Minerals yearbook: Metals and minerals 1986. Year 1986, Volume 1 1986

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Minerals Yearbook

1986

Volume I

METALS AND MINERALS

Prepared by staff of the

BUREAU OF MINES

UNITED STATES DEPARTMENT OF THE INTERIOR • Donald Paul Hodel, Secretary

BUREAU OF MINES • David S. Brown, Acting 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 : 1988

Foreword

This edition of the Minerals Yearbook discusses the performance of the worldwide minerals industry during 1986 and provides background information to assist in interpreting developments during the year being reviewed. Content of the individual volumes follows:

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 mineral industry of each of the 50 States, the U.S. island possessions in the Pacific Ocean and the Caribbean Sea, and the Commonwealth of Puerto Rico. This volume also has a statistical summary.

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.

David S. Brown, *Acting 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 Divisions of Ferrous Metals, Nonferrous Metals, and Industrial Minerals of the Assistant Directorate, Minerals Information. 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 Branches of Publication Support Services and Editorial Services, Division of Publication, provided general guidance on the preparation and coordination of the chapters in this volume and reviewed the manuscripts to insure statistical consistency among the tables, text, and figures between this volume and other volumes, and between this edition and those of former years.

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.

Julie N. Walker, *Chief, Division of Publication*

Contents

Nonfuel Minerals Survey Methods

By William R. Vogel[1]

The Bureau of Mines Minerals Information 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 Minerals Information 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.

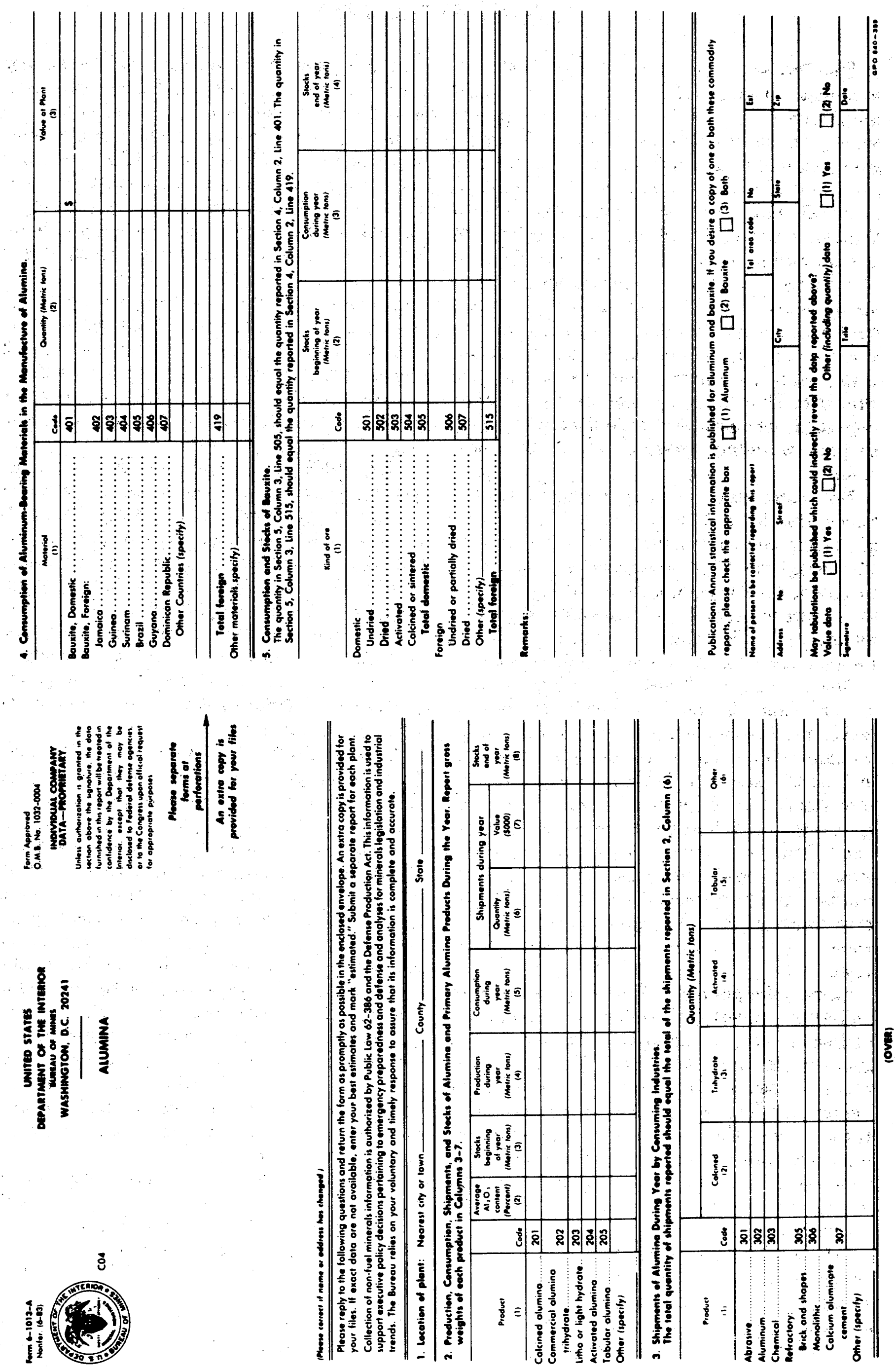
DATA COLLECTION SURVEYS

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. Those 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 167 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, Washington, DC 20241.



Form 6-1013-A
Nonfer. (6-83)

C04

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

ALUMINA

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 separate forms at perforations

An extra copy is provided for your files

(Please correct if name or address has changed)

Please reply to the following questions and return the form as promptly as possible in the enclosed envelope. An extra copy is provided for your files. 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 62-386 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 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

GPO 840-389

Figure 1.—A typical survey form.

SURVEY PROCESSING

The 167 surveys yield more than 60,000 responses from approximately 27,000 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 programed 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 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 specialists 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 three volumes of 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 Commodities 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 those 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 Division of Publication, U.S. Bureau of Mines, 4900 LaSalle Road, Avondale, MD 20782.

A 10-year time series of domestic supply-demand data on each commodity is available on 5-1/4-inch floppy disks from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161. These disks are compatible with many types of microcomputers and popular microcomputer application software packages. These data have been published every 5 years in "Mineral Facts and Problems" and are being updated annually in "Mineral Industry Surveys" and on the floppy disks. 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.

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

Mining and Quarrying Trends in the Metals and Industrial Minerals Industries

By Arnold O. Tanner[1]

Tables based on 1985 data, which were not available in time for publication of the "1985 Minerals Yearbook," are included in this chapter; corresponding tables for 1986 are not yet available. Raw nonfuel minerals produced in the United States during 1986 had an estimated value of $23.5 billion, an increase of $0.25 billion over the 1985 value. This is the fourth consecutive year that the value has increased, and except for a decrease in 1982, the value each year has increased since 1971, or 14 out of 15 years. Industrial minerals growth slowed from a 3% increase in value in 1985 to a 1.5% increase in 1986, reflecting the slow growth in the domestic economy. The value of industrial minerals, more than three times larger than the value of metals, easily offset the less than 0.5% decline in the value of metal mine production. Although the decline was small, this decrease makes 1986 the fourth year in the past 6 years in which a drop in the value of metal mining production occurred in the United States. U.S. production continued to lag behind the growing world production. Overall, the estimated raw nonfuel mineral production rose 1% over that of 1985.

Domestic mine production of ferrous metals declined as follows, in decreasing order of production: nickel, iron ore, tungsten, and molybdenum. All remaining domestic primary nickel and tungsten mines had closed down by yearend. Nonferrous metals that similarly declined included titanium, rare-earth metals, lead, silver, zinc, and magnesium. For the second consecutive year, aluminum, produced predominantly from imported bauxite, declined in production, while imports reached record-high levels. Somewhat modest gains were made in beryllium and copper. As has been the case for a number of years, gold was a bright spot in the domestic and international metal mining industry. Gold production was spurred on by the increasing usage and development of heap-leaching techniques that make lower grade ores, which were previously uneconomical, profitable. Additionally, various mining companies, the U.S. Mint, individual States, and a number of foreign countries began production of gold bullion and commemorative coins. Gold output in the United States increased from 2.43 million troy ounces (revised) in 1985 to about 3.73 million troy ounces in 1986, a dramatic 54% rise.

Along with gold, platinum was a very important target for mineral exploration and development, both domestically and internationally. Development of Montana's Stillwater palladium-platinum deposit proceeded. This operation was the first platinum mining operation in the United States since the mid-1970's and the first promising domestic prospect where substantial recoveries of palladium are anticipated. Though a small mine by South African standards, it will supply, at full capacity, a significant share of U.S. palladium needs and a partial share of platinum. A gallium and germanium facility in southern Utah began primary production in 1986; it will reduce U.S. dependence on imports when it reaches full production. This is significant, as some industry representatives expect substantial development of gallium mines worldwide during the next decade. Gallium has advantages over silicon in integrated circuits; it is inherently faster and far more resistant to radiation.[2]

Domestic mine production of industrial minerals was generally healthier than those of metals, with the exception of the following: phosphate, potash, and Frasch sulfur; barite and bentonite clays; and lime. The decline in these three groupings relates to the depressed state of the agricultural, oil and gas, and steel industries. Demand for cement remained strong while U.S. production dropped slightly. The cement industry was confronted with increasing U.S. reliance on cement imports—18% in 1986. Foreign ownership of domestic cement plants continued to rise, as 51% of U.S. finished cement was controlled by foreign-owned companies by the close of 1986.

Industrial minerals involved in construction, i.e., aggregate, sand and gravel, crushed stone, and gypsum, made a strong showing, with residential construction growing faster than commercial projects. Where plastics substituted for metals, filler and reinforcing minerals were given a boost, whereas refractories and fluxes were affected negatively.

Competition remained strong and continued to increase, especially in the metal industry, where prices have remained depressed and were forecast by many experts to remain so in 1987.[3] Most major companies realized that rigorous measures would have to be adopted in order to survive. Some reasons for this strong competition were inexpensive labor in many countries; overproduction by countries to meet their debts, causing oversupply and consequently lower prices; government support or ownership of some mining companies; relatively low energy costs in some countries; and the growing use of plastics and composite materials. Even the change in foreign exchange rates made a significant difference in some companies' viability in this highly competitive environment. These factors put a lot of pressure on the industrialized countries to cut costs in order to compete with developing countries, which are increasingly becoming "depended" upon for their raw materials, especially metals.[4]

In most of the industrialized countries, the greatest cost for producers was that of labor. Generally, wage cuts and new employment terms, which were less favorable than in workers' previous contracts, were agreed upon by the labor unions in the United States, rather than face mine or plant cutbacks or closings, with resultant layoffs. Also growing was competition from plastics and new composite materials as substitutes for the traditional materials. There were two major obstacles that these growing industries faced in taking over more of the traditional materials market: much higher cost and lack of material recyclability. The high costs were slowly being lowered, and recyclability was being studied but was progressing at an even slower pace.[5]

Creativity, including serving the customer's needs more energetically, and more cooperative efforts, as shown by recent agreements between labor and management, are needed in most mining and production efforts in order to compete in the present economic environment. The creativity is needed, both in business approaches and practices and also in the development of new and better technologies, wherever possible. Research and development, slowing down in the last several years owing to a tight money supply, is essential to new technology and competition in today's market. The cost of labor is unlikely to drop enough to remedy the situation, so business and scientific innovation will have to take up the slack. During 1986, one technological area that was making a definite and positive impact was computerization. The computer, adding speed, accuracy, and efficiency, was making inroads into most aspects of mining and beneficiation.

In the educational field, the University of Kentucky, with sponsorship from the Peabody Coal Co., developed an innovative alternative to the traditional classroom—the "Video Outreach Programme." With new technology being developed at its current rate, engineers of all types need periodic retraining. Often the distance between an appropriate university and the mining sites is prohibitive. The program comprised courses in the undergraduate mining engineering curriculum, the classes of which were videotaped while being taught on the university campus. These courses were available with college credit to individuals in companies involved in the minerals industry.[6]

Additionally, several short color films describing new technology developed through Bureau of Mines research were available from its Motion Picture Library in Pittsburgh, PA, on a free loan basis.

Legislation and Government Programs.—Under the Tax Reform Act of 1986

(Public Law 99-514), signed by the President in October, the U.S. corporate tax rate was reduced from 46% to 34%. Major tax incentives retained by the mining industry were the percentage depletion and the expensing of exploration and development costs. The effective depletion allowance for domestic iron ore decreased from 12.75% to 12.00%, effective January 1, 1987. However, the act eliminated investment tax credits and added a major new alternative minimum tax at a 20% rate. A number of mining companies will be subject to this new alternative tax, which has the following preferences added to the base: percentage depletion, exploration and development costs, accelerated depreciation on personal and real property, and one-half of the difference between actual company losses and the profit reported to its shareholders. Other corporate tax provisions included using unused investment tax credits to offset 25% of the tentative minimum tax liability and offsetting up to 90% of the minimum taxable income by the net operating losses.[7]

Also in October, the President approved the $9.0 billion Superfund Amendments and Reauthorization Act of 1986 (Public Law 99-499), a 5-year extension of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund) hazardous waste cleanup program. The Environmental Protection Agency (EPA) was required by the new law to start cleanup over the following 5 years at 375 sites—almost four times as many as during the initial 5 years of the program. In addition, the bill's cost was more than five times that of the initial 5-year toxic waste cleanup program. The EPA was given less discretion in the act because both standards and cleanup schedules were set by statute.[8] Also, some power was left to the individual States. In December, the U.S. Circuit Court of San Francisco declined to establish a uniform ruling nationwide when it decided that State law should be a determining factor in who is assigned Superfund cleanup liability in cases involving the sale of a plant. The metals recycling industry received exemption from the "chemical feedstock tax," a part of the Superfund revenue, because the metals being recycled were previously taxed when originally produced from primary material.

EPA left in place regulations that exempted mining waste from the hazardous waste requirements of the Resource Conservation and Recovery Act (RCRA). As part of a study to determine which specific processing wastes should be included in the exemption, the agency continued an investigation of six wastes that it considered potentially hazardous. The study had been ordered by a Federal court. The Hazardous Waste Treatment Council took issue with the EPA for including on the exemption list wastes from the primary smelting of aluminum, copper, ferroalloys, lead, and zinc, contending that the exemption was written not for processing wastes, but for the low-toxicity, high-volume wastes that result from mining alone.

Amendments to the Safe Drinking Water Act (Public Law 99-339) became law in midyear, requiring the EPA over the following 3 years to set standards for 83 contaminants while allowing 7 substitutions to the list. Also, a new Federal ground water protection program was established. These new laws assist the agency in enforcing the ban on injection of hazardous or radioactive wastes above an underground drinking water source. Additionally, EPA must issue rules within 18 months for the monitoring of wells where waste is to be injected below a drinking water source.[9]

The Clean Water Act (S. 1128), a renewal credits program, was passed by Congress and subsequently pocket vetoed by the President. The bill would have allowed companies to discharge certain pollutants into their municipal sewage systems if the local treatment plants could adequately remove those materials from the water. Without this legislation, steel mills, electroplating firms, and other industrial concerns in 26 cities could be adversely affected. For example, two steel companies in the Chicago Metropolitan Sanitary District might have to build $6 million worth of sewage treatment facilities of their own.

The debate on acid rain heated up in both Houses of Congress, where the major issues surrounded the questioned necessity of acid rain legislation and the proposed laws' economic consequences. More hard scientific evidence was called for concerning the causes and consequences of acid rain. Additionally, opponents claimed that the Clean Air Act appeared to be working, citing EPA's 1986 report stating that emissions of sulfur dioxide had declined 28% between 1973 and 1983. Everyone concerned agreed that the economic impact would be great, possibly costing a substantial number of electric utility companies, which were heavy users of coal, billions of dollars more annually by the mid-1990's.

The President's Commission on Americans Outdoors (PCAO) drafted a program proposal that included the establishment of an annual minimum $1.0 billion recreational trust fund as the successor to the Land and Water Conservation Fund, which was due to expire in 1989. The money would be used to acquire and rehabilitate lands for recreational use and create a nationwide network of corridors "to link together the open spaces of the American landscape." The mining industry could be affected by this program since PCAO was considering, as a funding alternative, increased severance taxes on nonrenewable resource extraction, including hard mineral mining, oil and gas drilling, and geothermal activities.[10]

The Office of Surface Mining published its final rule concerning conflicts between wild river preservation and proposed surface coal mining projects. Effective August 15, mining operations were prohibited along lands adjoining rivers under study pursuant to the Wild and Scenic Rivers Act until such study status would be removed.

With much concern all year over the international trade situation, the Export-Import Bank Act Amendments of 1986 (Public Law 99-472) was signed into law. The law extended the Export-Import Bank for 6 years and prohibited it from giving loans to companies producing specific commodities that compete with those of U.S. producers, unless the short- and long-term benefits outweighed the damage to U.S. producers. It also protects U.S. exports from unfair mixed credits and authorizes subsidizing export loans to U.S. firms under the "I-Match" program.

Congress voted to override the President's veto of legislation imposing economic and political sanctions on the Government of the Republic of South Africa. The law banned the import from the Republic of South Africa of a number of items including coal, steel, and uranium. Exempted from the ban were strategic minerals essential to the U.S. economy and defense needs. The law also required a report on the extent to which the United States is dependent on South African materials including chromium, cobalt, ferroalloys, manganese, and platinum-group metals.

The Military Land Withdrawals bill (Public Law 99-606) became law in November. The bill selectively allowed withdrawn military lands to be opened up to exploration and development under prevailing mining and mineral leasing laws. With the agreement of the military agency involved, the Secretary of the Interior was required to determine which public and acquired lands on five specified military reservations were suitable under current law to be opened for operation. Approximately 29 million acres of land is managed by the U.S. Department of Defense. A considerable amount of the land is not used actively by the military and could be opened to mining where such activity would not interfere with the military mission.

The Emery Mining Corp. was issued a favorable ruling in a precedent-setting mine safety-discrimination ruling by the Tenth Circuit U.S. Court of Appeals. The court held that mine operations were not required under the Mine Safety Act's mandatory training provision to compensate new miners for training expenses that they voluntarily undertook before being hired. The ruling said that the applicants were not "miners" when they voluntarily took on the independent courses.[11]

Through Public Law 99-272, the "black lung" tax, contained in H.R. 3128, was increased by 10% and made effective as of April 1. Additionally, the law provided for a one-time, 5-year moratorium on interest payments to the U.S. Treasury by the Black Lung Disability Trust Fund.

A hazard notification bill entitled "High-Risk Occupational Disease Notification and Prevention Act" was debated in Congress without final action. The bill, which was likely to come up in the 100th Congress, would create a new Federal agency that would find and assist worker groups that were determined to be at risk from exposure to hazardous substances at the workplace. The bill was very significant to industry lobbyists, including American Mining Congress representatives, because they believed that a wave of liability lawsuits could follow.

