both tanks and airborne helicopters.[12]

INDIUM[13]

Indium was produced by the Arconium Corp., Providence, RI, and Indium Corp. of America, Utica, NY. Domestic production in 1987 increased slightly more than that of 1986, and imports maintained a significant market share. The Bureau of Mines does not publish domestic production data on indium. Small quantities of secondary indium were available from specialty-metal-recycling firms. The potential for the use of indium in advanced materials was increased through research on component chemicals for coatings and solar cells.

CONSUMPTION AND USES

Indium usage increased in 1987. Consumption in the categories of fusible alloys and solders remained strong. Consumption for nuclear control rods remained low, essentially at a replacement level. Research continued on a broad range of possible new applications, especially for high-performance solders, for solar cells, and an indium-tin oxide coating for flat glass that would be transparent to visible light, electrically conductive, and would prevent entry of infrared rays. Estimated consumption patterns for indium metal were solder, alloys, and coatings, 50%; electrical and electronic components, 35%; and research and other uses, 15%.

PRICES

The producer price of indium, published in Metals Week, was $2.87 per troy ounce at the beginning of 1987. It increased steadily throughout the first 7 months to $9.95 per troy ounce in July, at which level it remained until yearend. The sharp price rise during 1987 was attributed by industry analysts to strong demand in Japan, particularly for liquid crystal displays.

Table 6.—U.S. imports for consumption of indium, by class and country

(Thousand troy ounces and thousand dollars)

Class and country	1985		1986		1987	
	Quantity	Value	Quantity	Value	Quantity	Value
Unwrought and waste and scrap:						
Belgium-Luxembourg	99	257	313	751	335	1,994
Canada	16	100	41	107	43	286
China	128	423	218	520	148	933
France	140	308	113	411	341	1,614
Germany, Federal Republic of	2	30	2	50	9	102
Hong Kong	19	50	26	72	15	144
Italy	259	596	331	759	185	1,121
Jamaica	(1)	17	--	--	--	--
Japan	2	43	6	104	29	478
Netherlands	16	67	23	50	46	219
Peru	111	260	60	139	102	643
Switzerland	16	36	8	17	--	--
United Kingdom	147	1,009	221	1,159	262	1,887
Total[2]	955	3,197	1,362	4,138	1,515	9,421
Wrought:						
China	--	--	9	21	(1)	17
France	19	90	--	--	--	--
Germany, Federal Republic of	(1)	3	1	9	--	--
Japan	3	60	1	70	1	61
United Kingdom	3	124	6	440	5	297
Other	(1)	6	(1)	7	--	--
Total[2]	25	283	18	495	7	375

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

Source: Bureau of the Census.

WORLD REVIEW

World production increased slightly to an estimated 2.5 million troy ounces. A world supply shortage existed primarily due to strong demand from Japan.

Major world refiners included Cominco in Canada; MHO in Belgium; Penarroya in France and Italy; Dowa Mining Co. Ltd. and Mitsui Mining & Smelting Co. Ltd. in Japan; Minero Perú Comercial in Peru; Mining and Chemical Products Ltd. in the United Kingdom; and Government metallurgical complexes in China and the U.S.S.R.

TECHNOLOGY

Research in Japan developed a new direct synthesis technique for making indium phosphide. In this method, liquid phosphorus was utilized instead of the normal phosphorus gas. During the phase transition of phosphorus from liquid to gas and then gas to liquid, the liquid phosphorus reacts with indium to produce indium phosphide of a very high-purity crystalline structure. This development may enhance the application of indium phosphide in commercial use in such areas as solar cells and laser diodes for fiber optics.[14]

Research in Taiwan resulted in direct deposition of the transparent conductor indium-tin-oxide by direct thermal evaporation of metallic indium and tin in an ambient oxygen environment. The key point in reducing the resistivity of the indium-tin-oxide film apparently was to control the tin-to-indium weight ratio to an optimum value of 3 to 1. These findings may enhance commercialization of a range of possible applications for indium coatings on glass and other surfaces.[15]

RHENIUM[16]

Cyprus Minerals Co. was the only domestic producer to recover rhenium in 1987. Rhenium contained in molybdenite was mined as a byproduct of porphyry copper ore from seven mines in the Southwestern United States. Consumption of rhenium increased about 19% in 1987. Imports for consumption decreased about 17%. The major use continued to be bimetallic platinum-rhenium catalysts to produce lead-free gasoline. The price of rhenium metal increased to $500 per pound in 1987 from $350 in 1986, and the price of ammonium perrhenate remained at $200 per pound.

Domestic Data Coverage.—Domestic mine production data for rhenium are developed by the Bureau of Mines from the reported molybdenum production at the seven operating porphyry-copper-molybdenum-rhenium mines in the United States.