Two pieces of National Defense Stockpile (NDS) legislation were signed by the President. The first one authorized the selling of silver on the open market if it is not needed for coinage and if the silver in the stockpile is not reduced to the specified level by the end of the 1987 fiscal year. The second NDS amendment, contained in Public Law 99-661, (1) extended the prohibition on stockpile goal reductions through fiscal 1987; (2) required the President to appoint a stockpile manager, who had jurisdiction over the

National Defense Stockpile Fund; (3) expanded the use of that fund; (4) allowed conversion of some stockpile materials to their ferroalloys; (5) allowed the disposal of quantities of specified stockpile materials; and (6) required the Secretary of Defense to annually report on stockpile management recommendations for emergency situations.[12]

Legislation for a Federal charter for the National Mining Hall of Fame and Museum was introduced in both the Senate and the House. Leadville, CO, was selected for the museum's site because it was close to Denver, providing year-round accessibility. Some initial local financial assistance was provided, and the historic mining community solidly supported it.

Exploration.—Mineral exploration and development activity in the United States continued to decline in 1986 following the downward trend that started in 1981. Gold and precious metals were still the major commodities sought, with an estimated 80% of the exploration activities for gold alone.

Geologic data processing software, dealing with numerous geological applications, was becoming widely available following the trend of the past several years. A rapidly growing assortment of exploration-related software was available, including exploration and prospecting systems (artificial intelligence), mining and mineral exploration data bases, mineral identification, and educational exploration simulation, among others. The growth of software proceeded in conjunction with the continual upgrading and standardization of reliable and increasingly powerful microcomputers. The increasing affordability of microcomputer hardware continued, allowing more individuals and small companies to gain access to computers for their daily processing work. As extensions of home-base computer systems, many compact portable computers were developed that could be used in the field for immediate data processing by individual geologists, thereby saving both time and money.[13]

For recording field data, the Commonwealth Scientific and Industrial Research Organization of Australia developed a software package for a handheld computer developed by Husky Hunter Computers Ltd. of London, England. The company claimed that recording and logging time could be reduced by up to 50%. The Interactive Data Acquisition Software (IDAS) program was intended for a wide variety of applications, such as borehole logging, geophysical surveys, and inventory and lithologic data storage. It acts as an electronic notebook to directly record a data base from field surveys or studies and verify the data at the same time. Without recourse to an external, office-based computer system, the IDAS program can produce data base information and rapidly give feedback of results and trends. Data then can be transferred to a host computer via the computer's industry-standard RS 232 interface, eliminating any manual retranscription.[14]

Spurred on by healthy market prices and by the increasing use and development of more efficient heap-leaching techniques, formerly uneconomic gold properties, from old abandoned mines to virgin unmined areas, were explored and developed, with discoveries stretching from coast to coast. One such heap-leaching innovation involved injecting air into the heap, a process recently patented by R. M. Hughes. Copper minerals, iron sulfides, and other contaminants compete for the oxygen needed for gold cyanidation. Increasing the oxygen available shortens the time required to produce a given amount of dissolved gold. In effect, this increased production increases the leaching season in colder climates because gold and silver solubilities decrease rapidly below 50° F. This process also reduces operating costs in hot arid regions where usually both evaporation of water in the heap and the cost of replacement water are high.[15]

Canyon Resources Corp. of Golden, CO, initiated a major exploration program in the geologically favorable plate-boundary settings of the Carribbean Basin. The main target there was large-tonnage, open pit-minable epithermal gold deposits, some in areas that have never undergone significant prior exploration.

Exploration efforts continued off U.S. coasts in the Exclusive Economic Zone (EEZ). The U.S. Geological Survey (USGS) expanded knowledge of the seafloor environment in the EEZ by completing 750,000 square miles of seafloor mapping. Many new mineral targets, volcanoes, submarine landslides, and other significant features were discovered in the process. The Bureau of Mines, working jointly with USGS, collected 6 tons of seamount crust and rock off the Atlantic coast and was conducting large-scale processing studies to determine the feasibility of future seafloor mining of cobalt, manganese, and nickel. Off the Oregon and northern California coasts, the USGS continued studies of massive sulfide deposits in the Gorda Ridge and in the southern Juan de Fuca Ridge, where zinc sulfide minerals predominate near hydrothermal vents.[16]

Mineral Analysis Probe (MAP-2),[17] a small easy-to-use version of Scitec Corp.'s portable X-ray fluorescence (XRF) analyzer, was introduced at the American Mining Congress International Show in October. Capable of detecting and measuring elements of atomic number 40 and above, the MAP-2 uses atomic K-shell measurement instead of the shallower L-shell measurement used by most XRF instruments. Because more energy is involved in fluorescence by this method, the resulting data were claimed to be more reliable and repeatable than data from other portable assay methods. It could be used wherever an analysis is needed, from the initial exploration, to grade control in the mine and on through the mineral processing. Sampling and drilling programs can be guided by on-the-spot analysis of chips from quicker and less expensive percussion or rotary drilling. The entire system weighs about 7 pounds and can easily be carried and operated by a single person. An assay value is usually produced in 30 seconds to 2 minutes, after which MAP-2 can then be connected to a printer to output data stored in its microprocessor or to mine computers for further data processing. Scitec professes that the potential of the system lies in its simplicity and in its ability to reduce exploration and production costs. No special skills are required to operate the equipment, which most workers can learn to use in a few hours.[18]

With an eye on phosphorite deposits within its offshore EEZ, North Carolina's State government made a cooperative agreement with the U.S. Department of the Interior, which resulted in a $175,000 transfer of funds to the State for studying offshore deposits. North Carolina began soliciting research proposals to determine the costs of phosphate recovery from its Oslow Bay deposits, markets for those deposits, and the costs of complying with environmental regulations.[19] Most member countries of the Council for Mutual Economic Assistance (CMEA) were also active in geological surveying of the seabed. Intermorgeo is CMEA's coordinating center for marine geology and geophysics and is based in Moscow, U.S.S.R. Since 1973, surveys were conducted in the Central Atlantic, the Baltic Sea, the Black Sea, offshore Cuba, and in the Pacific Ocean. In the Pacific, an area of seabed measuring 1.5 million square kilometers has been examined by Intermorgeo. Valuable scientific material was gathered concerning geology, geomorphology, and lithology, as well as verifications and descriptions of the relationship between the location and character of manganese nodules. Further information has not been communicated to other marine geological bodies outside the CMEA. The worldwide acceptance of the 200-mile-wide EEZ has caused Intermorgeo to transfer its activities toward the deeper seas in recent years. Intermorgeo's program, sanctioned up to 1990, is in general an extension of the study relating to the structure of the seabed and an evaluation of raw material reserves in the oceans for future exploitation by CMEA-participating countries. The introduction and improvement of technology and equipment is also a major thrust of their efforts.[20]

Development.—Following the slow pace of exploration activities, the rate of development of new mining properties, especially those involving metals, reflected the low prices and the highly competitive times felt through much of the mining community. Gold again was the exception, standing in the forefront with over 40 new mines opening in the United States in 1986; most of these were in California, Colorado, Idaho, and Nevada. The Sleeper Mine in northwest Nevada, brought into production in April by AMAX Mineral Resources Co., was the lowest cost gold mine in the United States. AMAX claimed that direct cash operating costs for the first 10 months were about $55 per troy ounce.[21] AMAX discovered additional substantial gold and silver ore reserves near the present facility; thus, further development seemed likely.

Galactic Resources Ltd.'s Summitville gold mine is a prime example of a low-grade, moderate-tonnage project that is amenable to low-cost open pit mining and heap leaching, a growing practice of the North American mining industry in the past several years. In a historic mining area near the town of Durango in southwest Colorado, the mine sits between 11,150 feet and 12,150 feet high in the Rocky Mountains and was developed by Bechtel Civil & Minerals Inc. Galactic, based in Vancouver, British Columbia, Canada, began commercial production at Summitville in May and produced about 60,000 ounces each of gold and silver in 1986, with average cash gold production costs of about $150 per ounce.

At Summitville, there are two types of ore—one is a very porous and permeable vuggy silica ore and the other is a clay ore. They are first separated and crushed, and then are segregated on the leach pad, which will eventually reach 260 feet in depth. When completed in 1987, the leach pad will take up 106 acres in size and be able to contain 16.2 million tons of ore, with expansion to a 30-million-ton capacity still possible. Conventional-technique cyanide leaching is employed to recover the gold. To further extend the leaching season, Galactic will heat its leach solutions during the winter months to prevent freezing over of the leach sprays. As a result of experience gained during the construction of the mine in the mild winter of 1985-86, Galactic projects a longer leaching season. Year-round leaching occasionally may be possible as it was in the first winter of production (1986-87). When snow does accumulate, it is expected to provide an insulating blanket over the leach pad. The Summitville venture, which was initially based on proven reserves of almost 18 million tons of ore, is in a small portion of the collapsed caldera of the South Mountain dome. Four-tenths of a mile to the north, Galactic's further exploration indicates another 10 million tons of ore that might further extend it's operation.[22]

Musto Explorations Ltd. of Vancouver, British Columbia, Canada, contracted Small Mine Development Co. of St. George, UT, to develop Musto's Apex Mine, also in St. George. The Apex Mine, a small underhand cut-and-fill operation, was developed mainly for its gallium and germanium, which are contained within a series of iron oxides. Significant amounts of copper, lead, silver, and zinc are also present. The ore body occurs in a usually steeply dipping elongated pipelike structure, up to 25 meters wide. The degree of oxidation is variable and unpredictable throughout the ore zone, and the ore and its surrounding fractured, altered dolomite has little inherent strength. These incompetent materials made narrow drift cutting and cement backfilling essential. Sixty to seventy percent of the ore appeared to be free digging with little blasting necessary. The ore was accessed by crosscuts coming off of a declining ramp, 15 meters from and more or less parallel to the ore body.

Several existing problems were overcome. First, a diesel-powered, load-haul-dump (LHD) minivehicle was needed because high mobility was required for moving between undercut levels. With such a vehicle unavailable, John Clark Inc. of Denver, CO, designed and built the "50M" to meet Apex's specifications. It powered a 0.38-cubic-meter-capacity bucket and was 0.86 meter wide. This allowed smooth entry and exit from 2.1-meter-wide main crosscuts, set at 1.5-meter intervals, and into the 1.2-meter-wide stoping drifts. These dimensions were derived from the practices of local old-timers who routinely drove drifts that size, as larger ones caused more cave-ins. This narrow tunneling in soft ground presented ground support problems. The company's solution was to spray fiber-crete with an accelerator, 3 to 6 millimeters thick, directly onto the ribs and back. This "egg-shelling" stabilized the ground long enough to safely mine and backfill. One to three weeks after being backfilled with a cement and crushed limestone mixture, mining could be commenced beside or below a mined tunnel. This was the first pneumatically placed cemented-backfill system to be installed in North America and was designed and built by Hanna-Beric Systems of Pennsylvania.[23]

Research and Development.—Research and development (R&D) along with capital investment in current technology continued to be sluggish in 1986. In a study of the mining industry, Arthur D. Little Inc. of Cambridge, MA, compared the periods 1976-80 and 1981-85. It found that R&D expenditures, in nominal terms, remained unchanged and that capital expenditures for current technologies declined 20%. Measured in real dollars though, both declined significantly. Arthur D. Little also observed that in difficult and economically depressed times, R&D was deemphasized while companies concentrated on more controllable cost-cutting measures. The development of new technologies, often involving long-term projects, generally promised higher rewards, and this, in effect, was cost cutting. However, this came at the expense of higher and more substantial risks. Survival too often was the issue, making the higher profits of yet unseen future technologies unalluring. Approximately 5 years prior to the report, industry improved productivity and reduced costs considerably in some cases, often developing sounder business practices in the process. However, a sizable portion of these gains were reflections of large cuts in employment; the closing of inefficient, high-cost operations; and sometimes substantial wage and benefit reductions, rather than quantum technological advances.

Three problems that still faced the mining industry were (1) a declining intensity of minerals use accompanied by a growing displacement of mineral end uses by organic and composite materials, (2) unfavorable long-term pricing trends, and (3) the increased intensity of global competition. An increasing emphasis on the adoption of modern technology via capital expenditures, along with future technological advancements through research and development, may be critical to the mining industry's future profitability and its ability to compete with alternative material and energy sources.[24]

Addressing the situation, the Second International Conference on Innovative Mining Systems dealt with innovations in mining systems, advances in mining automation and robotics, and current work in the application and development of knowledge-based expert systems (artificial intelligence) to mining situations. Supported by the conference organizers, the ASME Mining and Excavation Research Institute was created as an independent nonprofit corporation. The institute is a consortium of industry and university researchers who are joining together in the building of a broad field of mining expertise to cooperatively accelerate the development of new and innovative mining methods and technologies necessary for the increasingly competitive future of mining.

Concerning the U.S. research community as a whole, a new lobbying organization called the Council on Research and Technology (Coretech) was formed. Coretech was an outgrowth of the Coalition for the Advancement of Industrial Technology (CAIT), which lobbied for two major research breaks that were included in the 1986 Tax Reform Act: continuation of the tax credit for business investment in research and development and the establishment of a new credit for industry support for basic science and engineering research at universities and nonprofit research centers. CAIT concentrated on the corporation's needs and was exclusively tax oriented, whereas Coretech was created with the intention of promoting both university and corporation research efforts by striking a balance between basic scientific and applied research. Coretech, which is a coalition of major companies and leading universities, intended to lobby for the extension of tax credits for high-technology research and development (some of which expire in 1988); money to help modernize university laboratories; and more fellowships for graduate work in science, engineering, and mathematics. In line with Coretech's purpose was the administration's plans to almost double over the next 5 years the budget of the National Science Foundation, the Government agency that finances much university research.[25]

Underground Mining.—Mining, mining equipment, and related service companies made efforts to compete in the world market by taking a number of steps forward in the development of improved and innovative mining methods and equipment. Stolar Inc. has achieved clear audible voice communication between separate coal mines. Company engineers used their Radio Automatic Monitoring voice communications equipment to coordinate a Radio Imaging Survey of a coal seam between two neighboring Pennsylvania mines. Similar technology had been used regularly for coördinating surveys within one mine but not between mines. Communication through the solid rock is possible because the roof and floor of the seam act as waveguides, concentrating the radio transmission within the seam.[26]

Introduced into mining operations in the 1970's, hydraulic drills and rigs were used initially on horizontal drilling in drifting and crosscutting, as well as stoping, which was primarily confined to room-and-pillar systems. Although hydraulic jumbos gained ground in horizontal applications, large-diameter in-the-hole drills, which usually were used for vertical or near-vertical downholes, were increasingly used in stoping steeply dipping ores and often replaced a sublevel stoping system that used pneumatic ring or fan drills. Hydraulic drilling increasingly attracted more attention because of its faster penetration rates and an improved working environment of less noise and better visibility. Manufacturers, because of a small market for the product, took until the early 1980's, starting with the Tamrock Div. of Tampella Ltd. and Atlas Copco AB, to develop hydraulic longhole rigs for ring and fan drilling. They have continued to improve the machinery, now offered with computerized control and automated rod handling. Wear on the rig is minimized since preprogrammed pressures and penetration rates cannot be exceeded. Effective drilling time is increased because the rig can remain in operation during lunch breaks and crew changes. Most similar rigs are as likely to be used in undercut troughing for blasthole stopes as they are for primary stope drifting. Essential to these hydraulic rigs is the definite need for very careful maintenance and training of maintenance personnel.[27]

In recent years, water-jet-assisted cutting of rock and coal formations has been under study by the Bureau of Mines, British Coal International, and various countries, such as the Federal Republic of Germany and France. As to the cutting rate and the energy expended by the motors of such cutting devices, results have been mixed, with the more encouraging results coming when cutting hard rather than softer rocks. In an attempt to increase productivity from longwall shearers in coal mines, the Bureau used a basic design made up of a mechanical pick or drag bit in tandem with a high-pressure water jet, directed just in front of the pick tip. Tests were performed on coal, as well as sandstones and limestones, which had confined compressive strengths of 8,000 pounds per square inch (psi). The high pick speeds and deep cutting action typical in most mining applications resulted in low water jet penetration, which was not the case when using lower speeds with shallower cuts in the initial laboratory testing. This crucially minimized the effective cutting since the major function of the water jet is to remove the "cushioning" fines ahead of the pick, thus increasing the stresses transmitted to uncut rock by the pick. Through-flush picks could overcome the problem and are the subject of further research. Hard-rock results were more encouraging. British Coal, under a Bureau contract, conducted successful underground tests of a prototype roadheader, which cut 17,000-psi limestone while using water-jet assist of 8,000 psi. Without the high-pressure water, the rock could not be cut.

Even more encouraging were the clear benefits achieved in reducing dust and machine and pick wear when cutting both hard and soft rock. Respirable dust reduction was considerable, measuring up to 90%, in real mining situations where water-jet-assisted roadheaders were used. This effect is a function of water pressure with a minimal adequate flow being necessary. Though not measured, it was visually obvious from tests of a water-jet-equipped, 33.5-inch-diameter boring machine that cuttings were larger as the water pressure was increased. This suggested that there should be fewer fines, which in turn should lead to dust reduction, which very markedly occurred in the tests. Pick wear also was reduced, sometimes considerably, probably as a result of pick cooling, which could be achieved at water pressures as low as 3,000 psi. This not only saves pick replacement costs, but productivity was increased as well. There was less downtime needed to change picks, and overall better cutting was achieved with less vibration-induced machine wear, because of the sharper picks. Researchers, especially in the United Kingdom and the Federal Republic of Germany, were investigating the possibility of cutting-force reductions at water-jet-assist pressures greater than 10,000 psi and under the typical pick speeds and penetration depths of mining equipment.[28] The Bureau was testing water pressures of 20,000 psi and above on high-compressive-strength materials. More than 60 water-jet-assisted roadheaders were in operation worldwide in 1986 as a direct result of Bureau research.