Table 7.—Salient U.S. rhenium statistics

(Pounds of contained rhenium)

	1983	1984	1985	1986	1987
Mine production[1]	r16,200	r17,200	r21,100	r21,700	21,800
Recovered[2]	W	W	W	W	W
Consumption[e]	8,800	10,200	13,000	13,000	15,500
Imports (metal)	623	1,962	4,943	5,495	7,436
Imports for consumption of ammonium perrhenate	5,947	4,754	3,325	r12,189	7,225
Stocks, Dec. 31	W	W	W	W	W

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Calculated rhenium contained in MoS_2 concentrates.
[2]In prior years, this was shown as mine production.

FOREIGN TRADE

Imports for consumption decreased as a whole, but rhenium in the form of metal increased. Most of the ammonium-perrhenate was received from Chile, the Federal Republic of Germany, and Sweden. Chile and the Federal Republic of Germany supplied the rhenium metal.

World production of rhenium was estimated to be 40,000 pounds, exclusive of U.S. production. Rhenium was recovered from byproduct molybdenite concentrates from porphyry copper deposits in Canada, Chile, China, Iran, Peru, the U.S.S.R., and the United States. In addition, the U.S.S.R. also recovered rhenium as a byproduct from the Dzhezkazgan sedimentary copper deposit in Kazakhstan. Rhenium metal and compounds were recovered from molybdenum concentrates in Chile, France, the Federal Republic of Germany, Sweden, the U.S.S.R., the United Kingdom, and the United States. Chile's recovery of rhenium was the largest amount produced by a market economy country.

Table 8.—U.S. import duties for rhenium materials

Item	TSUS No.	Most favored nation (MFN) Jan. 1, 1987	Non-MFN Jan. 1, 1987
Unwrought metal	628.9000	3.7% ad valorem	25% ad valorem.
Wrought metal	628.9500	5.5% ad valorem	45% ad valorem.
Ammonium perrhenate	417.4520	3.1% ad valorem	25% ad valorem.
Perrhenic acid	416.4540	4.2% ad valorem	Do.

Table 9.—U.S. imports for consumption of ammonium perrhenate, by country

(Rhenium content)

Country	1985		1986		1987	
	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)
Belgium-Luxembourg	--	--	76	$22	--	--
Brazil	--	--	1,022	175	70	$27
Chile	2,918	$611	8,360	^{r}1,502	4,906	1,426
China	--	--	--	--	4	2
Ecuador	--	--	--	--	154	61
Germany, Federal Republic of	407	58	^{r}1,938	^{r}352	547	176
Japan	--	--	158	28	209	89
Netherlands	--	--	635	120	--	--
Sweden	--	--	--	--	1,040	272
United Kingdom	--	--	--	--	295	69
Total	3,325	669	^{r}12,189	^{r}2,199	7,225	2,122

^{r}Revised.

Source: Bureau of the Census.

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

Country	1985		1986		1987	
	Gross weight (pounds)	Value	Gross weight (pounds)	Value	Gross weight (pounds)	Value
Chile	3,300	$825,000	3,150	$2,014,000	5,463	$1,445,049
Germany, Federal Republic of	1,424	337,662	1,904	432,000	1,867	593,093
United Kingdom	193	54,065	441	171,000	--	--
Other[1]	27	8,378	--	--	106	34,342
Total	4,943	1,225,105	5,495	2,617,000	7,436	2,072,484

[1]Includes Haiti, Sweden, Switzerland, and Uruguay.

Source: Bureau of the Census.

SCANDIUM[17]

Production of refined scandium in the United States increased. Most of the scandium processed in the United States in 1987 was derived from previously mined domestic ores and concentrates. Demand for scandium for use in laser crystals and special-use light bulbs, its principal markets, increased slightly. Scandium was obtained as a byproduct from tungsten concentrates, fluorite tailings, and uranium solutions at three locations in the Western United States. The uranium-scandium mine source, which had ceased operating in 1985, reopened in 1987. As an advanced material, scandium-containing synthetic garnet crystals were components in high-energy lasers.

Domestic Data Coverage.—Domestic production data for scandium are estimated by the Bureau of Mines on the basis of discussions with domestic producers, processors, and consumers.

DOMESTIC PRODUCTION

Byproduct scandium-bearing ore and concentrate from three domestic mines were processed in 1987. Bingham Canyon was the only domestic mine operating in 1987 that produced ore containing byproduct scandium. As a result of scandium's high cost, the industry is reportedly investigating methods to economically recover scandium from scrap materials, principally laser rods.

Energy Fuels Nuclear Inc. produced scandium concentrate as a byproduct of uranium processing. Ore for Energy Fuels Nuclear's plant was derived as a byproduct of copper recovered by leaching at Kennecott's Bingham Canyon Mine, Bingham Canyon, UT. Energy Fuels Nuclear purchased the Bingham Canyon uranium-scandium recovery facility in 1986 from Westinghouse Electric Corp. and reopened the plant in February 1987. Prior to its purchase, Westinghouse had ceased operation of the plant in August 1985.

Refined scandium products, principally scandium oxide, were produced domestically by Baldwin Metal Processing Co., Phoenix, AZ; Boulder Scientific Co., Mead, CO; Materials Preparation Center, Ames, IA; Research Chemicals Div. of Nucor Corp., Phoenix, AZ; and Sausville Chemical Co. Inc., Garfield, NJ.

Refined scandium was recovered by Baldwin Metal Processing Co. from residual fluorite screenings accumulated at an inactive fluorite mine at Crystal Mountain, MT. By yearend, Baldwin Metal had reportedly closed its processing operations. Boulder Scientific produced scandium from previously mined tungsten concentrates derived from the processing of molybdenum ores at AMAX Inc.'s Climax Mine, Climax, CO, and from scandium concentrates produced by Energy Fuels Nuclear's uranium facility at Bingham Canyon, UT. AMAX's molybdenum and byproduct tungsten operations at Climax closed in mid-1986 and were kept on a maintenance basis throughout 1987.

Scandium was also refined by Sausville Chemical from scandium concentrate produced at Bingham Canyon, UT.

CONSUMPTION AND USES

Domestic consumption of scandium in 1987 was estimated at 66 kilograms of equivalent scandium oxide, an increase of 15 kilograms from the estimated quantity consumed in 1986. The major use for scandium was in laser crystals of gadolinium-scandium-gallium garnets (GSGG), which were used in high-average-energy laser systems. GSGG laser crystals are more than twice as energy efficient as yttrium-aluminum garnets as a lasing medium. Laser applications for GSGG are in communications and high-average-energy (not pulsed) applications such as hydrogen fusion research and antimissile defense systems, and in lower energy lasers used in medical, electronic, and industrial applications.

Scandium is used in high-intensity mercury vapor lights to produce a highly efficient, near-sunlight color emission that is used for indoor and outdoor nighttime lighting to simulate daylight for color television broadcast. Three to five milligrams of scandium are added per bulb.

The radioactive isotope scandium-46 was used as a tracing agent in petroleum refineries and in oil wells.

Scandium metal, backed by molybdenum, was used in dual anode tubes in X-ray fluorescence spectrometers. Excitation efficiency of the dual anode system is reportedly excellent in detection of the light elements through titanium.

Small amounts of scandium metal reportedly were used in semiconductors, while minor amounts found use in petroleum catalysts and collimators in neutron lenses.

Additions of scandium to titanium carbide reportedly create a binary carbide with a hardness close to that of diamond.

PRICES

No published prices for scandium were available. Yearend nominal prices for scandium oxide per kilogram, compiled by the Bureau of Mines from information from several suppliers, were as follows: 98% purity, $6,500; 99% purity, $7,000; 99.9% purity, $9,500; 99.99% purity, $11,000; 99.995% purity, $13,000; 99.999% purity, $15,000. Scandium metal prices varied considerably, depending on the quantity of material being purchased and its purity.

FOREIGN TRADE

No trade data were available for scandium as an individual item. However, analysis of small shipments of high value from probable scandium import sources suggested that about 2 kilograms of scandium oxide was imported from the United Kingdom.

Based on data compiled by the Bureau of Mines, the United States was a net exporter of scandium in 1987 and is no longer dependent on foreign sources for its current demands.

WORLD REVIEW

Foreign countries that mined scandium in 1987 included Australia, China, Norway, and the U.S.S.R. Refined scandium was processed in France, Japan, Norway, and the United Kingdom.

A/S Megon announced the opening of a scandium oxide processing pilot plant in June at Norway's Institute of Energy, near Oslo. The plant, which was scheduled to open in June, has a planned capacity of 10 kilograms of scandium oxide per month. The opening of the plant coincides with the discovery of two scandium-rich deposits in Finnmark County in northern Norway, and at Evje, 50 kilometers northwest of Kristiansand, in the south.[18]

TECHNOLOGY

Scandium and rare-earth elements in Jamaican bauxite wastes were characterized by researchers at the University of the West Indies, Kingston, Jamaica. The red mud waste generated by processing Jamaican bauxite by the Bayer process was determined to be enriched with scandium, compared with the ore. Scandium oxide contents of 200 to 390 parts per million were detected in the bauxite wastes at a uniform rate of distribution.[19]

Developers at Mitsubishi have added scandium oxide to the cathode ray tubes (CRT) of certain rear-projection, big-screen televisions. The addition of scandium oxide reportedly blocks the formation of a reactant on the cathodes oxide layer, allowing increased electron beam output and improved longevity of the CRT.[20]

SELENIUM[21]

Domestic output of refined selenium, a byproduct of copper refining, increased by about 50%. One domestic producer resumed production at its refinery, which had been closed since 1985, and the two other producers increased their production. Despite the increase in domestic production, the United States continued to rely heavily on imports, which met most of the domestic demand.