Researchers from the University of California at Berkeley and Flow Industries Inc. of the State of Washington cooperated on deep kerfing studies using abrasive water jets on norite, which is a hard rock with a relatively high compressive strength. Using a chromite abrasive and pressures up to 35,000 psi, they successfully cut the norite to a depth of 1 meter. The dominant influence on kerf depth was the jet power, which could be increased by either raising the pressure or the flow rate. Increasing the pressure is preferred because the water quantity as well as increases in underground temperatures can be minimized—water emerges from the nozzle at a high temperature. If chosen, the flow rate increase is achieved by using a larger diameter nozzle. The mass flow rate of the abrasive was shown to have only a secondary influence on the cut depth. Another result was that one slower pass of the abrasive jet rather than multiple fast passes was equally or more effective in most cases.[29]

The Bureau, taking the route of increased flow rate, was studying a prototype abrasive jet rock drill capable of drilling holes or deep narrow kerfs in hard rock. The drill operates with a 10,000-psi, 20-gallon-per-minute water jet into which 16 pounds of abrasive material is entrained per minute. The drill incorporated several novel design features. A collimator kept the high-velocity jet intact for over 6 feet from the nozzle. A jet diverter permitted the jet to cut a wide enough clearance for the drill to follow into the rock. The Bureau also incorporated inexpensive O-ring seals in a low-pressure swivel that was not subject to pressure levels as high as those found on the swivels in conventional water-jet drills.[30]

In laboratory studies, the Bureau was able to increase the drilling rates and bit life in conventional drilling with the addition of a number of rock surface conditioners. Impregnated-diamond coring drills were used on both Sioux quartzite and Westerly granite with varied concentrations of inorganic salt solutions as the drilling fluid. The Bureau embarked on this study both to maximize drilling and cutting efficiency in mining operations and to understand why some fluids help and some do not. The additive solution concentrations used were determined by their ability to neutralize the surface charge of the mineral components appearing on the rock surface. If applicable to large-scale drilling, certain rock surface conditioners could help increase productivity and reduce bit costs in mining operations.[31]

As in most aspects of mining, conveyors and conveyor belts were improved on in a variety of ways. Two interesting developments were a new approach to conventional conveying and a sturdy new conveyor belt material. A new concept in bulk materials conveying was introduced by Main Engineering AB of Sweden. Its "Non-Spill Conveyor" was intended to solve many problems of traditional conveyor configurations. Material spill from the belt was eliminated by inverting the conveyor system. All parts of the patented conveyor system were standard conventional units except a single but unique unloading device. The conveyor worked by carrying material on the lower strand of the belt. The return side was the upper belt. Both material-exposed surfaces faced inward and formed an enclosed configuration. The action involved in inverting the trough loosens most of the material from the belt surface, after which smaller particles still stuck to the belt surface eventually fall onto the lower conveying belt. Consequently, friction fires caused by spill buildup were prevented along with a reduction in accidents and health problems created by falling material and dust. The conveyor functioned well under all weather conditions and was reported to be comparable to conventional conveyors in its uses and overall costs. In its first year of operation, the first Non-Spill Conveyor moved over 300,000 metric tons of coal without problems from dockside to storage and loading in the Port of Gothenburg in Sweden.[32]

Depreux S.A. of Luxeuilles-Bains, France, produced a high performance, corrosion-resistant conveyor belt using E. I. du Pont de Nemours & Co. Inc.'s Kevlar para-aramid fiber for reinforcement. The new "solid woven" belts are comprised of a carcass reinforced with the Kevlar para-aramid fiber with an outer rubber cover. They operated with a breaking strength ranging from 1,800 to 3,150 newtons per millimeter and were manufactured in lengths between 420 and 1,440 meters. This resulted in a belt with excellent impact and wear resistance that required little or no maintenance. Ten such Depreux belts were used in European mines by yearend, and no specific maintenance had been required even after wear of the rubber edges. Steel belts require frequent stops for repairs in avoiding corrosion. The aramid fiber was also claimed to have significant advantages when it was used as a reinforcement over polyester and steel. It is stronger than polyester; it elongates comparably with steel; it does not corrode; and it encounters no splitting problems. Primed by their successes, Depreux sought other possible applications for its reinforced belt where extremes of wear and/or atmospheric conditions exist.[33]

Surface Mining.—Increasingly sophisticated on-board electronics and computer systems were the most obvious development in 1986, providing efficiency on all types of equipment. The miner was aided in a variety of ways, from assisting the operator in running the hydraulic shovel or walking dragline, to managing and monitoring the performance and productivity of the mine's mobile equipment. A substantial amount of new software was also available. Applications included designing an open pit mine using the three-dimensional Lerchs-Grossman method, computer-simulated blasting for better planned and more efficient blasting, and assisting mine maintenance managers and planners in making the most accurate repair and replacement decisions.

One way to improve open pit mining efficiency is to reduce the amount of mining equipment that is necessary for the job. Computer technology has assisted this situation in recent years with computer systems to dispatch open pit haulage trucks efficiently and continued to do so in 1986.

Such a system provided on-line performance statistics, available on demand during a shift, making possible the initiation of near instantaneous corrective action at problem sites. Typically, such a system was made up of a central computer, either in a control tower or connected to the tower by hardware or microwave. Digital data radio communication via repeaters linked microcontrol units aboard field equipment, such as trucks, shovels, and crushers, to the tower and central computer. Haul trucks received broadcasts via roadside beacons. By narrowly defining truck or shovel loading time, loaded truck travel time, dumping, empty travel time, queue time at the shovel or dump, spot time to get under a shovel on arrival, or leaving queue and shovel idle time while waiting for a truck to load, many on-line operating efficiencies could be programmed, continuously monitored, and called up for analysis. Such efficiencies could be used to determine truck dispatching efficiency and shovel dispatching efficiency, and these combined determined mine dispatching efficiency. Modular Mining Systems Inc. (MMS) of Tucson, AZ, which is this technology's leading developer, further refined its computer-based truck shovel dispatch system known as DISPATCH. In an effort to make its system more user friendly, among other improvements, MMS worked on DISPATCH "Version 4.2." MMS also expanded its number of successful installations worldwide to 12 with the addition of systems in Liberia and Colombia.[34]

A wider use of emulsion-type explosives, which can be prepared on-site, and nonelectric initiation systems are seen as trends for the immediate future. Nitroglycerine-based explosives accounted for a fair percentage of the explosives in most operations in 1986. They were used as primers for bulk explosives such as ammonium nitrate-fuel oil (ANFO) and for other specific purposes. ANFO, the most widely used bulk explosive, was inexpensive, easy to use, and safe to mix, but was not water resistant. Emulsion-type explosives were gaining in popularity because of their safety and versatility. They are very water resistant and can be accurately tailored to each application. The cartridge product, Emulite (solid), consists of ammonium nitrate and other oxides in an oil and wax mixture. The micrometer-size droplets provide a very large contact area for the explosive reaction, and the high water resistance results from the wax film that forms. Minute glass balloons are added to initiate the explosive by collapsing upon detonation. This creates myriads of hot spots throughout the mixture. The emulsion's sensitivity is controlled by the quantity of microballoons, and the force is affected by the amount of fuel additives. A pumpable slurry, called Emulan, can be produced by changing the proportions of oil and wax. Instead of a bulk product with one recipe, the explosive in the future will be tailored on-site to the hole size, rock strength, and other individual parameters.

To reduce vibration in environmentally sensitive areas and ensure good fragmentation, accurate timing of the blast is critical, enabling each charge to be detonated in the correct sequence. More accurate delay times and more interval times in each blast have been achieved by nonelectric initiation systems. Nonel, a nonelectric initiation cord, is an internally coated plastic tube that transmits a shock wave to the detonator. It is a little more expensive than an electric cord, but it is much safer because stray currents do not affect it. Nonel also is claimed to accommodate a far greater number of delay intervals. However, further technological advances in making more accurate delay times possible are still necessary to take full advantage of the nonelectric systems.[35]

Whether on the surface or underground, the decision to use electric or diesel power is often difficult. A very slow and yet steady shift to electric power for mining vehicles had been occurring for a number of years through 1986, but because of the high mobility of diesel-powered vehicles, the diesel was preferred and probably will remain so in the near future. It did not need hard-to-maneuver umbilical cables nor did it rely on the often less-than-needed power and endurance of today's batteries. Nevertheless, the advantages of the electric power source continued to encourage its increasing use and spurred on continuing research. Through improvements in electronics and by electrical engineering advances, electric power application grew in versatility, and research on the lithium alloy-iron monosulfide battery at the U.S. Department of Energy's Argonne National Laboratory was very encouraging. Tests showed an improvement of over 50% in the distance a vehicle could travel on one charge. Also under development at Argonne was a sodium-sulfur (Na-S) battery. Using a glass electrolyte, the Na-S battery has the potential to store four to seven times as much energy as a lead-acid battery of equivalent weight.

Electric-powered systems, though more expensive initially, were more efficient than diesel systems, leading to greater output at lower costs. They were often 15% to 20% lower in operating costs, while maintenance costs were extremely low as a result of fewer moving parts. Other benefits over diesel power included quieter operation with less pollution, less power loss at high altitudes, better tire wear from a smoother transmission that caused less wheel spin, and less expensive flameproofing. Electric drives in the last 20 years acheived a much improved power-to-weight ratio as well as an increased ability to withstand higher temperatures and unexpected surges in operating voltages. They increasingly were used on excavation equipment of all sizes; underground, most manufacturers offered electric drives on even their smallest LHD machines.[36]

Hydraulic excavators, which came on the scene prior to the mid-1950's, have proven to be among the most versatile pieces of mining and construction equipment ever produced. In the early 1980's, Orenstein & Koppel AG, a West German firm, built the world's largest hydraulic excavator, a 500-ton vehicle called RH300. Rapid growth in machine size, apparent until then, slowed because of a growing lack of large-scale mining developments. Though reversals of this trend are still unlikely, Mannesmann Demag Baumaschinen (Demag), also of the Federal Republic of Germany, introduced in midyear its 500-ton hydraulic excavator, the H-485, which became the world's largest, being a few tons heavier than the RH-300. Demag again took the single engine approach used in its other large excavators, including its 295-ton H-285, also introduced in 1986. Demag claimed that overall fuel consumption and maintenance costs were less than with twin-engine machines manufactured by other companies. Servicing is also simplified with a single engine unless the engine fails; a twin engine machine is still mobile if one of its two engines fail. The H-485 has a rock shovel with a 23-cubic-meter capacity and is designed to load 3,500 tons per hour. Assuming material with a density of 1.8 tons per cubic meter, it will load a 140- to 180-ton-capacity truck in four passes. A bullclam front shovel and a backhoe can be used with it. The undercarriage moves it at up to 2.1 kilometers per hour, provides a theoretical gradability of 60%, and has crawler shoes for both standard and low-ground-pressure applications.

The H-485's maximum horizontal reach is 18.8 meters; vertically, it rises to 20.3 meters, and its cleanup reach is 7.5 meters. This allows an operator, who has excellent visibility from 8 meters above the ground, to work from one position for long periods before having to move. Unlikely to be produced in large numbers in today's market, it has a lower priority for, and number of, microprocessors. It also has fewer operating, controlling, and monitoring systems than does the 500-ton excavator from Orenstein & Koppel.[37]

Formation rock strength and abrasiveness, which are critical factors when deciding the often unclear economic division between using hydraulic excavators or bucket-wheel excavators (BWE), became measurable with Demag's mobile measuring lip. Demag claims that it is adaptable to virtually any earthmoving machine and is very convenient to use. Because of cost considerations, BWE's, usually preferred for high tonnages of very soft loose material, may be desired for hard clays, schists, soft coals, etc. The lip enables direct measurements to be made of the cutting forces a BWE would encounter on the undisturbed formation. It has no sidecutters like a BWE and only loosens, does not remove, the material, but these factors are taken into account with suitable measuring, calculating, and control techniques. The lip is ideally suited to a hydraulic excavator with backhoe attachment because of the downward curved slicing motion that results. To best simulate the conditions of a BWE, the operating unit used must be capable of making a circular cut.[38]

The use of in-pit crushing increased as mine operators looked to belt conveyor systems for a more economical way to transport large volumes of material. A maximum size or granulation of the transported material, which is the major limitation of this method, is determined by belt width, speed, inclination, and troughing. Oversized material, which is approximately 30% of the belt width and over, must be reduced in size. Larger materials typically occur with harder consolidated formations especially if blasting is needed while excavating. Many different types of mobile and semimobile (not self-propelled) crushing units are available, the choice of which depends upon the material's size and composition and how much it must be reduced.

During the last 100 years, exploitation of much of the favorably situated, high-quality mineral surface deposits in the United States has made necessary the mining of deeper near-surface deposits by means of opencast mining. This has resulted in the need for more continuous and economical haulage of larger volumes of material. Through 1986, shiftable belt conveyors were proving to be a versatile and economical tool for extending the scope of standard conveying systems. When a surface mining operation is large enough or deep enough, transportation costs per ton are lower with conveyors than those of any other system. Only electric power and a few personnel are needed for its operation. Also, continuous systems usually lend themselves to easier reclamation of the land, a very important consideration with stricter environmental regulations being enforced worldwide for reclaiming mined-out areas. Shiftable conveyors are composed of specially constructed components: a drive station with approach bridge; conveyor modules with rails; and a return station with transfer feeder. The conveyor module design allows a certain flexibility but remains rigid during operation. The drive and return stations are usually mounted on pontoons but are anchored if necessary, in order to keep the entire shiftable conveyor stationary. When either the excavating or stacking operation has reached its limit, the unit is moved step by step to its new position by dozers, walking foot mechanisms, or transport crawlers, which are used for heavy stations.

In the future, large shiftable mining equipment will be necessary, especially where climate conditions are extreme or overburden removal is difficult. This is the case in the Rocky Mountains, where studies were under way to replace trucks and shovels with in-pit crushers linked to shiftable conveyors and stackers. One example in 1986 was the Captain Mine in Illinois, which transported its coal by truck but reclaimed the land by moving the overburden and topsoil by a conveyor system designed to handle 4,400 cubic meters per hour. The conveyor system was composed of three subsystems, each 4.4 kilometers long, containing a BWE, one spreader, and three shiftable conveyors (the face, connecting, and dump segments). During its first few months of operation, the availability of the complete system was 75%. Four or five times per year, the conveyors are advanced in 60-meter steps, which take 2 to 3 days each. A crew of five plus a shift supervisor operated the entire system.[39]

Remote Mining.—Remote mining is normally accomplished through a borehole containing appropriate piping and fluids that are associated with a variety of in situ leaching, solution, and water cutting and transport methods. Advances with the modern computer, automation including robotics, and vision and guidance systems, which include both real-time and artificial vision by means of digital image processing systems contribute to a broadening of the concept. Conventional underground mining involving the extended use of specially developed remote-controlled mining equipment, though not remote in the pure sense, makes the mining operation temporarily remote and provides greater safety for the miner. Such technological advancements during the year provided a portion of the ground work for new and innovative remote mining methods and technologies of the future, including a more extensive use of automation and robotics.

The areas within 25 feet of extraction faces are widely documented as the most hazardous areas in all of mining. The Bureau of Mines is attacking the problem by modifying thin-seam continuous miners (TSCM), normally operated within this 25-foot area, with remote operating systems that remove workers from the extraction face, and allow safe, efficient operation from a distant protected station. Two initial deployments were planned: (1) first as an element of a highwall coal extraction system and (2) to be followed by installation at a deep mine worked by the room-and-pillar method. The two different approaches employed modifications to a Jeffrey model 101-102 TSCM; a continuous haulage system; and an electronics system to supervise communications between the protected, human-engineered operator station and the TSCM. Major additions to the TSCM were to include two color television cameras; explosion-proof housing for the electronics package; and pressure, temperature, current, and linear displacement sensors. Operator commands, video signals, and sensory data were designed to be transmitted between the microprocessor in the operator station and the TSCM's microprocessing unit over a single cable run alongside the standard power and water lines. The operator controls the TSCM from a panel of digital and analog displays below two color television monitors, allowing the TSCM to operate as it normally would, only via a tethered control box.

The remote operating system is currently being interfaced to a new Jeffrey model

102HP TSCM to mine in a highwall extraction system. System evaluation and refinement, originally scheduled for late 1986, was rescheduled for July 1987 at the Bureau's mining equipment test facility at Bruceton, PA, with actual production mining still scheduled for the late summer.[40]

Automation is not new to mining but has greatly increased in the last decade with such introductions as hydraulic drills and expansions of computer applications. A long step toward robotization was taken when microprocessors became technically and economically feasible. Researchers in the mining equipment engineering field claimed that the technology was available to automate and/or robotize most of the major aspects of a mining operation. But such projects were expensive, and they were unsure how soon, if ever, that the expected advantages of these technologies could justify the costs, unless it would become possible to benefit from a completely robotized system. In softer rocks, this might be possible, but hard-rock mining involved the notable exception to the technological availability that the researchers professed. A new method of fragmentation in hard rocks would be needed. Mechanical fragmentation of coal and other soft rocks generally gives a comparatively well-defined product, which is easy to handle with most kinds of loading and transportation equipment, and therefore, amenable to automation. Many of the separate operations involved in hard-rock mining could be adapted to robotization, but owing to a lack of control over the size of some blasted materials, problems in loading and transportation would be created. More precise drilling and blasting might help but is unlikely to consistently produce ore fragments amenable to automated loading and transportation.[41]

If successful with coal alone, any further cost-effective automation would be very beneficial. According to the National Coal Association (NCA), coal, following its rebound that began in the mid-1970's, was the country's number one domestic energy source in both 1984 and 1985. The NCA reported that in 1985, domestic coal accounted for 30% of the Nation's British thermal unit production, although crude oil ran a close second with a 29.3% share. Data for 1986 had not yet been given.[42] With future acid rain legislation that is more favorable to industry interests and/or substantial successes in developing cleaner coal technologies, experts in the coal industry expected the upward trend to continue into the 21st century.[43]

Borehole television (TV), fairly new on the scene, is a potentially valuable investigative tool that now permits on-site viewing of boreholes and underground voids, both above and below the water table. As an addition to such traditional informational probes as drilling, core logging, and sampling, as well as geophysical surveys and ground water studies, this visual tool can complement procedures and be a permanent audiovisual record to study when used with a videocassette recorder. Westinghouse Electric Corp. developed a TV camera for use in a 3-inch-diameter borehole by modifying a miniature camera originally designed for nuclear inspection and by adding electro-optical technology advancements to it. The camera transmits a clear high-resolution image to a surface TV monitor for the in situ inspection of subsurface conditions. The camera head weighs only 450 grams but totals 77 kilograms when it is suspended a full 152 meters on its long cable. It can be lowered with the 152-meter cable by two persons and has an optional cable delivery reel for easier handling.

A wide range of applications was made possible through the designing of four lighted viewing attachments that allow adaption of the camera to four major needs: downhole viewing; close, sidehole viewing; the viewing of larger voids, caverns, and tunnels (up to a 30-foot distance in air); and a compass spotlight attachment that gives accurate directional information. The one major design tradeoff involved some overheating of the camera and its accessories in fulfilling the need for sufficient lighting in such a small contained space. During a geotechnical investigation, where visual inspection is sufficient, boring can be destructively drilled to the desired depth, thereby reducing the higher costs incurred from the often used core drilling. One of a variety of successful applications has been mine subsidence control projects in the Eastern United States. Mined areas that had been mapped were viewed for accuracy, and where mine workings were unmapped, the borehole camera was used to map existing voids, especially near an area where collapse was seen on the surface. In some cases, the injection of backfill was monitored underground. As future needs come up, further adaptations are anticipated along with the use of color, of continuous operation at greater depths, and possibly the eventual use of robotics down the hole.[44]

Beneficiation.—Whether to crush or grind ore is often a difficult decision. Because of the many variables involved, the nature of ore itself being the most important, there is no one comminution circuit that is the most efficient in all cases. Since comminution, followed by flotation, is usually the largest energy consumer in mineral processing, it is an obvious target in efforts aimed at cost cutting.