Apparent consumption of refined selenium rose about 10%, reflecting increased agricultural use and an increase in the production of photoreceptors for plain paper copiers, the largest use for refined selenium. With world demand exceeding production, the price of selenium rose steadily throughout the year.

Domestic Data Coverage.—Domestic data for selenium are developed by the Bureau of Mines from a voluntary survey of stocks, production, and shipments at the three U.S. producers. All three producers responded to the survey. Data are withheld to avoid disclosing company proprietary information.

Table 11.—Salient selenium statistics

(Kilograms of contained selenium unless otherwise specified)

	1983	1984	1985	1986	1987
United States:					
Production, primary refined	353,860	253,598	W	W	W
Shipments to consumers	374,030	224,401	W	W	W
Exports, metal, waste and scrap	93,368	122,929	154,122	161,007	162,217
Imports for consumption	297,029	376,946	400,658	462,646	495,862
Consumption, apparent	577,691	478,418	W	W	W
Stocks, Dec. 31: Producers'[1]	152,790	139,159	W	W	W
Dealers' price, average per pound, commercial-grade[2]	$3.87	$9.02	r$7.44	r$5.70	$6.51
World: Refinery production	r1,402,992	r1,493,851	1,324,756	p1,193,744	e1,245,059

eEstimated. pPreliminary. rRevised. W Withheld to avoid disclosing company proprietary data.
[1]Granular selenium, a semirefined form of selenium, is included in stocks.
[2]Metals Week. 1985-87 calculated from published price ranges.

Legislation and Government Programs.—In April, the Food and Drug Administration, U.S. Department of Health and Human Services, published new regulations concerning the use of selenium as an additive in feed for major food-producing animals. The new regulations allow for an increase in the maximum supplementation level of selenium in "complete" feed from 0.1 to 0.3 part per million, as well as proportional increases in separate feed supplements and salt-mineral mixtures. This action was in response to a petition filed in 1986 by the American Feed Industry Association Inc.[22]

DOMESTIC PRODUCTION

Primary selenium was recovered as a byproduct of the electrolytic refining of copper. Selenium, along with precious metals, accumulates in anode slimes generated in the electrolytic cells.

Primary selenium was recovered by three domestic copper refiners: Asarco at Amarillo, TX; Phelps Dodge Refining Corp. at El Paso, TX; and BP Minerals America Corp. (formerly Kennecott) at Magna, UT. Production at the Magna refinery, which had been closed since 1985, resumed during the third quarter of the year. Selenium-bearing anode slimes from other domestic copper refineries were either shipped to one of the above refineries or exported for processing.

Production of refined selenium increased 50% despite an increase of only 4% in electrolytic copper production. Responding to higher prices, producers sought to increase production of refined selenium by maximizing their recovery of selenium from anode slimes and by processing accumulated stocks of crude selenium into refined material. However, shipments by domestic producers increased by only 15%, as producers sought to replenish depleted stocks, possibly in anticipation of further price increases.

Most selenium of domestic origin was produced as commercial-grade selenium, averaging 99.5% selenium, and available as powder, shot or small lumps, and pigment-grade selenium powder, with a minimum 99.8% purity. A small quantity of high-grade selenium, with a minimum 99.99% selenium content, and ferroselenium, were also produced.

About 100 tons of selenium contained in scrap derived from the manufacture of photocopier drums and from used photocopier drums was exported for processing.

CONSUMPTION AND USES

Consumption of selenium increased by more than 10% in 1987, as a result of demand in a strong agricultural market and the effects of a weakened U.S. dollar. Demand for selenium by end use was estimated as follows: electronic and photocopier components, 43%; pigments and chemicals, 20%; glass manufacturing, 20%; and other, including agriculture and metallurgy, 17%.