Jet milling, a new concept in autogenous grinding, was developed by Larox Oy of Finland, which claimed that up to 70% of energy costs can be saved over conventional methods. The process is based on interparticulate collisions between opposed compressed air suspension jets and has a wide range of applications, including the grinding of calcite, cement, quartz, slag, and talc. The material to be ground is dispersed and dried in hot suspension gases. It is then divided into two similar flows of material and directed into opposing nozzles, which accelerate the particles into the grinding chamber, where they collide and are broken down. The residual pressure of the transporting gases carries the particles to a pneumatic classifier, which works in closed circuit with the jet mill.[45]

Another new concept in comminution was under development at the Royal School of Mines in London, England. Plasma comminution, which relies on high-voltage pulses on the order of 1 megavolt, generates plasma (gas) within the rocks and explodes them from within. Through a complex but extremely fast (nanoseconds) process of heating and gasification, the solid in the current's path through the rock is converted directly to gas, which expands rapidly causing an explosive effect. Pulses of energy at 100 to 300 joules and at frequencies of 10 to 50 hertz are applied across the rocks, which are placed in a water medium in a chamber. The water improves the electrical contact between the electrode and the rock and prevents dust generation. Plasma forms in a dendritic fashion up to an optimum energy level, exploding the rock in all directions. Beyond that level, the charge tends to tunnel in a straight line through the rock and is less effective. There are four notable advantages of fragmentation by this method. First, tensile failure is the predominant cause of fracture, and it occurs preferentially along the natural grain boundaries of the rock, giving excellent liberation characteristics. Second, energy consumption is reduced since the rock is shattered under tensile stress. Tensile strength for many rocks is 20 to 70 times less than compressive strengths, which are contended with in conventional methods. Third, this process eliminates contact in the earliest stage of size reduction and should therefore reduce the heavy maintenance costs caused by the abrasion that is inherent with conventional crushing machinery. Last, although the power applied is very high, power consumption is low since the time involved is so short, typically nanoseconds. Design of a 100-ton-per-hour pilot plant was begun as well as test work in an emerald mine in Zimbabwe.[46]

In an effort to improve concentrate grade, increase productivity, and reduce costs, many companies used on-line XRF analysis to control their mineral processing operations. Though not a new technique, XRF, when used on-line for elemental analysis, provided a promising way for companies to operate more efficiently in an economic environment that demanded it. Balanced against its benefits are the initial capital costs and the continuing maintenance and operating expenses of the machinery. Two of Texas Nuclear Corp.'s XRF installations were claimed to be cost effective. At the Cyprus Mines Corp.'s Bagdad Mine in Arizona, five streams received analysis by XRF at the 50,000-ton-per-day copper-molybdenum operation, and the gross economic benefit was $1.1 million per year. This was based on a 1% increase in copper recovery. At the Fletcher operation of The Doe Run Co. in Missouri, three streams were being analyzed in that 5,000-ton-per-day lead-zinc facility. When considering zinc recovery by itself, Cyprus Mines realized a similar benefit of $800,000 per year, and also used less reagent. The XRF was used both for material balance and accounting, which require very accurate analysis, and for controlling the mineral processing. Process control, more suited to on-line XRF, requires less accuracy, but high precision and reproducability are necessary so that process changes can readily be observed and proper action taken. When a system was deemed appropriate by an interested company, Texas Nuclear advised the initial selection of a few key streams that would demonstrate the projected payback and give the operation experience with on-line analysis. Also advised was the choice of a system that was expandable as economic and process conditions merited.[47]

Another development in on-line analyzers was the Cyanostat, developed by Polymetron Ltd. of Switzerland. To ensure that there is enough free cyanide to dissolve the precious metals in a leaching solution, operators commonly overdose milling-grade ores with cyanide for the staged oxidizing leach cycle in pechucas or agitators. Cyanide is normally metered on empirically based head assays, feed rates, intuition, and other indicators based on experiences with specific ores. Among the variables encountered are grinding and flow rate fluctuations and the possible hourly changes in gold grade and ore types. Little is known of the leach environment on a real-time basis that would allow corrective actions to be automatically set in motion as conditions change. Several years prior to 1986, Gold Fields of South Africa Ltd. (GFSA) developed a two-step photometric method for determining free cyanide in solution. This involved the addition of excess reagent of known quantity to a filtered leach solution. If in equilibrium, then a colorless complex was formed, but when a chelating reagent was added to a solution containing an excess of the initial reagent, a colored complex resulted, the contents and quantity of which could be determined photometrically. After extensive and successful lab and plant testing, Polymetron was invited to design an analyzer based on GFSA's methods.

Polymetron used copper sulfate as the reagent. Any excess of copper ions unclaimed by the cyanide colored the solution blue when the chelating reagent ethylenediaminetetra-acetic acid was added, making the photometric analysis possible. Using special methods to reliably present a representative cut of the slurry, Polymetron's newly designed on-line analyzer, called the Cyanostat, was claimed to include a total microprocessor control package. It provides continuous sampling and filtration of leach slurries in up to six process streams along with fully automatic monitoring of their free cyanide contents. The company claimed that at typical cyanide consumption rates and costs in the Republic of South Africa at the end of 1986, it was reasonable to assume that a 200,000-metric-ton-per-month operation could save about $13,000 with an automatic cyanide metering system. This estimate was based in part on a test performed at GFSA's 180,000-metric-ton-per-month Kloof Mine. Over its normal usage there, the company saved 0.05 kilogram per metric ton of cyanide flake at $0.65 per kilogram. At that rate, a Cyanostat would pay back its capital cost in 3 to 4 months of reagent savings alone. Other advantages to be considered were the avoidance of gold losses and the real-time observations of the leach environment.[48]

Commonly used low-intensity wet magnetic separation is a very efficient method for processing iron ores but has a limited potential for the improvement of its selectivity. Poor selectivity is usually caused by the presence of nonmagnetic particles in the magnetic concentrate following magnetic flocculation. In an effort to increase iron yield, the vibromagnetic separator was developed at the Higher Institute of Mining and Geology in Sofia, Bulgaria. The researchers based their work on the idea that the agitation of the magnetic flocs or their partial destruction should create favorable conditions in the magnetic concentrate for entrapped nonmagnetics to drop down. The generation of low-frequency vibrations in the separation zone in the pulp should improve the selectivity of the process.

The vibromagnetic separator is made up of a standard permanent magnet drum separator with a vibrator mounted on the base of the bath under the drum. In operation, the vibrations are distributed perpendicular to the immersed drum surface, where the magnetic flocs are normally located, their long axes following the magnetic lines of force. Inherent in the design, the drum cycle sets up two gradationally distinct populations of flocs in the water, one smaller and the other larger. As a result, the vibrating liquid also makes the flocs pulsate. Although the magnetic particles are held steady by magnetic forces, the flocs are subjected to deformation. The nonmagnetic particles, subjected to friction forces within the flocs, should be liberated and pass freely into the pulp if the energy generated in the liquid is greater than the friction forces within the flocs. However, magnetic flocs can be partially or entirely destroyed if the vibration is too intense. The process was used successfully on several magnetic separators in industry. Variations for some installations were needed, such as an internal vibrator for the large magnetic separators. Roasted ore, which is more difficult to process, needed an inertial vibration device, which allowed the vibration parameters to be varied with the changing magnetic properties of the roasted ore. It had a frequency range of 20 to 200 hertz and amplitudes up to 3 millimeters. Variation in the intensity of vibrations created the desired degree of turbulence in the pulp to allow for the different magnetic properties of the particles to be separated.[49]

In an effort to reduce costs, a number of rotary kiln operators successfully used an insulation material called Lytherm 1535-GC. It was applied on the outer surface of the refractory material within the hot zone sections of the rotary kilns that were tested. According to Lydall Inc., manufacturer of the product, previous industry attempts had been unsuccessful because of the insufficient integrity of the insulating materials, usually ceramic papers, to withstand the applied stresses from the rotating kiln.

Lydall claimed it to be the first high-efficiency insulating product specifically designed for rotary kilns. Lytherm is made up of long, high-purity ceramic fibers combined with a blend of binder materials to give the toughness needed for such an application. Both sides of the insulation are clad with a fiberglass material to enhance abrasion resistance. Lytherm reduced the heat loss, which in turn reduced fuel combustion. The insulation material provided a thermal buffer between the refractory material and conditions outside the kiln, slowing down any drastic changes caused by outside ambient air, rain, etc. Less spalling of the refractory lining occurred because of a reduction in the temperature gradient of as much as several hundred degrees across the refractory. Because of the reduced heat loss, the refractory material could be worn down thinner than previously allowed before a refit was necessary. In a test of a similar kiln, the refractory lasted 50 weeks, whereas a Lytherm-insulated kiln was operating well after more than 85 weeks without signs of hot spots requiring a shutdown for repairs. One kiln, uncovered after more than a year's operation, showed that the material had withstood creepage forces. Additionally, Lydall stated that the material is firm yet compressible, which allows it to conform to irregular surfaces found in older kilns and also allows the liner rings and the keys to be installed much more tightly.[50]

Health and Safety.—Preliminary injury statistics compiled by the Mine Safety and Health Administration show that fatalities in 1986 were the lowest in history, with 47 miners killed in metal and industrial minerals mines. Although employment had dropped, the fatality rates were still very low, with nine fewer deaths than the previous record-low years of 1983 and 1985. Injury rates in 1986 came to 4.71 per 200,000 employee-hours, up a little from the 4.26 record low set in 1985. All 1986 figures included independent contractors.

The Bureau of Mines designed and field tested a model health and safety program, which, upon implementation, can improve mine safety by reducing occupational injuries and accidents. The program is based on five criteria: (1) it must be readily adaptable to all types and sizes of mines; (2) it should only identify essential features for illness and injury-reduction effectiveness; (3) the program must be manageable and compatible with U.S. management concepts to encourage its implementation; (4) it should strive for practices that are likely to increase overall profit; and (5) the model program, which is entirely voluntary, should be acceptable, without inducements, to all on its own merits of reduced losses owing to accident and illness alone. The program is a simple and inexpensive approach that stresses management's responsibility to do a more complete and better job. For example, according to the report, the separate listing of safety procedures and detailed programs in some cases are not necessary. Each employee should initially be given well-prepared instructions concerning the proper performance of his or her job, which take into account safety as well as other issues. The supervisor, having had basic safety and health training, needs to be actively involved in guiding the employee's progress, not just a disciplinarian. Feedback is an important aspect of the program. For example, if employees reported accidents that almost occurred, potentially dangerous situations could be evaluated and either improved on or corrected, thereby avoiding that costly future accident. Dramatic improvements occurred at the mines participating in the study, one a coal mine and the other a gold mine. The results strongly suggest that if the program is thoroughly understood and conscientiously implemented, it will significantly reduce injuries, illnesses, equipment damage, production losses, and other unplanned costs.[51]

A research cooperative, made up of the Canadian Center for Mineral and Energy Technology, the Ontario Ministry of Labor, and the Bureau of Mines as well as several private sector contractors and manufacturers, developed a new technology that reduces particulates (soot) and, in some cases, gaseous pollutants given off by diesel-powered vehicles in underground mines. Largely, it consists of a ceramic-element, diesel-particulate filter and a means for its regeneration. Their joint effort, begun in 1981, resulted in the development of a recirculating venturi scrubber to cool the hot gases, air quality monitoring and measurement techniques, an air quality index for evaluating underground mines using diesels, and the filter. The filter was novel, made from a honeycomb ceramic element that was altered and over the years optimized for filtration efficiency, durability, and effects on the mutagenic properties of the exhaust. Various means were devised to cause the soot to burn off as it was collected in order to avoid costly downtime for maintenance. Evaluations, including a simulated, carefully instrumented mine laboratory underground and an actual production situation, showed the filter's effectiveness with about 90% soot removal. It has an estimated life of about 2,000 hours, and mutagenic activity is greatly reduced.[52]

In another approach to the same problem, the Bureau entered into a cost-sharing project with EIMCO Mining Machinery International in the development of a novel and safe, nonpolluting power source for underground mining equipment. On an underground mining utility truck, they installed an 85-horsepower diesel engine, converted to burn hydrogen, along with a "solid-state" metal hydride hydrogen fuel storage system. Engine modifications, including turbocharging, adding an after-cooler, and using a parallel (hydrogen and air intake) fuel induction system, brought the output up to 102 horsepower while the engine emitted nitrogen oxide pollutants only, and at a mere 10% the rate of an equivalent diesel engine. The fuel storage system incorporated 21 separate metal hydride modules containing a total of 18 pounds of hydrogen. The hydride modules give the EIMCO 975, a 100,000-pound-payload vehicle, about 8 hours of use with a moderate load. Recharging the fuel is rapid; 90% of the hydrogen capacity is absorbed in 90 seconds with an ample flow of 68° F cooling water and 400 psi of hydrogen pressure. The engine, with 500 hours of test time, and the vehicle, with well over 170 hours of aboveground testing, have performed without problems or malfunctions. The disadvantages of the vehicle lie in the higher cost of hydrogen, three times that of diesel fuel, and in the heavy and space-consuming metal hydride fuel storage system. This new technology could be scaled up or down to replace any mobile piece of mining equipment, and in 1986, the engine was especially suited to use with track locomotives on long hauls, especially in locales where the electric power, needed to generate the hydrogen fuel, was relatively inexpensive.[53]

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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:									
1981	592	1,050	1,650	82	15	97	674	1,070	1,740
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
Industrial minerals:									
1981[2]	1,150	584	1,740	68	6	74	1,220	590	1,820
1982[3]	837	366	1,200	61	2	63	899	368	1,270
1983[2]	1,070	155	1,230	62	1	62	1,130	155	1,290
1984[3]	1,060	286	1,340	40	1	41	1,100	287	1,390
1985[2]	1,260	450	1,710	54	2	56	1,320	452	1,770
Total metals and industrial minerals:[1]									
1981	1,750	1,640	3,390	151	20	171	1,900	1,660	3,560
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

[1]Data may not add to totals shown because of independent rounding.
[2]Includes industrial sand and gravel. Construction sand and gravel data were not available for 1981, 1983, and 1985 because of biennial canvassing.
[3]Crushed and broken and dimension stone data were not available for 1982 and 1984 because of biennial canvassing.

Table 2.—Material handled at surface and underground mines[1] in the United States in 1985, 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	795	W	795	--	--	--	795	W	795
Copper	170,000	260,000	429,000	18,900	362	19,300	189,000	260,000	449,000
Gold:									
Lode	51,400	93,400	145,000	2,640	663	3,310	54,100	94,100	148,000
Placer	3,720	2,040	5,760	--	6	6	3,720	2,040	5,770
Iron ore	165,000	73,300	238,000	W	W	W	165,000	73,300	238,000
Lead	--	W	W	7,490	2,650	10,100	7,490	2,650	10,100
Silver	2,590	8,780	11,400	4,260	377	4,640	6,850	9,160	16,000
Uranium	938	16,000	17,000	391	137	527	1,330	16,100	17,500
Zinc	W	--	W	4,910	466	5,370	4,910	466	5,370
Other[3]	16,800	46,300	63,100	9,370	4,200	13,600	26,200	50,500	76,600
Total metals[2]	411,000	499,000	911,000	48,000	8,860	56,800	459,000	508,000	968,000
INDUSTRIAL MINERALS									
Abrasives[4]	140	W	140	W	--	W	140	W	140
Asbestos	1,100	4,410	5,510	--	--	--	1,100	4,410	5,510
Barite	733	W	733	W	W	W	733	W	733
Clays	44,600	e38,700	83,300	353	e5	358	44,900	e38,700	86,700
Diatomite	635	--	635	--	--	--	635	--	635
Feldspar	1,510	W	1,510	--	--	--	1,510	W	1,510
Gypsum	11,700	7,120	18,800	3,360	--	3,360	15,100	7,120	22,200
Mica (scrap)	837	W	837	--	--	--	837	W	837
Perlite	672	W	672	W	--	W	672	W	672

Phosphate rock	175,000	307,000	482,000	W	W	W	175,000	307,000	482,000
Potassium salts	--	--	--	11,500	W	11,500	11,500	W	11,500
Pumice[5]	565	113	679	--	--	--	565	113	679
Salt	340	W	340	14,300	1,200	15,500	14,700	1,200	15,900
Sand and gravel[6]	28,800	--	28,800	--	--	--	28,800	--	28,800
Sodium carbonate (natural)	--	--	--	5,680	W	5,680	5,680	W	5,680
Stone:									
Crushed and broken	987,000	[e]80,900	1,070,000	17,700	[e]124	17,800	1,000,000	[e]81,100	1,090,000
Dimension	2,440	[e]1,290	3,720	--	--	--	2,440	[e]1,290	3,720
Talc, soapstone, pyrophyllite	1,240	8,430	9,670	94	9	103	1,330	8,440	9,770
Vermiculite	1,620	W	1,620	--	--	--	1,620	W	1,620
Other[7]	2,150	2,300	4,450	777	695	1,470	2,920	3,000	5,920
Total industrial minerals[2]	1,260,000	450,000	1,710,000	53,800	2,040	55,800	1,320,000	452,000	1,770,000
Grand total[2]	1,670,000	950,000	2,620,000	102,000	10,900	113,000	1,770,000	961,000	2,740,000

[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, manganiferous ore, mercury, molybdenum, nickel, platinum-group metals, rare-earth metals, tin, titanium (ilmenite), tungsten, and metal items indicated by symbol W.

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

[5]Excludes volcanic cinder and scoria.

[6]Includes industrial sand and gravel. Construction sand and gravel data were not available for 1985 because of biennial canvassing.

[7]Includes aplite, boron minerals, greensand marl, iron oxide pigments (crude), kyanite, magnesite, olivine, wollastonite, and industrial mineral items 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 1985, by State

(Thousand short tons)

State	Surface			Underground			All mines[2]		
	Crude ore	Waste[2]	Total[3]	Crude ore	Waste[2]	Total[3]	Crude ore	Waste[2]	Total[3]
Alabama	28,400	3,870	32,300	W	W	W	28,400	3,870	32,300
Alaska	4,500	2,400	6,910	W	W	W	4,500	2,400	6,910
Arizona	142,000	153,000	295,000	W	W	W	142,000	153,000	295,000
Arkansas	17,700	14,000	31,600	--	--	--	17,700	14,000	31,600
California	51,700	21,900	73,600	1,270	27	1,300	53,000	21,900	74,900
Colorado	8,850	3,940	12,800	3,250	3,010	6,270	12,100	6,950	19,100
Connecticut	7,660	715	8,380	--	--	--	7,660	715	8,380
Delaware	W	--	W	--	--	--	W	--	W
Florida	233,000	306,000	539,000	--	--	--	233,000	306,000	539,000
Georgia	59,800	11,800	71,600	W	W	W	59,800	11,800	71,600
Hawaii	5,650	461	6,110	--	--	--	5,650	461	6,110
Idaho	12,300	33,300	45,600	1,020	W	1,020	13,300	33,300	46,600
Illinois	44,600	3,680	48,300	985	18	1,000	45,600	3,700	49,300
Indiana	24,700	2,800	27,500	W	--	W	24,700	2,800	27,500
Iowa	24,600	2,330	26,900	W	W	W	24,600	2,330	26,900
Kansas	16,000	2,000	18,000	2,300	W	2,300	18,300	2,000	20,300
Kentucky	36,800	3,560	40,400	2,080	15	2,090	38,900	3,580	42,400
Louisiana	5,860	715	6,570	5,090	W	5,090	10,900	715	11,700
Maine	1,530	166	1,700	--	--	--	1,530	166	1,700
Maryland	24,550	2,290	26,800	287	2	289	24,830	2,300	27,100
Massachusetts	9,830	1,080	10,900	--	--	--	9,830	1,080	10,900
Michigan	80,500	41,400	122,000	W	W	W	80,500	41,400	122,000
Minnesota	130,000	36,600	167,000	--	--	--	130,000	36,600	167,000
Mississippi	3,160	1,480	4,650	--	--	--	3,160	1,480	4,650
Missouri	48,500	5,270	53,700	13,600	2,730	16,300	62,100	8,000	70,100
Montana	15,800	8,770	24,500	3,260	1,010	4,360	19,000	9,870	28,900
Nebraska	3,060	441	3,500	1,390	10	1,400	4,450	451	4,900
Nevada	40,000	83,500	124,000	260	82	342	40,300	83,500	124,000
New Hampshire	1,800	236	2,030	--	--	--	1,800	236	2,030
New Jersey	18,600	1,400	20,000	W	W	W	18,600	1,400	20,000
New Mexico	37,300	107,000	144,000	16,100	606	16,700	53,500	108,000	161,000

New York	36,200	3,570	39,800	5,350	916	6,260	41,600	4,490	46,100
North Carolina	59,000	6,020	65,000	--	--	--	59,000	6,020	65,000
North Dakota	W	W	W	--	--	--	W	W	W
Ohio	41,900	5,170	47,100	W	W	W	41,900	5,170	47,100
Oklahoma	34,900	3,480	38,300	--	--	--	34,900	3,480	38,300
Oregon	16,600	1,420	18,100	1	1	2	16,600	1,430	18,100
Pennsylvania	65,500	6,280	71,800	1,260	9	1,270	66,700	6,280	73,000
Rhode Island	1,200	94	1,290	--	--	--	1,200	94	1,290
South Carolina	20,600	3,540	24,100	--	--	--	20,600	3,540	24,100
South Dakota	5,110	4,150	9,260	W	W	W	5,110	4,150	9,260
Tennessee	41,500	9,450	51,000	6,660	408	7,070	48,200	9,860	58,000
Texas	94,100	12,800	107,000	1,050	5	1,060	95,200	12,800	108,000
Utah	10,500	5,410	15,900	543	190	733	11,000	6,000	16,600
Vermont	2,500	349	2,850	--	--	--	2,500	349	2,850
Virginia	53,300	5,170	58,500	W	W	W	53,300	5,170	58,500
Washington	10,300	1,270	11,500	W	W	W	10,300	1,270	11,500
West Virginia	8,920	857	9,780	1,510	11	1,530	10,400	868	11,300
Wisconsin	15,600	1,210	16,900	92	1	93	15,700	1,210	16,900
Wyoming	6,050	16,700	22,700	5,780	330	6,110	11,800	17,000	28,800
Undistributed	9,870	6,610	16,500	28,600	1,430	30,000	38,500	8,050	46,500
Total[3]	1,670,000	950,000	2,620,000	102,000	10,900	113,000	1,770,000	961,000	2,740,000

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

Table 4.—Value of principal mineral products and byproducts of surface and underground ores mined in the United States in 1985

(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	$11.81	$1.53	$13,34	--	--	--	$11.81	$1.53	$13.34
Copper	8.91	.68	9.59	$7.74	$3.62	$11.36	8.79	.99	9.77
Gold:									
Lode	15.40	1.12	16.52	19.12	9.18	28.30	15.62	1.59	17.22
Placer	4.11	.01	4.12	W	--	W	4.11	.01	4.12
Iron ore	12.40	--	12.40	W	--	W	12.40	--	12.40
Lead	--	--	--	21.05	12.95	34.00	21.05	12.95	34.00
Silver	W	W	W	34.26	11.50	45.76	34.26	11.50	45.76
Zinc	W	W	W	29.15	.43	29.59	29.15	.43	29.59
Average[1]	11.24	.49	11.73	17.04	4.97	22.01	11.88	.98	12.86
INDUSTRIAL MINERALS									
Barite	28.52	--	28.52	W	--	W	28.52	--	28.52
Clays	22.30	.08	22.37	23.45	--	23.45	22.31	.08	22.38
Diatomite	199.93	--	199.93	--	--	--	199.93	--	199.93
Feldspar	12.34	56.63	68.97	--	--	--	12.34	56.63	68.97
Gypsum	7.81	--	7.81	6.74	.40	7.13	7.57	.09	7.66
Mica (scrap)	6.21	W	6.21	--	--	--	6.21	W	6.21
Perlite	14.63	--	14.63	W	--	W	14.63	--	14.63
Phosphate rock	3.63	--	3.63	W	--	W	3.63	--	3.63
Potassium salts	--	--	--	13.22	--	13.22	13.22	--	13.22
Pumice[2]	8.26	W	8.26	--	--	--	8.26	--	8.26
Salt	W	W	W	15.14	2.54	17.69	15.14	2.54	17.69

Sand and gravel[3]	12.51	W	12.51	--	--	--	12.51	W	12.51
Sodium carbonate (natural)	--	--	--	54.78	--	54.78	54.78	--	54.78
Stone:									
Crushed and broken	3.99	.04	4.03	5.58	--	5.58	4.02	.04	4.06
Dimension	69.55	--	69.55	--	--	--	69.55	--	69.55
Talc, soapstone, pyrophyllite	16.01	1.57	17.58	24.10	--	24.10	16.48	1.48	17.96
Vermiculite	21.15	--	21.15	--	--	--	21.15	--	21.15
Average[1]	5.23	.10	5.32	16.87	.99	17.86	5.65	.13	5.78
Average, metals and industrial minerals[1]	6.52	.18	6.71	16.95	2.87	19.82	7.08	.32	7.41
Average, industrial minerals (excluding sand and gravel and stone)[1]	7.38	.24	7.62	22.36	1.48	23.84	8.64	.35	8.98
Average, metals and industrial minerals (excluding sand and gravel)[1]	9.29	.36	9.66	19.33	3.47	22.80	10.27	.67	10.93

W Withheld to avoid disclosing company proprietary data.
[1]Includes unpublished data.
[2]Excludes volcanic cinder and scoria.
[3]Includes industrial sand and gravel. Construction sand and gravel data were not available for 1985 because of biennial canvassing.

Table 5.—Crude ore and total material handled at surface and underground mines in the United States in 1985, by commodity

(Percent)

Commodity	Crude ore		Total material	
	Surface	Underground	Surface	Underground
METALS				
Bauxite	100.0	--	100.0	--
Copper	90.0	10.0	95.7	4.3
Gold:				
Lode	95.1	4.9	97.8	2.2
Placer	100.0	--	99.9	.1
Iron ore	[1]100.0	W	[1]100.0	W
Lead	--	100.0	--	100.0
Silver	37.8	62.2	71.0	29.0
Uranium	70.6	29.4	97.0	3.0
Zinc	W	[2]100.0	W	[2]100.0
Average[3]	89.6	10.4	94.1	5.9
INDUSTRIAL MINERALS				
Abrasives[4]	[1]100.0	W	[1]100.0	W
Asbestos	100.0	--	100.0	--
Barite	[1]100.0	W	[1]100.0	W
Clays	99.2	.8	99.6	.4
Diatomite	100.0	--	100.0	--
Feldspar	100.0	--	100.0	--
Gypsum	77.7	22.3	84.8	15.2
Mica (scrap)	100.0	--	100.0	--
Perlite	99.3	.7	99.5	.5
Phosphate rock	[1]100.0	W	[1]100.0	W
Potassium salts	--	100.0	--	100.0
Pumice[5]	100.0	--	100.0	--
Salt	2.3	97.7	2.2	97.8
Sand and gravel[6]	100.0	--	100.0	--
Sodium carbonate (natural)	--	100.0	--	100.0
Stone:				
Crushed and broken	98.2	1.8	98.4	1.6
Dimension	100.0	--	100.0	--
Talc, soapstone, pyrophyllite	93.0	7.0	98.9	1.1
Vermiculite	100.0	--	100.0	--
Average[3]	95.9	4.1	96.8	3.2
Average, metals and industrial minerals[3]	94.3	5.7	95.9	4.1

W Withheld to avoid disclosing company proprietary data; included with "Surface" or "Underground."
[1]Includes underground; the Bureau of Mines is not at liberty to publish separately.
[2]Includes surface; the Bureau of Mines is not at liberty to publish separately.
[3]Includes unpublished data.
[4]Includes abrasive stone, emery, garnet, millstones, and tripoli.
[5]Excludes volcanic cinder and scoria.
[6]Includes industrial sand and gravel. Construction sand and gravel data were not available for 1985 because of biennial canvassing.

Table 6.—Crude ore and total material handled at surface and underground mines in the United States in 1985, by State

(Percent)

State	Crude ore		Total material	
	Surface	Under-ground	Surface	Under-ground
Alabama	[1]100.0	W	[1]100.0	W
Alaska	[1]100.0	W	[1]100.0	W
Arizona	89.1	10.9	94.3	5.7
Arkansas	100.0	--	100.0	--
California	97.6	2.4	98.3	1.7
Colorado	73.1	26.9	67.1	32.9
Connecticut	100.0	--	100.0	--
Delaware	100.0	--	100.0	--
Florida	100.0	--	100.0	--
Georgia	[1]100.0	W	[1]100.0	W
Hawaii	100.0	--	100.0	--
Idaho	92.3	7.7	97.3	2.7
Illinois	97.8	2.2	98.0	2.0
Indiana	[1]100.0	W	[1]100.0	W
Iowa	[1]100.0	W	[1]100.0	W
Kansas	87.4	12.6	88.6	11.4
Kentucky	94.7	5.3	95.1	4.9
Louisiana	53.5	46.5	56.0	44.0
Maine	100.0	--	100.0	--
Maryland	98.8	1.2	98.9	1.1
Massachusetts	100.0	--	100.0	--
Michigan	[1]100.0	W	[1]100.0	W
Minnesota	100.0	--	100.0	--
Mississippi	100.0	--	100.0	--
Missouri	78.1	21.9	76.7	23.3
Montana	82.9	17.1	84.9	15.1
Nebraska	68.8	31.2	71.5	28.5
Nevada	99.4	.6	99.7	.3
New Hampshire	100.0	--	100.0	--
New Jersey	[1]100.0	W	[1]100.0	W
New Mexico	69.8	30.2	89.6	10.4
New York	87.1	12.9	86.4	13.6
North Carolina	100.0	--	100.0	--
North Dakota	100.0	--	100.0	--
Ohio	[1]100.0	W	[1]100.0	W
Oklahoma	100.0	--	100.0	--
Oregon	100.0	--	100.0	--
Pennsylvania	98.1	1.9	98.3	1.7
Rhode Island	100.0	--	100.0	--
South Carolina	100.0	--	100.0	--
South Dakota	[1]100.0	W	[1]100.0	W
Tennessee	86.2	13.8	87.8	12.2
Texas	98.9	1.1	99.0	1.0
Utah	95.1	4.9	95.6	4.4
Vermont	100.0	--	100.0	--
Virginia	[1]100.0	W	[1]100.0	W
Washington	[1]100.0	W	[1]100.0	W
West Virginia	85.5	14.5	86.5	13.5
Wisconsin	99.4	.6	99.5	.5
Wyoming	51.2	48.8	78.8	21.2
Average[2]	94.3	5.7	95.9	4.1

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 1985, 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	19	--	--	2	3	7	7
Gold:							
Lode	75	21	6	13	22	12	1
Placer	33	7	15	4	6	1	--
Iron ore	21	1	--	4	3	7	6
Lead	10	1	--	2	3	4	--
Silver	23	6	5	4	6	2	--
Uranium	27	8	5	10	4	--	--
Zinc	11	--	--	1	9	1	--
Other[2]	62	1	6	45	6	4	--
Total	285	45	37	88	63	38	14
INDUSTRIAL MINERALS							
Abrasives[3]	17	9	2	6	--	--	--
Asbestos	3	--	--	1	2	--	--
Barite	21	--	10	9	2	--	--
Clays	917	29	203	543	142	--	--
Diatomite	10	--	2	6	2	--	--
Feldspar	12	--	1	4	7	--	--
Gypsum	67	--	4	21	41	1	--
Mica (scrap)	14	1	6	3	4	--	--
Perlite	11	--	3	5	3	--	--
Phosphate rock	35	--	1	1	11	15	7
Potassium salts	5	--	--	--	1	4	--
Pumice[4]	23	2	10	10	1	--	--
Salt	15	--	2	3	3	7	--
Sand and gravel[5]	172	9	21	67	74	1	--
Sodium carbonate (natural)	4	--	--	--	1	3	--
Stone:							
Crushed and broken	3,613	92	366	1,439	1,498	218	--
Dimension	273	62	140	70	1	--	--
Talc, soapstone, pyrophyllite	36	4	13	15	4	--	--
Vermiculite	5	--	--	3	1	1	--
Other[6]	31	1	17	7	5	1	--
Total	5,284	209	801	2,213	1,803	251	7
Grand total	5,569	254	838	2,301	1,866	289	21

[1]Excludes wells, ponds, or pumping operations.
[2]Includes antimony, beryllium, manganiferous ore, mercury, molybdenum, nickel, platinum-group metals, rare-earth metals, tin, titanium (ilmenite), and tungsten.
[3]Includes abrasive stone, emery, garnet, millstones, and tripoli.
[4]Excludes volcanic cinder and scoria.
[5]Includes industrial sand and gravel. Construction sand and gravel data were not available for 1985 because of biennial canvassing.
[6]Includes aplite, boron minerals, fluorspar, greensand marl, iron oxide pigments (crude), kyanite, magnesite, olivine, and wollastonite.

Table 8.—Twenty-five leading metal and industrial mineral[1] mines in the United States in 1985, in order of output of crude ore

Mine	State	Operator	Commodity	Mining method
		METALS		
Morenci	Arizona	Phelps Dodge Corp	Copper	Open pit.
Sierrita	do	Duval Sierrita Corp	do	Do.
Minntac	Minnesota	USX Corp	Iron ore	Do.
Empire	Michigan	Empire Iron Mining Co	do	Do.
Pinto Valley	Arizona	Newmont Mining Corp	Copper	Do.
Hibbing Taconite	Minnesota	Pickands Mather & Co	Iron ore	Do.
Tyrone	New Mexico	Phelps Dodge Corp	Copper	Do.
San Manuel	Arizona	Magma Copper Co	do	Caving and open pit.
Round Mountain	Nevada	Round Mountain Gold Corp	Lode gold	Open pit.
Tilden	Michigan	Tilden Mining Co	Iron ore	Do.
Erie Commercial	Minnesota	Pickands Mather & Co	do	Do.
Chino	New Mexico	Chino Mines Co	Copper	Do.
Ray Pit	Arizona	Kennecott	do	Do.
Peter Mitchell	Minnesota	Reserve Mining Co	Iron ore	Do.
National Pellet Project-Itasca.	do	M.A. Hanna Co	do	Do.
Thunderbird	do	Oglebay Norton Co	do	Do.
Inspiration	Arizona	Inspiration Consolidated Copper Co.	Copper	Do.
Eisenhower	do	ASARCO Incorporated	do	Do.
Bagdad	do	Cyprus Mines Corp	do	Do.
Green Cove	Florida	Associated Minerals Corp	Titanium	Dredging.
Golden Sunlight	Montana	Golden Sunlight Mines Inc	Lode gold	Open pit.
National Pellet Project-St. Louis.	Minnesota	M.A. Hanna Co	Iron ore	Do.
Minorca	do	Inland Steel Mining Co	do	Do.
Zortman-Landusky	Montana	Pegasus Gold Inc	Lode gold	Do.
Esperanza	Arizona	Duval Sierrita Corp	Copper	Do.
		INDUSTRIAL MINERALS[2]		
Noralyn	Florida	International Minerals & Chemical Corp.	Phosphate rock.	Open pit.
Swift Creek	do	Occidental Petroleum Corp	do	Do.
Kingsford	do	International Minerals & Chemical Corp.	do	Do.
Suwanee	do	Occidental Petroleum Corp	do	Do.
Ft. Green	do	Agrico Chemical Co	do	Do.
Lee Creek	North Carolina	Texasgulf Inc	do	Do.
Haynsworth	Florida	American Cyanamid Co	do	Do.
Lonesome	do	do	do	Do.
Georgetown	Texas	Texas Crushed Stone Co	Stone	Open quarry.
Calcite	Michigan	USX Corp	do	Do.
Clear Spring	Florida	International Minerals & Chemical Corp.	Phosphate rock.	Open pit.
Wingate Creek	do	Beker Industries Corp	do	Do.
Payne Creek	do	Agrico Chemical Co	do	Do.
Hookers	do	W. R. Grace & Co	do	Do.
Ft. Meade	do	Mobil Oil Corp	do	Do.
FEC Hialea	do	Rinker Materials Corp	Stone	Open quarry.
Rockland	do	USS Agri-Chemicals	Phosphate rock.	Open pit.
Stoneport	Michigan	Presque Isle Corp	Stone	Open quarry.
Pennsuco	Florida	Tarmac Florida Inc	do	Dredging.
Thornton	Illinois	General Dynamics Corp	do	Open quarry.
McCook	do	Vulcan Materials Co	do	Do.
International	New Mexico	International Minerals & Chemical Corp.	Potassium salts.	Stopes.
Hardee	Florida	C. F. Mining Corp	Phosphate rock.	Open pit.
Norcross	Georgia	Vulcan Materials Co	Stone	Open quarry.
St. Genevieve	Missouri	Tower Rock Stone Co	do	Do.

[1]Excludes brines and materials from wells.
[2]Includes industrial sand and gravel. Construction sand and gravel were not available for 1985 because of biennial canvassing.