The major demand for selenium in the electronics end-use sector was as a photoreceptor on the drums of plain-paper electrophotographic copiers. This end use contributed significantly to the growth in U.S. demand, with several Japanese manufacturers having established production facilities in the United States and world demand for photoreceptors having grown at about 5% per year. Agricultural use of selenium, where sodium selenate or selenite was used as feed additives or nutritional supplements to compensate for animal feed grown in selenium-deficient soil, increased significantly in response to new Food and Drug Administration regulations increasing the allowable supplemental levels. Most of the domestic demand in this sector was met by imports.

In the glass industry, selenium was used primarily in the production of container glass as a decolorant. It was also used in architectural glass to reduce solar-heat transmission. Selenium-bearing cadmium sulfoselenide red pigments were used as colorants for plastics, glass, and ceramics.

PRICES

The price of selenium, which had been depressed throughout 1986, rose steadily during 1987 in response to declining stock levels and world demand in excess of production. The New York dealer price range for commercial-grade selenium, quoted by Metals Week on a weekly basis, began the year at $5.40 to $5.65 per pound and rose steadily to $9.00 to $9.50 per pound at yearend. The free-market European price followed the same pattern.

FOREIGN TRADE

Total imports for consumption of selenium, as measured in terms of contained selenium, rose for the fourth consecutive year, to a level about two-thirds above the 1983 level. The strength of imports was tied to the high domestic industrial demand stimulated by the weakened U.S. dollar, and to new regulations governing agricultural usage. Total exports were at about the same level as in 1986; about two-thirds of the exports was scrap.

Table 12.—U.S. exports of selenium metal, waste and scrap, by country

Country	1985		1986		1987	
	Quantity (kilograms, contained selenium)	Value	Quantity (kilograms, contained selenium)	Value	Quantity (kilograms, contained selenium)	Value
Argentina	1,179	$22,750	2,907	$44,163	998	$10,704
Australia	962	29,220	--	--	--	--
Belgium-Luxembourg	--	--	--	--	17,941	140,504
Brazil	650	10,400	319	5,099	59	3,250
Canada	2,207	40,595	324	5,171	2,772	44,307
China	--	--	--	--	1,955	28,290
Colombia	894	22,660	7,387	144,870	--	--
France	318	5,075	1,011	16,150	1,159	18,526
Germany, Federal Republic of	7,861	126,793	--	--	--	--
India	68	4,765	--	--	--	--
Italy	1,456	20,015	1,883	21,835	299	4,290
Japan	36,951	289,592	42,875	245,381	34,611	270,252
Korea, Republic of	45	1,800	10,165	52,265	1,031	21,662
Malaysia	--	--	4,802	76,752	--	--
Mexico	19,265	308,481	15,231	237,033	30,385	462,450
Netherlands	7,711	106,360	19,421	180,238	7,484	83,160
Norway	236	6,760	--	--	--	--
Philippines	18,144	42,000	17,178	43,486	9,072	6,000
Portugal	91	1,950	272	3,350	--	--
Spain	--	--	--	--	1,014	12,258
Switzerland	4,990	75,350	2,984	32,763	--	--
United Kingdom	51,096	316,177	34,200	342,461	51,246	546,020
Venezuela	--	--	48	1,446	1,814	28,987
Other	--	--	--	--	377	5,520
Total[1]	154,122	1,430,743	161,007	1,452,463	162,217	1,686,180

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

Source: Bureau of the Census.

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

Class and country	1985		1986		1987	
	Quantity (kilograms, contained selenium)	Value	Quantity (kilograms, contained selenium)	Value	Quantity (kilograms, contained selenium)	Value
Unwrought and waste and scrap:						
Belgium-Luxembourg	63,353	$1,572,220	86,143	$2,736,960	94,477	$2,649,893
Canada	111,927	2,353,429	130,038	2,386,721	136,621	2,784,833
Chile	7,500	153,902	3,000	42,118	--	--
China	--	--	--	--	4,475	47,503
Costa Rica	--	--	362	11,940	--	--
Finland	--	--	--	--	1,000	13,302
German Democratic Republic	45	14,743	--	--	--	--
Germany, Federal Republic of	5,550	126,877	205	9,496	1,940	25,767
Japan	72,609	2,056,694	87,858	1,958,821	85,657	1,759,989
Korea, Republic of	--	--	2,000	19,852	1,500	13,524
Netherlands	15,239	30,851	3,680	61,216	--	--
Philippines	16,748	243,747	10,000	86,200	12,000	111,667
Sweden	100	3,750	--	--	--	--
United Kingdom	66,434	910,947	97,408	1,501,694	76,379	1,245,330
Yugoslavia	--	--	5,000	43,572	20,000	153,657
Total	359,505	7,467,160	425,694	8,858,590	434,049	8,805,465
Selenium dioxide:						
Belgium-Luxembourg	--	--	8	1,011	--	--
Germany, Federal Republic of	6,916	164,471	5,405	113,472	3,594	70,990
Japan	--	--	--	--	6,227	138,782
United Kingdom	--	--	142	3,114	1,314	29,724
Total	6,916	164,471	5,555	117,597	11,135	239,496
Selenium salts:						
Belgium-Luxembourg	567	29,839	--	--	--	--
France	--	--	--	--	46	1,233
Korea, Republic of	4,847	4,962	1,626	2,662	--	--
United Kingdom	7,000	114,959	650	7,798	300	7,677
Total	12,414	149,760	2,276	10,460	346	8,910