Table 9.—Twenty-five leading metal and industrial mineral[1] mines in the United States in 1985, 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.
Sierrita	do	Duval Sierrita Corp	do	Do.
Inspiration	do	Inspiration Consolidated Copper Co.	do	Do.
Chino	New Mexico	Phelps Dodge Corp	do	Do.
Empire	Michigan	Empire Iron Mining Co	Iron ore	Do.
Ray Pit	Arizona	Kennecott	Copper	Do.
Pinto Valley	do	Newmont Mining Corp	do	Do.
Minntac	Minnesota	USX Corp	Iron ore	Do.
Tilden	Michigan	Tilden Mining Co	do	Do.
Hibbing Taconite	Minnesota	Pickands Mather & Co	do	Do.
Battle Mountain	Nevada	Battle Mountain Gold Co	Lode gold	Do.
Erie Commercial	Minnesota	Pickands Mather & Co	Iron ore	Do.
San Manuel	Arizona	Magma Copper Co	Copper	Caving and open pit.
Round Mountain	Nevada	Copper Range Co	Lode gold	Open pit.
Thompson Creek	Idaho	Cyprus Mines Corp	Molybdenum	Do.
National Pellet Project-Itasca.	Minnesota	M.A. Hanna Co	Iron ore	Do.
Bagdad	Arizona	Cyprus Mines Corp	Copper	Do.
Eisenhower	do	ASARCO Incorporated	do	Do.
Carlin & Maggie Creek	Nevada	Carlin Gold Mining Co	Lode gold	Do.
Jerritt Canyon	do	Freeport Gold Co	do	Do.
Thunderbird	Minnesota	Oglebay Norton Co	Iron ore	Do.
Peter Mitchell	do	Reserve Mining Co	do	Do.
Candelaria	Nevada	Nerco Minerals Co	Silver	Do.
Minorca	Minnesota	Inland Steel Mining Co	Iron ore	Do.
INDUSTRIAL MINERALS[2]				
Noralyn	Florida	International Minerals & Chemical Corp.	Phosphate rock.	Open pit.
Kingsford	do	do	do	Do.
Suwannee	do	Occidental Petroleum Corp	do	Do.
Swift Creek	do	do	do	Do.
Ft. Green	do	Agrico Chemical Co	do	Do.
Haynsworth	do	American Cyanamid Co	do	Do.
Clear Spring	do	International Minerals & Chemical Corp.	do	Do.
Payne Creek	do	Agrico Chemical Co	do	Do.
Lonesome	do	American Cyanamid Co	do	Do.
Wingate Creek	do	Beker Industries Corp	do	Do.
Hookers	do	W. R. Grace & Co	do	Do.
Lee Creek	North Carolina	Texasgulf Inc	do	Do.
Hardee	Florida	C. F. Mining Corp	do	Do.
Mabie Canyon	Idaho	Conda Partnership	do	Do.
Ft. Meade	Florida	Gardinier Inc	do	Do.
Georgetown	Texas	Texas Crushed Stone Co	Stone	Open quarry.
Calcite	Michigan	USX Corp	do	Do.
FEC Hialea	Florida	Rinker Materials Corp	do	Do.
Ft. Meade	do	Mobil Oil Corp	Phosphate rock.	Open pit.
Stoneport	Michigan	Presque Isle Corp	Stone	Open quarry.
Pennsuco	Florida	Tarmac Florida Inc	do	Dredging.
Thornton	Illinois	General Dynamics Corp	do	Open quarry.
Rockland	Florida	USS Agri-Chemicals	Phosphate rock.	Open pit.
McCook	Illinois	Vulcan Materials Co	Stone	Open quarry.
Conda	Idaho	J. R. Simplot Co	Phosphate rock.	Open pit.

[1]Excludes brines and materials from wells.
[2]Includes industrial sand and gravel. Construction sand and gravel were not available for 1985 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 1985, 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	1,090	663	1.6:1	--	--	--	1,090	663	1.6:1
Copper	thousand short tons	161,000	1,070	150.3:1	18,900	109	173.1:1	180,000	1,180	152.4:1
Gold:										
Lode	thousand troy ounces	42,000	2,040	206.:1	2,620	158	16.6:1	44,600	2,190	20.3:1
Placer	do	3,660	47	77.2:1	--	--	--	3,660	47	77.2:1
Iron ore	thousand long tons	164,000	48,300	3.4:1	W	W	W	164,000	48,300	3.4:1
Lead	thousand short tons	--	--	--	7,350	406	18.1:1	7,350	406	18.1:1
Silver	thousand troy ounces	W	W	W	4,210	23,500	.2:1	4,210	23,500	.2:1
Zinc	thousand short tons	W	W	W	4,930	178	27.7:1	4,930	178	27.7:1
INDUSTRIAL MINERALS										
Abrasives[3]	do	150	70	2.2:1	W	W	W	150	70	2.2:1
Asbestos	do	W	W	W	--	--	--	W	W	W
Barite	do	733	729	1.0:1	W	W	W	733	729	1.0:1
Clays	do	44,600	44,400	1.0:1	353	353	1.0:1	44,900	44,800	1.0:1
Diatomite	do	635	635	1.0:1	--	--	--	635	635	1.0:1
Feldspar	do	1,520	575	2.6:1	--	--	--	1,520	575	2.6:1
Gypsum	do	11,700	11,700	1.0:1	3,360	3,040	1.1:1	15,100	14,700	1.0:1
Mica (scrap)	do	848	110	7.7:1	--	--	--	848	110	7.7:1
Perlite	do	1,160	676	1.7:1	W	W	W	1,160	676	1.7:1
Phosphate rock	do	328,000	55,800	5.9:1	W	W	W	328,000	55,800	5.9:1
Potassium salts	do	--	--	--	11,800	1,230	9.6:1	11,800	1,230	9.6:1
Pumice[4]	do	551	508	1.1:1	--	--	--	551	508	1.1:1
Salt	do	W	W	W	14,300	14,300	1.0:1	14,300	14,300	1.0:1
Sand and gravel[5]	do	28,800	28,800	1.0:1	--	--	--	28,800	28,800	1.0:1
Sodium carbonate (natural)	do	--	--	--	5,710	4,740	1.2:1	5,710	4,740	1.2:1
Stone:										
Crushed and broken	do	987,000	978,000	1.0:1	17,700	17,700	1.0:1	1,000,000	996,000	1.0:1
Dimension	do	[e]2,440	1,110	2.2:1	--	--	--	[e]2,440	1,110	2.2:1
Talc, soapstone, pyrophyllite	do	1,540	1,090	1.4:1	96	94	1.0:1	1,640	1,190	1.4:1
Vermiculite	do	1,530	314	4.9:1	--	--	--	1,530	314	4.9:1

[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 abrasive stone, emery, garnet, millstones, and tripoli.
[4]Excludes volcanic cinder and scoria.
[5]Includes industrial sand and gravel. Construction sand and gravel data were not available for 1985 because of biennial canvassing.

Table 11.—Material handled per unit of marketable product at surface and underground mines[1] in the United States in 1985, by commodity

Commodity	Surface			Underground			Total[2]		
	Total material handled[3] (thousand short tons)	Marketable product (units)	Ratio of units of material handled to units of marketable product[4]	Total material handled[3] (thousand short tons)	Marketable product (units)	Ratio of units of material handled to units of marketable product[4]	Total material handled[3] (thousand short tons)	Marketable product (units)	Ratio of units of material handled to units of marketable product[4]
METALS									
Bauxite ---- thousand long tons	9,990	663	15.1:1	--	--	--	9,990	663	15.1:1
Copper ---- thousand short tons	429,000	1,070	400.1:1	19,300	109	173.1:1	449,000	1,180	379.1:1
Gold:									
Lode ---- thousand troy ounces	145,000	2,040	63.3:1	3,310	158	17.5:1	149,000	2,190	60.0:1
Placer ---- do	5,760	47	119.8:1	6	--	--	5,770	47	119.8:1
Iron ore ---- thousand long tons	238,000	48,300	4.8:1	W	W	W	238,000	48,300	4.8:1
Lead ---- thousand short tons	--	--	--	10,100	406	19.1:1	10,100	406	19.1:1
Silver ---- thousand troy ounces	11,400	W	W	4,640	23,500	.2:1	16,004	23,500	W
Zinc ---- thousand short tons	W	W	W	5,370	178	28.3:1	5,370	178	28.3:1
INDUSTRIAL MINERALS									
Abrasives[5] ---- do	197	70	2.0:1	W	W	--	197	70	2.0:1
Asbestos ---- do	5,510	W	--	--	--	--	5,510	W	W
Barite ---- do	748	729	1.0:1	W	W	--	748	729	1.0:1
Clays ---- do	e83,300	44,400	1.9:1	e358	353	1.0:1	e83,700	44,800	1.9:1
Diatomite ---- do	635	635	1.0:1	--	--	--	635	635	1.0:1
Feldspar ---- do	1,520	575	2.6:1	--	--	--	1,520	575	2.6:1
Gypsum ---- do	18,800	11,700	16.6:1	3,360	3,040	1.1:1	22,200	14,700	1.5:1
Mica (scrap) ---- do	1,000	110	9.1:1	--	--	--	1,000	110	9.1:1
Perlite ---- do	1,060	676	1.5:1	W	W	--	1,060	676	1.5:1
Phosphate rock ---- do	482,000	55,800	8.6:1	W	W	--	482,000	55,800	8.6:1
Potassium salts ---- do	--	--	--	11,800	1,240	9.6:1	11,800	1,240	9.6:1

Pumice[6]	do	679	508	1.3:1	--	--	--	679	508	1.3:1
Salt	do	W	W	--	15,500	14,300	1.0:1	15,500	14,300	1.0:1
Sand and gravel[7]	do	28,800	28,800	1.0:1	--	--	--	28,800	28,800	1.0:1
Sodium carbonate (natural)	do	--	--	--	6,010	4,740	1.3:1	6,010	4,740	1.3:1
Stone:										
Crushed and broken	do	1,070,000	978,000	1.1:1	17,800	17,700	1.0:1	1,090,000	996,000	1.1:1
Dimension	do	3,730	1,110	3.4:1	--	--	--	3,730	1,110	3.4:1
Talc, soapstone, pyrophyllite	do	9,670	1,090	8.3:1	103	94	1.0:1	9,770	1,190	7.8:1
Vermiculite	do	3,040	314	8.8:1	--	--	--	3,040	314	8.8:1

[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 development and exploration 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.
[7]Includes industrial sand and gravel. Construction sand and gravel data were not available for 1985 because of biennial canvassing.

Table 12.—Mining methods used in open pit mining in the United States in 1985, by commodity

(Percent)

Commodity	Total material handled: Preceded by drilling and blasting	Total material handled: Not preceded by drilling and blasting[1]
METALS		
Bauxite	99	1
Beryllium	1	99
Copper	94	6
Gold:		
Lode	99	1
Placer	--	100
Iron ore	88	12
Manganiferous ore	--	100
Mercury	10	90
Molybdenum	100	--
Nickel	100	--
Rare-earth metals	100	--
Silver	99	1
Tin	--	100
Titanium (ilmenite)	--	100
Tungsten	100	--
Uranium	32	68
INDUSTRIAL MINERALS		
Abrasives[2]	88	12
Aplite	100	--
Asbestos	100	--
Barite	91	9
Boron	--	100
Clays	--	100
Diatomite	--	100
Feldspar	100	--
Greensand marl	100	--
Gypsum	96	4
Kyanite	100	--
Magnesite	100	--
Mica (scrap)	21	79
Olivine	100	--
Perlite	68	32
Phosphate rock	10	90
Pumice[3]	27	73
Salt	3	97
Sand and gravel[4]	--	100
Stone:		
Crushed and broken	99	1
Dimension	--	100
Talc, soapstone, pyrophyllite	96	4
Vermiculite	78	22
Wollastonite	100	--
Average	73	27

[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.
[4]Includes industrial sand and gravel. Construction sand and gravel data were not available for 1985 because of biennial canvassing.

Table 13.—Exploration and development activity in the United States in 1985, 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	12,700	0.4	--	--	12,700	0.4
Diamond drilling	492,000	16.7	105,000	42.5	598,000	18.7
Percussion drilling	759,000	25.8	9,530	3.8	769,000	24.1
Rotary drilling	1,200,000	40.7	47,500	19.2	1,250,000	39.0
Other drilling	428,000	14.5	83,000	33.5	511,000	16.0
Trenching	57,300	1.9	2,520	1.0	59,800	1.9
Total[1]	2,950,000	100.0	248,000	100.0	3,200,000	100.0
DEVELOPMENT						
Drifting, crosscutting, or tunneling	459,000	86.8	39,400	99.0	499,000	87.7
Raising	64,900	12.3	418	1.0	65,300	11.5
Shaft and winze sinking	4,960	.9	--	--	4,960	.9
Solution mining	([3])	--	--	--	--	--
Total[1]	529,000	100.0	39,900	100.0	569,000	100.0
Grand total[1]	3,480,000	XX	288,000	XX	3,770,000	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 1985, by commodity

(Feet)

Commodity	Exploration: Churn drilling	Exploration: Diamond drilling	Exploration: Percussion drilling	Exploration: Rotary drilling	Exploration: Other drilling	Exploration: Trenching	Exploration: Total[1]	Development: Drifting, crosscutting, or tunneling	Development: Raising	Development: Shaft and winze sinking	Development: Solution mining	Development: Total[1]
METALS												
Antimony	--	--	--	--	--	--	--	250	--	--	--	250
Copper	--	5,300	W	W	W	20	5,320	44,500	W	--	--	44,500
Gold:												
Lode	W	298,000	344,000	207,000	71,500	54,400	975,000	70,500	8,290	896	--	79,700
Placer	--	--	--	W	W	466	466	1,260	--	--	--	1,260
Iron ore	--	W	--	--	--	--	W	5,430	--	--	--	5,430
Lead	W	W	W	--	W	--	W	49,000	1,230	--	--	50,200
Mercury	--	--	8,490	--	--	--	8,490	--	--	--	--	--
Silver	--	63,000	17,400	110,000	8,710	1,250	200,000	17,900	1,850	2,320	--	22,100
Uranium	--	W	76,900	619,000	52,800	--	748,000	11,000	1,450	--	W	12,400
Zinc	--	48,800	W	17,000	--	1,120	66,900	35,300	3,840	--	--	39,100
Other[2]	12,700	76,900	313,000	247,000	294,000	32	944,000	[3]224,000	48,200	1,750	([3])	274,000
Total[1]	12,700	492,000	759,000	1,200,000	428,000	57,300	2,950,000	459,000	64,900	4,960	--	529,000
INDUSTRIAL MINERALS												
Barite	--	--	W	--	--	--	W	392	--	--	--	392
Diatomite	--	--	--	5,000	--	--	5,000	--	--	--	--	--
Pumice[4]	--	--	--	--	--	2,500	2,500	--	--	--	--	--
Salt	--	--	--	--	--	--	--	30,300	--	--	--	30,300
Other[5]	--	105,000	9,530	42,500	83,000	20	240,000	8,730	418	--	--	9,150
Total[1]	--	105,000	9,530	47,500	83,000	2,520	248,000	39,400	418	--	--	39,900
Grand total[1]	12,700	598,000	769,000	1,250,000	511,000	59,800	3,200,000	499,000	65,300	4,960	--	569,000

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, mercury, molybdenum, platinum-group metals, tungsten, and items indicated by symbol W.
[3]"Solution mining" included with "Drifting, crosscutting, or tunneling" to avoid disclosing company proprietary data.
[4]Excludes volcanic cinder and scoria.
[5]Includes boron minerals; fluorspar; lime; phosphate rock; stone (crushed); talc, soapstone, and pyrophyllite; vermiculite; wollastonite; and mineral items indicated by symbol W.

Table 15.—Exploration and development in the United States in 1985, by State

(Feet)

State	Exploration							Development				
	Churn drill-ing	Diamond drilling	Percussion drilling	Rotary drilling	Other drilling	Trench-ing	Total[1]	Drifting, cross-cutting, or tunneling	Rais-ing	Shaft and winze sinking	Solution mining	Total[1]
Alaska	--	54,000	800	32,600	--	1,150	88,600	W	W	--	--	W
Arizona	--	21,100	4,150	W	20,000	3,100	48,400	37,600	W	2,440	--	40,100
California	--	23,100	45,600	50,700	43,200	1,110	164,000	2,610	650	W	--	3,260
Colorado	--	32,200	W	W	1,650	W	33,800	20,000	3,720	W	--	23,800
Idaho	--	32,900	W	W	785	--	33,400	9,700	2,070	W	--	11,700
Maine	--	1,540	--	--	--	--	1,540	--	--	--	--	--
Missouri	W	W	--	--	W	--	W	50,700	--	--	--	50,700
Montana	--	29,600	10,600	21,600	--	10,400	72,200	10,800	994	W	--	11,800
Nevada	W	16,600	208,000	234,000	12,600	39,200	510,000	5,380	W	--	--	5,380
New Hampshire	--	698	--	--	--	--	698	--	--	--	--	--
New Mexico	--	14,200	57,900	39,700	45,100	435	157,000	25,300	13,500	--	--	38,900
New York	--	W	--	--	--	--	W	42,800	2,370	--	--	45,200
Oregon	--	1,750	W	2,000	--	120	3,870	240	60	--	--	300
South Carolina	--	W	3,000	2,500	--	2,500	5,500	--	--	--	--	--
South Dakota	--	190,000	105,000	7,830	W	--	302,000	W	W	--	--	W
Tennessee	--	W	W	--	W	--	W	28,300	W	--	--	28,300
Utah	--	6,130	27,000	76,600	7,500	--	117,000	11,400	W	--	--	11,400
Washington	--	8,590	6,080	--	W	970	15,600	W	30	--	--	30
Wyoming	--	--	--	107,000	--	--	107,000	--	--	--	--	--
Undistributed[2]	12,700	166,000	301,000	675,000	380,000	771	1,540,000	[3]254,000	41,800	2,520	([3])	298,000
Total[1]	12,700	598,000	769,000	1,250,000	511,000	59,800	3,200,000	499,000	65,300	4,960	--	569,000

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, Florida, Illinois, Kentucky, Louisiana, Michigan, Minnesota, New Jersey, Texas, and items indicated by symbol W.
[3]"Solution Mining" included with "drafting, 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 1985, by commodity and State

(Thousand short tons)

	Shaft and winze sinking	Raising	Drifting, crosscutting, or tunneling	Stripping	Total[1]
COMMODITY					
METALS					
Antimony	1	--	--	--	1
Copper	300	W	--	11	311
Gold:					
Lode	487	39	9	16,000	16,500
Placer	6	--	--	81	87
Iron ore	78	--	--	W	78
Lead	2,390	4	--	--	2,400
Mercury	--	--	--	1,100	1,100
Silver	95	46	13	674	827
Tungsten	--	--	--	2	2
Uranium	65	6	--	6,530	6,600
Zinc	316	11	--	--	327
Other[2]	3,120	760	301	10,300	14,500
Total[1]	6,860	867	322	34,700	42,700
INDUSTRIAL MINERALS					
Barite	9	--	--	15	24
Salt	759	--	--	--	759
Talc, soapstone, pyrophyllite	W	W	--	557	557
Other[3]	29	2	--	2,260	2,290
Total[1]	797	2	--	2,830	3,630
Grand total[1]	7,650	869	322	37,500	46,300
STATE					
Alaska	W	W	--	80	80
Arizona	213	W	15	685	914
California	9	2	W	4,730	4,740
Colorado	W	257	301	1,140	1,700
Idaho	63	47	W	W	110
Missouri	2,440	--	--	--	2,440
Montana	675	422	W	562	1,660
Nevada	78	W	--	9,800	9,870
New Mexico	204	39	--	75	318
New York	708	9	--	1	718
Oregon	1	([4])	--	--	1
South Carolina	--	--	--	261	261
Tennessee	341	W	--	--	341
Utah	89	W	--	--	89
Washington	W	([4])	--	184	184
Wyoming	--	--	--	6,340	6,340
Undistributed[5]	2,830	92	7	13,600	16,600
Total[1]	7,650	869	322	37,500	46,300

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]Includes molybdenum, platinum-group metals, and items indicated by symbol W.
[3]Includes abrasives, asbestos, fluorspar, gypsum, perlite, phosphate rock, pumice, vermiculite, and items indicated by symbol W.
[4]Less than 1/2 unit.
[5]Includes Arkansas, Illinois, Kansas, Kentucky, Louisiana, Michigan, Minnesota, New Jersey, North Carolina, Oklahoma, South Dakota, and items 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
1981	2,249,262	695,449	493,771	3,438,482	902,567	4,341,049
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	2,241,303	382,410	510,500	3,134,213	666,141	3,800,354

[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				
1981	49,814	166	1,638	51,618
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
OTHER HIGH EXPLOSIVES				
1981	22,314	23,384	43,223	88,921
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
WATER GELS AND SLURRIES				
1981	99,796	174,528	86,671	360,995
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
AMMONIUM NITRATE: FUEL—MIXED AND UNPROCESSED				
1981	2,077,338	497,371	362,239	2,936,948
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]	2,051,177	306,174	374,266	2,731,617
TOTAL				
1981	2,249,262	695,449	493,771	3,438,482
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	2,241,303	382,410	510,500	3,134,213

[1]Data for 1985 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, Division of Ferrous Metals. The author was assisted in preparation of this chapter by Barbara M. Carrico, Chief, Branch of Nonferrous Metals Data; Sarah P. Guerrino, Chief, Branch of Ferrous Metals Data; Barbara E. Gunn, Chief, Branch of Industrial Minerals Data; William L. Zajac, Chief, Branch of Geographic Data.

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

Mineral	1984 Quantity	1984 Value (thousands)	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
METALS						
Antimony (content of ore and concentrate) short tons	557	W	W	W	W	W
Bauxite thousand metric tons, dried equivalent	856	$15,643	674	$12,855	510	$10,366
Copper (recoverable content of ores, etc.) metric tons	1,102,613	1,625,116	1,105,758	1,632,483	1,147,277	1,670,660
Gold (recoverable content of ores, etc.) troy ounces	2,084,615	751,833	[r]2,427,232	[r]771,032	3,733,190	1,374,710
Iron oxide pigments, crude short tons	53,017	2,819	46,585	2,826	40,987	2,908
Lead (recoverable content of ores, etc.) metric tons	322,677	181,745	413,955	174,008	339,793	165,150
Magnesium metal[2] short tons	--	--	--	--	138,493	423,788
Manganiferous ore (5% to 35% Mn) short tons, gross weight	88,423	860	19,882	W	14,320	W
Mercury 76-pound flasks	19,048	W	16,530	W	W	W
Molybdenum (content of ore and concentrate) thousand pounds	102,405	326,780	111,936	347,812	95,006	240,484
Nickel (content of ore and concentrate) short tons	14,540	W	6,127	W	1,175	W
Silver (recoverable content of ores, etc.) thousand troy ounces	44,592	363,006	[r]39,433	[r]242,205	34,220	187,183
Tungsten (content of ore and concentrate) metric tons	1,173	13,409	983	9,143	817	5,774
Vanadium (content of ore and concentrate) short tons	1,617	24,551	W	W	W	W
Zinc (recoverable content of ores, etc.) metric tons	252,768	270,833	226,545	201,607	202,983	170,050
Combined value of beryllium concentrate, iron ore (usable), magnesium chloride for magnesium metal (1984-85),[3] rare-earth metal concentrates, tin, titanium concentratess (ilmenite and rutile), zircon concentrate, and values indicated by symbol W	XX	2,427,624	XX	[r]2,234,916	XX	1,562,607
Total[4]	XX	6,004,000	XX	[r]5,629,000	XX	5,814,000
INDUSTRIAL MINERALS (EXCEPT FUELS)						
Abrasive stones[5] short tons	1,290	602	1,157	515	W	W
Asbestos metric tons	57,422	24,238	57,457	20,485	51,437	17,367
Barite thousand short tons	775	25,445	739	21,501	297	12,326
Boron minerals do	1,367	456,687	1,269	404,775	1,251	426,086
Bromine thousand pounds	385,000	95,000	320,000	80,000	310,000	93,000
Calcium chloride (natural) short tons	[e]838,000	[e]93,000	W	W	W	W
Cement:						
Masonry thousand short tons	3,281	219,877	3,187	213,096	3,525	231,551
Portland do	74,376	3,810,446	74,250	3,817,335	75,181	3,759,942
Clays do	43,702	1,032,127	44,974	1,011,377	44,620	1,095,179
Diatomite do	627	120,926	635	127,030	628	128,362
Emery short tons	W	W	W	W	2,878	W
Feldspar do	710,000	23,500	700,000	22,800	735,000	26,100
Fluorspar do	[e]72,000	W	66,000	W	[e]78,000	W
Garnet (abrasive) do	29,647	[e]2,487	36,727	2,973	32,296	2,603
Gem stones	NA	[e]7,450	NA	[e]7,425	NA	9,247
Gypsum thousand short tons	14,319	113,671	14,726	114,229	15,789	102,047
Helium:						
Crude million cubic feet	W	W	W	W	432	9,504
Grade-A do	1,642	61,575	1,865	69,938	1,941	72,788
Lime thousand short tons	15,922	811,183	15,690	809,000	14,474	757,867
Mica (scrap) do	161	7,139	138	6,330	148	7,108
Peat do	814	19,907	882	21,892	1,012	23,560
Perlite do	498	16,638	507	17,160	507	15,646
Phosphate rock thousand metric tons	49,197	1,182,244	50,835	[r]1,236,000	38,710	878,000
Potassium salts (K_2O equivalent) do	1,639	241,800	1,266	178,400	1,147	152,000
Pumice thousand short tons	502	4,929	508	4,553	554	5,756
Salt do	39,225	675,099	[r]40,067	[r]739,609	36,663	665,400
Sand and gravel:						
Construction do	773,900	2,244,000	[e]800,100	[e]2,438,000	883,000	2,747,200
Industrial do	29,380	377,200	29,430	374,070	27,420	359,300
Sodium sulfate (natural) do	435	40,125	389	35,860	396	34,102
Stone:[6]						
Crushed do	[e]956,000	[e]3,755,600	1,000,800	4,053,000	[e]1,023,200	[e]4,255,000
Dimension do	[r e]1,141	[r e]161,912	[r]1,104	[r]172,435	[e]1,163	[e]173,269

See footnotes at end of table.

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

Mineral	1984 Quantity	1984 Value (thousands)	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
INDUSTRIAL MINERALS (EXCEPT FUELS) —Continued						
Sulfur (Frasch) thousand metric tons	5,001	$546,106	4,678	$573,570	4,180	$508,512
Talc and pyrophyllite thousand short tons	1,127	23,167	1,269	29,188	1,302	31,227
Tripoli short tons	124,482	699	W	W	117,174	918
Vermiculite thousand short tons	315	31,500	314	32,400	317	34,400
Combined value of aplite, asphalt (native), graphite (1984), iodine, kyanite, lithium minerals, magnesite, magnesium compounds,[7] marl (greensand), olivine, pyrites, sodium carbonate (natural), staurolite, wollastonite, and values indicated by symbol W	XX	937,900	XX	r1,046,003	XX	1,003,162
Total[4]	XX	r17,164,000	XX	r17,681,000	XX	17,639,000
Grand total[4]	XX	r23,168,000	XX	r23,309,000	XX	23,452,000

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]Magnesium metal (refinery production) not reported in 1984 and 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 1986

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

[1]Grindstones, pulpstones, and sharpening stones; excludes mill liners and grinding pebbles.

Table 3.—Value of nonfuel mineral production in the United States and principal nonfuel minerals produced in 1986

State	Value (thousands)	Rank	Percent of U.S. total	Principal minerals, in order of value
Alabama	$405,216	19	1.73	Cement (portland), stone (crushed), lime, sand and gravel (construction).
Alaska	91,480	42	.39	Sand and gravel (construction), gold, stone (crushed), cement (portland).
Arizona	1,556,035	3	6.63	Copper, sand and gravel (construction), cement (portland), molybdenum.
Arkansas	263,007	29	1.12	Bromine, stone (crushed), cement (portland), sand and gravel (construction).
California	2,269,417	1	9.68	Cement (portland), sand and gravel (construction), boron minerals, stone (crushed).
Colorado	370,008	23	1.58	Molybdenum, cement (portland), sand and gravel (construction), gold.
Connecticut	80,454	43	.34	Stone (crushed), sand and gravel (construction), feldspar, sand and gravel (industrial).
Delaware	[1]4,169	50	.02	Magnesium compounds, sand and gravel (construction), marl (greensand), gem stones.
Florida	1,295,153	4	5.52	Phosphate rock, stone (crushed), cement (portland), sand and gravel (construction).
Georgia	1,091,455	7	4.65	Clays, stone (crushed), cement (portland), sand and gravel (construction).
Hawaii	70,412	44	.30	Stone (crushed), cement (portland), sand and gravel (construction), cement (masonry).
Idaho	246,716	32	1.05	Silver, phosphate rock, molybdenum, gold.
Illinois	469,525	16	2.00	Stone (crushed), cement (portland), sand and gravel (construction), sand and gravel (industrial).
Indiana	305,348	26	1.30	Cement (portland), stone (crushed), sand and gravel (construction), cement (masonry).
Iowa	248,732	30	1.06	Stone (crushed), cement (portland), sand and gravel (construction), gypsum (crude).
Kansas	317,645	24	1.35	Cement (portland), salt, stone (crushed), helium (Grade-A).
Kentucky	267,265	28	1.14	Stone (crushed), lime, cement (portland), sand and gravel (construction).
Louisiana	446,798	18	1.91	Sulfur (Frasch), salt, sand and gravel (construction), stone (crushed).
Maine	52,859	46	.23	Cement (portland), sand and gravel (construction), stone (crushed), cement (masonry).
Maryland	313,345	25	1.34	Stone (crushed), cement (portland), sand and gravel (construction), cement (masonry).
Massachusetts	134,397	37	.57	Sand and gravel (construction), stone (crushed), stone (dimension), lime.
Michigan	1,252,850	5	5.34	Iron ore (usable), cement (portland), calcium chloride (natural), magnesium compounds.
Minnesota	1,127,627	6	4.81	Iron ore (usable), sand and gravel (construction), stone (crushed), stone (dimension).
Mississippi	101,095	40	.43	Sand and gravel (construction), clays, cement (portland), stone (crushed).
Missouri	748,585	10	3.19	Cement (portland), stone (crushed), lead, lime.
Montana	236,960	33	1.01	Gold, copper, silver, cement (portland).
Nebraska	94,088	41	.40	Cement (portland), sand and gravel (construction), stone (crushed), lime.
Nevada	977,331	8	4.17	Gold, sand and gravel (construction), cement (portland), silver.
New Hampshire	38,577	47	.16	Sand and gravel (construction), stone (crushed), stone (dimension), clays.
New Jersey	186,248	35	.79	Stone (crushed), sand and gravel (construction), sand and gravel (industrial), zinc.
New Mexico	612,075	12	2.61	Copper, potassium salts, sand and gravel (construction), cement (portland).
New York	677,562	11	2.89	Stone (crushed), cement (portland), salt, sand and gravel (construction).
North Carolina	466,423	17	1.99	Stone (crushed), phosphate rock, lithium minerals, sand and gravel (construction).
North Dakota	20,802	48	.09	Sand and gravel (construction), lime, salt, clays.
Ohio	609,984	13	2.60	Stone (crushed), salt, sand and gravel (construction), lime.
Oklahoma	247,015	31	1.05	Stone (crushed), cement (portland), sand and gravel (construction), sand and gravel (industrial).
Oregon	126,432	39	.54	Stone (crushed), sand and gravel (construction), cement (portland), lime.
Pennsylvania	843,058	9	3.59	Cement (portland), stone (crushed), lime, sand and gravel (construction).
Rhode Island	14,196	49	.06	Sand and gravel (construction), stone (crushed), sand and gravel (industrial), gem stones.
South Carolina	295,889	27	1.26	Cement (portland), stone (crushed), clays, sand and gravel (construction).
South Dakota	232,886	34	.99	Gold, cement (portland), sand and gravel (construction), stone (dimension).
Tennessee	481,656	15	2.05	Stone (crushed), zinc, cement (portland), pyrites.
Texas	1,711,988	2	7.30	Cement (portland), stone (crushed), sulfur (Frasch), magnesium metal.
Utah	374,056	22	1.59	Magnesium metal, cement (portland), gold, sand and gravel (construction).
Vermont	55,211	45	.24	Stone (dimension), sand and gravel (construction), stone (crushed), talc and pyrophyllite.

See footnote at end of table.

Table 3.—Value of nonfuel mineral production in the United States and principal nonfuel minerals produced in 1986 —Continued

State	Value (thousands)	Rank	Percent of U.S. total	Principal minerals, in order of value
Virginia	$393,037	20	1.68	Stone (crushed), cement (portland), sand and gravel (construction), lime.
Washington	376,625	21	1.61	Magnesium metal, sand and gravel (construction), gold, cement (portland).
West Virginia	129,809	38	.55	Cement (portland), stone (crushed), salt, sand and gravel (industrial).
Wisconsin	164,532	36	.70	Sand and gravel (construction), stone (crushed), lime, sand and gravel (industrial).
Wyoming	556,094	14	2.37	Sodium carbonate (natural), clays, sand and gravel (construction), cement (portland).
Total[2]	23,452,000	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 1986, 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	$405,216	7,837	25	100	21
Alaska	591,004	534	91,480	155	50	171	11
Arizona	114,000	3,317	1,556,035	13,649	12	469	3
Arkansas	53,187	2,372	263,007	4,945	33	111	17
California	158,706	26,981	2,269,417	14,300	10	84	26
Colorado	104,091	3,267	370,008	3,555	38	113	15
Connecticut	5,018	3,189	80,454	16,033	8	25	46
Delaware	2,044	633	[1]4,169	2,040	44	7	50
Florida	58,664	11,675	1,295,153	22,077	3	111	16
Georgia	58,910	6,104	1,091,455	18,527	6	179	10
Hawaii	6,471	1,062	70,412	10,881	16	66	34
Idaho	83,564	1,003	246,716	2,952	41	246	8
Illinois	56,345	11,553	469,525	8,333	24	41	40
Indiana	36,185	5,504	305,348	8,439	23	55	37
Iowa	56,275	2,851	248,732	4,420	34	87	24
Kansas	82,277	2,461	317,645	3,861	37	129	14
Kentucky	40,409	3,728	267,265	6,614	26	72	29
Louisiana	47,751	4,501	446,798	9,357	20	99	22
Maine	33,265	1,174	52,859	1,589	46	45	39
Maryland	10,460	4,463	313,345	29,957	1	70	31
Massachusetts	8,284	5,832	134,397	16,224	7	23	48
Michigan	58,527	9,145	1,252,850	21,406	4	137	13
Minnesota	84,402	4,214	1,127,627	13,360	13	268	7
Mississippi	47,689	2,625	101,095	2,120	43	39	41
Missouri	69,697	5,066	748,585	10,741	17	148	12
Montana	147,046	819	236,960	1,611	45	289	6
Nebraska	77,355	1,598	94,088	1,216	48	59	35
Nevada	110,561	963	977,331	8,840	22	1,015	2
New Hampshire	9,279	1,027	38,577	4,157	36	38	43
New Jersey	7,787	7,620	186,248	23,918	2	24	47
New Mexico	121,593	1,479	612,075	5,034	32	414	4
New York	49,107	17,772	677,562	13,798	11	38	42
North Carolina	52,669	6,331	466,423	8,856	21	74	28
North Dakota	70,703	679	20,802	294	49	31	45
Ohio	41,330	10,752	609,984	14,759	9	57	36
Oklahoma	69,956	3,305	247,015	3,531	39	75	27
Oregon	97,073	2,698	126,432	1,302	47	47	38
Pennsylvania	45,308	11,889	843,058	18,607	5	71	30
Rhode Island	1,212	975	14,196	11,713	14	15	49
South Carolina	31,113	3,378	295,889	9,510	19	88	23
South Dakota	77,116	708	232,886	3,020	40	329	5
Tennessee	42,144	4,803	481,656	11,429	15	100	20
Texas	266,807	16,682	1,711,988	6,417	27	103	18
Utah	84,899	1,665	374,056	4,406	35	225	9
Vermont	9,614	541	55,211	5,743	28	102	19

See footnotes at end of table.

Table 4.—Value of nonfuel mineral production per capita and per square mile in 1986, 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	5,787	$393,037	9,641	18	68	32
Washington	68,138	4,463	376,625	5,527	30	84	25
West Virginia	24,231	1,919	129,809	5,357	31	68	33
Wisconsin	56,153	4,785	164,532	2,930	42	34	44
Wyoming	97,809	507	556,094	5,685	29	1,097	1
Total[2] or average	3,618,700	240,452	[3]23,452,000	6,481	XX	98	XX

XX Not applicable.
[1]Partial total; excludes values that must be concealed to avoid disclosing company proprietary data.
[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 indepent rounding.

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

Mineral	1984 Quantity	1984 Value (thousands)	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
ALABAMA						
Cement:						
Masonry thousand short tons	259	$17,247	268	$18,113	267	$18,165
Portland do	3,656	167,191	3,721	165,972	3,477	153,629
Clays[2] do	1,906	30,500	1,873	13,139	2,077	14,828
Gem stones	NA	[e]1	NA	[e]1	NA	1
Lime thousand short tons	1,163	50,560	1,216	52,295	1,180	50,377
Sand and gravel:						
Construction do	10,348	26,188	[e]11,000	[e]32,000	10,781	30,807
Industrial do	442	3,600	524	4,533	433	3,388
Stone:						
Crushed do	[e]22,000	[e]98,500	25,853	109,176	[e]24,000	[e]120,500
Dimension do	[r] [e]9	[r] [e]2,231	[r]10	[r]2,661	[e]8	[e]968
Combined value of bauxite, clays (bentonite), and salt	XX	13,380	XX	[r]8,719	XX	12,553
Total	XX	[r]409,398	XX	[r]406,609	XX	405,216
ALASKA						
Gem stones	NA	[e]$60	NA	[e]$60	NA	$25
Gold (recoverable content of ores, etc.) troy ounces	19,433	7,009	44,733	14,210	48,271	17,775
Sand and gravel (construction) thousand short tons	30,861	66,883	[e]29,000	[e]63,000	27,762	61,954
Silver (recoverable content of ores, etc.) thousand troy ounces	([3])	1	W	W	W	W
Stone (crushed) thousand short tons	[e]2,500	[e]10,800	1,907	8,535	[e]2,000	[e]8,500
Combined value of cement (portland), tin, and values indicated by symbol W	XX	2,543	XX	4,164	XX	3,226
Total	XX	87,296	XX	89,969	XX	91,480
ARIZONA						
Clays thousand short tons	138	$819	186	$1,503	201	$1,366
Copper (recoverable content of ores, etc.) metric tons	746,453	1,100,182	796,556	1,175,995	789,175	1,149,193
Gem stones	NA	[e]2,700	NA	[e]2,700	NA	2,533
Gold (recoverable content of ores, etc.) troy ounces	54,897	19,799	52,053	16,535	W	W
Gypsum thousand short tons	261	2,332	251	1,926	260	1,820
Lead (recoverable content of ores, etc.) metric tons	W	W	581	244	W	W
Lime thousand short tons	359	17,304	476	21,226	505	21,016
Molybdenum thousand pounds	24,013	76,112	24,125	63,389	29,382	75,607
Pumice thousand short tons	2	21	W	2	2	30
Sand and gravel (construction) do	30,439	101,959	[e]37,000	[e]118,000	40,468	140,004

See footnotes at end of table.