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

Class and country	1985 Quantity (kilograms, contained selenium)	1985 Value	1986 Quantity (kilograms, contained selenium)	1986 Value	1987 Quantity (kilograms, contained selenium)	1987 Value
Sodium selenite:						
Belgium-Luxembourg	--	--	--	--	230	$5,550
Canada	42	$2,090	4	$1,648	345	8,454
Germany, Federal Republic of	3,013	80,091	14,987	125,108	19,734	259,174
Japan	1,058	29,575	230	15,917	414	35,260
United Kingdom	13,835	332,551	10,931	258,425	26,640	597,024
Total	17,948	444,307	26,152	401,098	47,363	905,462
Other selenium compounds:						
Belgium-Luxembourg	--	--	--	--	464	35,478
Canada	1,105	3,394	--	--	48	2,400
Germany, Federal Republic of	22	1,443	338	10,351	250	5,324
Japan	1,588	81,559	--	--	--	--
Sweden	123	1,398	--	--	264	6,296
United Kingdom	1,037	44,072	2,631	152,070	1,943	99,668
Total	3,875	131,866	2,969	162,421	2,969	149,166
Grand total	400,658	8,357,564	462,646	9,550,166	495,862	10,108,499

Source: Bureau of the Census; figures adjusted by the Bureau of Mines.

WORLD REVIEW

World consumption of selenium increased by an estimated 10% in 1987 and continued to grow faster than world production. Consumption growth was particularly strong in the United States and China. It was estimated that Chinese imports more than doubled from the 1986 level, making China the fourth largest selenium consumer after the United States, the United Kingdom, and Japan.

In Belgium, a planned expansion of MHO selenium-refining capacity at its Hoboken operations during 1987 was delayed. The expansion from 160 tons per year to an estimated 360 tons per year was rescheduled for completion by yearend 1988. MHO recovered selenium from anode slimes generated at its Olen refinery, principally from imported Zairian copper, and from purchased anode slimes, some of which originated in the United States. Most of the selenium produced was high-purity metal suitable for electronic applications.

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

(Kilograms, contained selenium)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Belgium[e]	[r]140,000	[r]180,000	[r]230,000	250,000	230,000
Canada[3]	266,000	[e]354,000	361,000	345,000	345,000
Chile	43,869	25,450	50,037	16,267	20,000
Finland	11,172	16,975	14,038	5,693	10,000
India	3,684	4,191	4,850	[r e]4,800	4,800
Japan	433,122	464,524	496,835	426,567	[4]481,109
Mexico	24,000	44,000	42,000	23,000	25,000
Peru	19,514	20,758	14,506	12,012	12,000
Sweden	42,000	68,000	46,000	[r e]50,000	50,000
United States	353,860	253,598	W	W	W
Yugoslavia[e]	[4]43,720	45,000	46,000	45,000	45,000
Zambia[5]	22,051	17,355	19,490	15,405	[4]22,150
Total	[r]1,402,992	[r]1,493,851	1,324,756	1,193,744	1,245,059

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

[1]Insofar as possible, data relate to refinery output only; thus, countries that produced selenium contained in copper ores, copper concentrates, blister copper, and/or refinery residues, but did not recover refined selenium from these materials indigenously, were excluded to avoid double counting. Table includes data available through June 10, 1988.

[2]In addition to the countries listed, Australia, the Federal Republic of Germany, and the U.S.S.R. produced refined selenium, but output is not reported, and available information is inadequate for formulation of reliable estimates of output levels. Australia is known to produce selenium in intermediate metallurgical products and has facilities to produce elemental selenium. In addition to having facilities for processing imported anode slimes for the recovery of selenium and precious metals, the United Kingdom has facilities for processing selenium scrap.

[3]The 1983-85 refinery output is from all sources, including imported materials and secondary sources; 1986-87 excludes secondary production.

[4]Reported figure.

[5]Data are for fiscal year ending Mar. 31 of that stated. In addition to refined selenium produced, Zambia exported significant quantities of selenium contained in anode slimes.

TECHNOLOGY

Copper indium diselenide ($CuInSe_2$) continued to draw interest as a thin-film solar-cell material. Research efforts were being directed at improving cell efficiency and building large-area modules suitable for practical application. Although efficiencies of about 12% have been achieved, the U.S. Department of Energy predicts that an efficiency of about 15% will be required to produce cost-effective solar power.[23]

The Fifth International Conference on the Chemistry of Selenium and Tellurium was held in Oak Ridge, TN. Sessions held included those on the organic, physical, and biochemical aspects of selenium, and on selenium films.

The Selenium-Tellurium Development Association Inc., Darien, CT, published a brochure providing background information on selenium as an essential nutrient for animals, humans, and plants. The brochure outlines some of the detrimental effects of selenium deficiency and effective ways of providing selenium to animals whose diets are deficient in selenium.[24]

TELLURIUM[25]

Commercial-grade tellurium (minimum 99% tellurium) and tellurium dioxide were produced by Asarco as byproducts of copper processing at its electrolytic copper refinery at Amarillo, TX. Asarco provided tellurium production data to the Bureau of Mines; however, the data are withheld to avoid disclosing company proprietary data.

Domestic demand for tellurium and its compounds increased by at least 15% in 1987. Most of the demand for commercial-grade material was satisfied by domestic production, but demand for high-purity tellurium was met almost entirely by imports.

The principal use of tellurium was as an alloying metal in free-machining steel and copper. High-purity tellurium was of strategic significance because of its use in mercury-cadmium-telluride, an infrared sensing material for thermal imaging in night vision and navigation systems. Estimated consumption of tellurium, by end-use category, was iron and steel, 58%; nonferrous metals, 20%; chemicals and rubber manufacturing, 15%; other uses, including xerographic and electronic applications, 7%.

Table 15.—U.S. imports for consumption of tellurium, by class and country

Class and country	1985[r] Gross weight (kilograms)	1985[r] Value	1986[r] Gross weight (kilograms)	1986[r] Value	1987 Gross weight (kilograms)	1987 Value
Unwrought and waste and scrap:						
Belgium-Luxembourg	5	$5878	47	$1,021	1,041	$32,401
Canada	13,458	453,929	7,159	504,983	4,525	463,462
Germany, Federal Republic of	5	1,404	--	--	5	1,441
Japan	499	29,083	754	43,891	347	38,149
Netherlands	500	9,653	--	--	--	--
Peru	963	18,963	4,863	70,244	--	--
United Kingdom	4,999	107,398	9,000	175,543	2,962	72,904
Total	20,429	626,308	21,823	795,682	8,880	608,357
Compounds:						
Belgium-Luxembourg	907	15,381	10	1,277	--	--
Canada	90	1,904	--	--	(1)	1,879
Germany, Federal Republic of	64	3,369	--	--	133	6,463
Japan	103	10,900	63	7,161	188	9,743
Philippines	9,220	202,483	--	--	--	--
Switzerland	--	--	--	--	7	1,633
United Kingdom	22	5,536	359	76,545	932	114,192
Total	10,406	239,573	432	84,983	1,260	133,910
Salts:						
Germany, Federal Republic of	--	--	8,466	30,397	16,550	64,238
Netherlands	2,400	5,410	--	--	--	--
United Kingdom	--	--	--	--	10	1,355
Total	2,400	5,410	8,466	30,397	16,560	65,593
Grand total	33,235	871,291	30,721	911,062	26,700	807,860

[r]Revised.
[1]Less than 1/2 unit.

Source: Bureau of the Census.

In response to a global production deficit and a drawdown in domestic and world stocks, the domestic producer price of tellurium metal, which had remained stable at about $10 per pound since 1982, rose steadily throughout the year to about $20 per pound at yearend.

Table 16.—Tellurium: World refinery production, by country[1]

(Kilograms, contained tellurium)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Canada[3]	16,000	[e]21,000	19,000	[r] [e]20,000	27,000
Japan	54,800	64,500	65,600	55,600	[4]53,305
Peru	15,806	14,066	15,007	9,836	10,000
United States	W	W	W	W	W

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Insofar as possible, data relate to refinery output only; thus, countries that produced tellurium contained in copper ores, copper concentrates, blister copper, and/or refinery residues, but did not recover refined tellurium, are excluded to avoid double counting. Table is not totaled because of the exclusion of data from major world producers, notably the U.S.S.R. and the United States. Table includes data available through June 10, 1988.

[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 tellurium, but output is not reported, and available information is inadequate for formulation of reliable estimates of output levels. Moreover, the other major copper-refining nations such as Chile 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]Reported figure.

THALLIUM[26]

The U.S. demand for thallium during the last 6 years has been met by imports. The small market size and the toxicity of thallium are the principal factors that will continue to influence domestic dependence on foreign sources for the supply of thallium. Based on import data, the domestic consumption of thallium was estimated to be 3,000 pounds in 1987, significantly higher than in 1986. Metal traders reported that the average price of thallium metal in 200-pound lots ranged from $60 per pound for 99.9%-pure thallium metal to about $100 per pound for 99.999%-pure metal, compared with $20 and $65 per pound, respectively, in 1986.

Legislation and Government Programs.—The Superfund Amendments and Reauthorization Act (SARA) of 1986 (Public Law 99-499) extended and amended the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA or Superfund). Certain requirements were established for the EPA and the Agency for Toxic Substances and Disease Register (ATSDR) with regard to hazardous substances that are most commonly found at facilities on the CERCLA National Priorities List (NPL), and which pose the most significant potential threat to human health. Section 110 of SARA amends section 104(i) of CERCLA by establishing requirements for the preparation of (1) a list of hazardous substances found at NPL sites (in order of priority), (2) toxicological profiles of those substances, and (3) a research program to improve or expand the information available on these substances. EPA and ATSDR published the first priority list of 100 hazardous substances on April 17, 1987, in compliance with the law. The list was divided into 4 priority groups of 25 substances each. In this list, thallium was among the hazardous substances of the fourth priority group.[27]

In July, EPA published its final rule on land-disposal restrictions of liquid wastes in response to the Resource Conservation and Recovery Act (RCRA), as amended by Hazardous and Solid Waste Amendments of 1984. The RCRA required EPA to restrict the land disposal of hazardous wastes, containing the so-called California list. The rule prohibited land disposal of liquid wastes containing thallium compounds at concentrations greater than or equal to 130 milligrams per liter, thallium content.[28]

[1]Prepared by J. Roger Loebenstein, physical scientist.

[2]Federal Register. Environmental Protection Agency. Inorganic Arsenicals; Preliminary Determination To Cancel Registration of Pesticide Products Containing Inorganic Arsenicals Registered for Nonwood Preservative Use. V. 52, No. 1, Jan. 2, 1987, pp. 132-140.

[3]U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry. Toxicological Profile For Arsenic. Nov. 1987, 130 pp.

[4]Prepared by staff, Branch of Nonferrous Metals.

[5]McCulloch, R. Advances in Japanese Batteries. Mater. Edge, No. 3, Jan. 1988, pp. 45, 47.

[6]Prepared by Thomas O. Llewellyn, physical scientist.

[7]Federal Register. Federal Emergency Management Agency. Determination of National Defense Stockpile Goal for Germanium. V. 52, No. 174, Sept. 9, 1987, p. 33992.
[8]Where necessary, values have been converted from Belgian francs (BF) to U.S. dollars at the 1987 average exchange rate of BF37.334=US$1.00.
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[16]Prepared by John W. Blossom, physical scientist.
[17]Prepared by James B. Hedrick, physical scientist.
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[21]Prepared by Daniel L. Edelstein, physical scientist.
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[24]Oldfield, J. E. Selenium: Uses in Agriculture by Plants, Animals, and Humans. Selenium-Tellurium Development Association Inc., Darien, CT, 9 pp.
[25]Prepared by Daniel L. Edelstein, physical scientist.
[26]Prepared by Thomas O. Llewellyn, physical scientist.
[27]Federal Register. Environmental Protection Agency. Notice of the Fist Priority List of Hazardous Substances That Will Be the Subject of Toxicological Profiles. V. 52, No. 74, Apr. 17, 1987, pp. 12866-12874.
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Table 17.—U.S. imports for consumption of thallium, by country

Country	Compounds			Unwrought and waste and scrap	
	Gross weight (pounds)	Content[1] (pounds)	Value	Gross weight (pounds)	Value
1986:					
Belgium-Luxembourg	867	694	$19,223	1,037	$29,661
Canada	--	--	--	2	1,033
France	440	352	8,643	--	--
Germany, Federal Republic of	524	419	28,898	--	--
Japan	22	18	1,414	--	--
Netherlands	(2)	(2)	(2)	--	--
United Kingdom	10	8	2,250	--	--
Total	r1,863	r1,491	r60,428	1,039	30,694
1987:					
Belgium-Luxembourg	237	190	16,670	1,151	23,731
France	220	176	4,573	--	--
Germany, Federal Republic of	485	388	20,929	--	--
United Kingdom	11	9	2,450	1,034	20,756
Total	953	763	44,622	2,185	44,487

rRevised.
[1]Estimated by the Bureau of Mines.
[2]Revised to zero.

Source: Bureau of the Census.

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