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

Mineral	1984 Quantity	1984 Value (thousands)	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
ARIZONA—Continued						
Silver (recoverable content of ores, etc.) thousand troy ounces	4,247	$34,570	4,885	$30,007	4,202	$22,987
Stone (crushed) thousand short tons	[e]5,200	[e]27,300	5,929	23,111	[e]5,600	[e]25,100
Combined value of cement, perlite, pyrites (1984-85), salt (1984, 1986), sand and gravel (industrial), stone (dimension), tin (1984), and values indicated by symbol W	XX	[r]102,840	XX	95,447	XX	116,379
Total	XX	[r]1,485,938	XX	1,550,085	XX	1,556,035
ARKANSAS						
Clays thousand short tons	1,019	$7,838	1,052	$10,769	[2]974	[2]$8,998
Gem stones	NA	[e]200	NA	[e]200	NA	522
Sand and gravel:						
Construction thousand short tons	8,334	23,786	[e]8,500	[e]24,400	8,571	26,999
Industrial do	459	6,207	412	5,414	400	3,975
Stone:						
Crushed do	[e]15,200	[e]59,800	14,815	60,874	[e]15,500	[e]58,500
Dimension do	W	W	5	305	[e]5	[e]305
Combined value of abrasives, bauxite, bromine, cement, clays (fire clay, 1986), gypsum, lime, talc and pyrophyllite, tripoli (1984, 1986), vanadium (1984-85), and value indicated by symbol W	XX	[r]175,019	XX	[r]168,290	XX	163,708
Total	XX	[r]272,850	XX	[r]270,252	XX	263,007
CALIFORNIA						
Boron minerals thousand short tons	1,367	$456,687	1,269	$404,775	1,251	$426,086
Cement (portland) do	8,715	520,026	9,462	601,506	9,490	578,502
Clays[2] do	2,100	23,868	2,203	26,600	2,449	33,289
Gem stones	NA	[e]500	NA	[e]550	NA	418
Gold (recoverable content of ores, etc.) troy ounces	85,858	30,965	[r]187,813	[r]59,660	425,617	156,729
Gypsum thousand short tons	1,382	12,443	1,332	12,201	1,378	10,777
Lime do	406	26,827	367	24,733	371	24,187
Pumice do	80	1,600	78	1,491	46	1,263
Sand and gravel:						
Construction do	102,420	360,427	[e]112,800	[e]430,000	128,407	498,456
Industrial do	2,281	39,176	2,255	37,434	2,364	44,813
Silver (recoverable content of ores, etc.) thousand troy ounces	W	W	115	709	155	849
Stone:						
Crushed thousand short tons	[e]38,600	[e]158,000	41,199	174,395	[e]38,500	[e]159,300
Dimension do	[r][e]23	[r][e]1,658	23	2,449	[e]23	[e]2,582
Talc and pyrophyllite do	74	1,642	100	2,493	64	1,528
Combined value of asbestos, calcium chloride (natural), cement (masonry), clays (ball clay, 1986, and fire clay, 1984-85), copper, diatomite, feldspar, iron ore (usable), lead (1984), magnesium compounds, molybdenum, peat, perlite, potassium salts, rare-earth metal concentrates, salt, sodium carbonate (natural), sodium sulfate (natural), tungsten ore and concentrate, wollastonite (1984, 1986), and value indicated by symbol W	XX	360,085	XX	[r]333,014	XX	330,638
Total	XX	[r]1,993,904	XX	[r]2,112,010	XX	2,269,417

See footnotes at end of table.

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

Mineral	1984 Quantity	1984 Value (thousands)	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
COLORADO						
Clays ---------- thousand short tons--	308	$2,111	303	$1,743	242	$1,523
Gem stones----------------------	NA	[e]80	NA	[e]80	NA	100
Gold (recoverable content of ores, etc.) troy ounces--	60,010	21,643	43,301	13,755	120,347	44,317
Gypsum-------- thousand short tons--	291	W	233	1,800	W	W
Sand and gravel:						
Construction--------------do----	28,024	87,324	[e]27,500	[e]88,000	23,233	70,095
Industrial --------------do----	149	2,213	W	W	W	W
Silver (recoverable content of ores, etc.) thousand troy ounces--	2,200	17,909	549	3,370	645	3,526
Stone:						
Crushed------ thousand short tons--	[e]7,200	[e]26,200	7,037	25,930	[e]8,000	[e]30,700
Dimension --------------do----	[r][e]2	[r][e]204	2	204	[e]4	[e]255
Combined value of cement, copper, iron ore (usable, 1984-85), lead, lime, molybdenum, peat, perlite, pyrites (1984-85), salt (1984), tin (1984-85), tungsten ore and concentrate, vanadium, zinc, and values indicated by symbol W------------------	XX	278,609	XX	[r]273,611	XX	219,492
Total---------------------	XX	[r]436,293	XX	[r]408,493	XX	370,008
CONNECTICUT						
Clays ---------- thousand short tons--	99	$565	106	$632	157	$975
Gem stones----------------------	NA	W	NA	W	NA	2
Sand and gravel (construction) thousand short tons--	6,718	22,817	[e]6,000	[e]21,000	7,254	25,984
Stone:						
Crushed-----------------do----	[e]8,300	[e]49,400	7,277	43,937	[e]7,700	[e]45,800
Dimension --------------do----	[r][e]20	[r][e]1,285	20	1,285	[e]24	[e]1,653
Combined value of feldspar, lime (1984), mica (scrap), sand and gravel (industrial), and values indicated by symbol W --------	XX	5,834	XX	5,532	XX	6,040
Total---------------------	XX	[r]79,901	XX	72,386	XX	80,454
DELAWARE						
Gem stones----------------------	--	--	--	--	NA	$1
Marl (greensand) -- thousand short tons--	1	$18	2	$29	1	12
Sand and gravel (construction)----do----	1,003	2,795	[e]1,300	[e]4,000	1,547	4,156
Total[4] -------------------	XX	2,813	XX	4,029	XX	4,169
FLORIDA						
Cement:						
Masonry ----- thousand short tons--	383	$24,624	316	$17,137	352	$21,269
Portland ---------------do----	3,564	172,548	3,282	148,908	3,189	147,643
Clays ------------------do----	772	34,048	672	33,074	726	43,261
Gem stones----------------------	NA	[e]6	NA	[e]6	NA	W
Lime --------- thousand short tons--	171	9,379	W	W	W	W
Peat--------------------do----	263	5,454	243	5,333	365	5,743
Sand and gravel:						
Construction--------------do----	21,032	48,494	[e]22,500	[e]49,500	28,233	67,898
Industrial --------------do----	1,533	9,815	2,123	12,642	1,467	14,930
Stone (crushed) -------------do----	[e]68,500	[e]290,000	69,266	287,237	[e]69,000	[e]288,200
Combined value of magnesium compounds (1984), phosphate rock, rare-earth metal concentrates, staurolite, titanium concentrates (ilmenite and rutile), zircon concentrate, and values indicated by symbol W--	XX	915,996	XX	[r]1,007,899	XX	706,209
Total---------------------	XX	1,510,364	XX	[r]1,561,736	XX	1,295,153
GEORGIA						
Clays ---------- thousand short tons--	8,679	$600,029	8,671	$575,097	9,827	$669,200
Gem stones----------------------	NA	[e]20	NA	[e]20	NA	20

See footnotes at end of table.

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

Mineral	1984 Quantity	1984 Value (thousands)	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
GEORGIA—Continued						
Sand and gravel:						
Construction thousand short tons	5,347	$13,623	e5,000	e$13,400	8,126	$23,222
Industrial do	478	6,795	571	6,675	W	W
Stone:						
Crushed do	e45,900	e220,000	52,062	256,588	e56,700	e293,100
Dimension do	r e184	r e19,660	r183	19,466	e199	e20,678
Talc and pyrophyllite do	15	104	16	111	9	61
Combined value of barite, bauxite (1984), cement, feldspar, iron oxide pigments (crude), kyanite, mica (scrap), peat, and value indicated by symbol W	XX	79,914	XX	74,718	XX	85,174
Total	XX	r940,145	XX	946,075	XX	1,091,455
HAWAII						
Cement:						
Masonry thousand short tons	5	$792	7	$588	7	$1,078
Portland do	186	18,282	215	16,050	287	24,253
Gem stones	NA	e25	NA	e25	NA	25
Lime thousand short tons	W	W	W	W	3	W
Sand and gravel (construction) do	436	2,031	e500	e2,100	605	2,666
Stone (crushed) do	e5,400	e29,700	5,627	34,183	e7,100	e42,100
Combined value of other industrial minerals and values indicated by symbol W	XX	r417	XX	r326	XX	290
Total	XX	51,247	XX	53,272	XX	70,412
IDAHO						
Antimony short tons	557	W	W	W	W	W
Clays[2] thousand short tons	1	W	2	W	2	W
Copper (recoverable content of ores, etc.) metric tons	3,701	$5,455	3,551	$5,242	W	W
Gem stones	NA	e150	NA	e175	NA	$305
Gold (recoverable content of ores, etc.) troy ounces	W	W	44,306	14,074	70,440	25,938
Lead (recoverable content of ores, etc.) metric tons	W	W	33,707	14,169	9,951	4,836
Lime thousand short tons	87	5,616	93	5,803	89	4,729
Phosphate rock thousand metric tons	4,722	126,586	3,784	r104,000	2,625	55,000
Sand and gravel (construction) thousand short tons	4,725	13,509	e4,000	e11,400	5,708	14,830
Silver (recoverable content of ores, etc.) thousand troy ounces	18,869	153,608	18,828	115,645	11,207	61,301
Stone (crushed) thousand short tons	e1,800	e7,100	2,019	6,977	e3,700	e12,700
Zinc (recoverable content of ores, etc.) metric tons	W	W	W	W	351	294
Combined value of cement, clays (bentonite, common clay (1986), fire clay, kaolin), garnet (abrasive), gypsum (1984), molybdenum, perlite, pumice, sand and gravel (industrial), stone (dimension), vanadium, and values indicated by symbol W	XX	r100,327	XX	r81,181	XX	66,783
Total	XX	r412,351	XX	r358,666	XX	246,716
ILLINOIS						
Cement (portland) thousand short tons	1,997	$82,622	2,101	$86,211	2,118	$83,783
Clays[2] do	253	940	265	876	283	1,092
Gem stones	NA	e15	NA	e15	NA	15
Peat thousand short tons	49	W	W	W	W	W
Sand and gravel:						
Construction do	25,969	72,477	e26,600	e77,000	27,867	82,523
Industrial do	4,100	52,197	4,056	56,915	4,039	52,133
Stone:						
Crushed do	e48,500	e191,600	41,044	164,117	e44,200	e179,600
Dimension do	r e2	r e107	2	107	e2	e107
Combined value of barite (1984-85), cement (masonry), clays (fuller's earth), copper (1985-86), fluorspar, lead, lime, silver, tripoli, zinc, and values indicated by symbol W	XX	72,010	XX	74,679	XX	70,272
Total	XX	r471,968	XX	459,920	XX	469,525

See footnotes at end of table.

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

Mineral	1984 Quantity	1984 Value (thousands)	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
INDIANA						
Cement:						
Masonry ----- thousand short tons--	W	W	W	W	395	$22,936
Portland ----------------do----	W	W	W	W	2,136	92,327
Clays ------------------do----	[2]653	[2]$2,085	740	$2,776	744	3,044
Gem stones--------------------	NA	[e]1	NA	[e]1	NA	1
Peat ---------- thousand short tons--	61	1,358	54	W	79	W
Sand and gravel:						
Construction-------------do----	16,071	44,744	[e]18,600	[e]55,800	19,642	61,232
Industrial --------------do----	194	1,129	182	1,209	193	1,490
Stone:						
Crushed-----------------do----	[e]26,700	[e]99,400	[5]23,384	[5]81,119	[e] [5]22,600	[e] [5]76,500
Dimension ---------------do----	[r] [e]163	[r] [e]17,113	[r]169	20,186	[e]191	[e]20,252
Combined value of abrasives, clays (fire clay, 1984), gypsum, lime, stone (crushed marl, 1985-86), and values indicated by symbol W	XX	130,250	XX	141,863	XX	27,566
Total--------------------	XX	[r]296,080	XX	302,954	XX	305,348
IOWA						
Cement:						
Masonry ----- thousand short tons--	42	$3,260	39	$3,372	48	$3,199
Portland ----------------do----	1,730	92,699	1,618	77,890	1,819	86,984
Clays ------------------do----	623	2,695	503	2,450	486	1,421
Gem stones--------------------	NA	W	NA	[e]1	NA	20
Gypsum-------- thousand short tons--	1,527	12,421	1,639	13,682	1,826	12,602
Peat -------------------do----	11	400	11	415	14	381
Sand and gravel (construction) ----do----	13,882	37,027	[e]12,000	[e]30,500	14,511	40,418
Stone (crushed) -------------do----	[e]23,800	[e]100,000	23,657	94,496	[e]23,400	[e]98,000
Combined value of other industrial minerals and value indicated by symbol W ------	XX	[r]5,246	XX	5,211	XX	5,707
Total--------------------	XX	[r]253,748	XX	228,017	XX	248,732
KANSAS						
Cement:						
Masonry ----- thousand short tons--	W	W	W	W	51	$3,264
Portland ----------------do----	W	W	W	W	1,763	91,110
Clays ------------------do----	918	$5,537	878	$5,326	903	5,295
Gem stones--------------------	NA	[e]1	NA	[e]1	NA	3
Helium:						
Crude --------- million cubic feet--	402	8,844	W	W	W	W
Grade-A ----------------do----	1,015	38,063	W	W	W	W
Salt[6]---------- thousand short tons--	1,712	71,558	1,790	71,970	1,656	68,887
Sand and gravel:						
Construction-------------do----	11,796	26,358	[e]13,200	[e]31,800	15,609	33,721
Industrial --------------do----	W	W	134	1,124	132	1,155
Stone (crushed) -------------do----	[e]13,600	[e]48,500	15,653	57,155	[e]16,600	[e]60,300
Combined value of gypsum, lime (1984), pumice, salt (brine), stone (dimension), and values indicated by symbol W --------	XX	[r]113,774	XX	[r]154,793	XX	53,910
Total--------------------	XX	[r]312,635	XX	[r]322,169	XX	317,645
KENTUCKY						
Clays --------- thousand short tons--	[2]662	[2]$2,533	775	$6,487	[2]721	[2]$3,450
Gem stones--------------------	NA	[e]1	NA	[e]1	NA	3
Sand and gravel (construction) thousand short tons--	7,839	18,252	[e]7,600	[e]19,000	7,194	16,986
Stone (crushed) -------------do----	[e]37,300	[e]133,000	[5]38,022	[5]134,978	[e] [5]38,400	[e] [5]137,000
Combined value of cement, clays (ball clay and fire clay, 1984, 1986), lime, sand and gravel (industrial), stone (crushed sandstone, 1985-86), and zinc (1984-85) ------	XX	103,422	XX	107,092	XX	109,826
Total--------------------	XX	257,208	XX	267,558	XX	267,265

See footnotes at end of table.

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

Mineral	1984 Quantity	1984 Value (thousands)	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
LOUISIANA						
Clays ---------- thousand short tons--	[2]547	[2]$10,858	334	$7,017	332	$7,670
Gem stones----------------------	NA	[e]1	NA	[e]1	NA	1
Salt ---------- thousand short tons--	13,101	112,142	[r]12,271	[r]137,273	11,608	103,611
Sand and gravel:						
Construction--------------do----	17,040	54,664	[e]15,000	[e]48,000	14,292	46,134
Industrial --------------do----	266	3,757	267	3,838	256	4,225
Stone (crushed) --------------do----	[e]4,100	[e]19,500	[5]4,820	[5]25,956	[e] [5]5,400	[e] [5]25,300
Sulfur (Frasch) -- thousand metric tons--	2,007	W	1,698	W	1,602	W
Combined value of cement (masonry, 1984-85, and portland), clays (bentonite, 1984), gypsum (1984-85), lime, stone (crushed miscellaneous, 1985-86), and values indicated by symbol W ---------------	XX	310,548	XX	298,501	XX	259,857
Total---------------------	XX	511,470	XX	[r]520,586	XX	446,798
MAINE						
Clays ---------- thousand short tons--	43	$97	50	$100	46	$90
Gem stones----------------------	NA	[e]400	NA	[e]400	NA	200
Sand and gravel (construction) thousand short tons--	7,885	19,228	[e]7,200	[e]18,000	8,572	22,843
Stone (crushed) --------------do----	[e]1,300	[e]4,400	1,459	5,114	[e]1,600	[e]4,400
Combined value of cement, garnet (abrasive), peat (1984, 1986), and stone (dimension) --	XX	[r]14,088	XX	17,494	XX	25,326
Total---------------------	XX	[r]38,213	XX	41,108	XX	52,859
MARYLAND						
Cement (portland) - thousand short tons--	W	W	W	W	1,785	$89,799
Clays[2]------------------do----	347	$1,484	336	$1,647	362	1,757
Gem stones----------------------	NA	[e]2	NA	[e]2	NA	5
Lime ---------- thousand short tons--	7	419	10	608	10	546
Peat---------------------do----	5	W	W	W	W	W
Sand and gravel (construction)-----do----	14,234	46,671	[e]17,000	[e]58,000	18,173	86,925
Stone:						
Crushed------------------do----	[e]22,100	[e]94,000	24,406	98,584	[e]26,400	[e]126,000
Dimension ----------------do----	[r] [e]16	[r] [e]1,065	18	1,218	[e]21	[e]1,286
Combined value of cement (masonry), clays (ball clay), sand and gravel (industrial), and values indicated by symbol W ---------	XX	98,261	XX	98,215	XX	7,027
Total---------------------	XX	[r]241,902	XX	258,274	XX	313,345
MASSACHUSETTS						
Clays ---------- thousand short tons--	240	$1,212	265	$1,388	140	$871
Lime ---------------------do----	171	12,426	159	10,935	W	W
Sand and gravel:						
Construction--------------do----	14,168	42,139	[e]14,900	[e]47,500	19,200	60,464
Industrial --------------do----	W	W	W	W	45	739
Stone:						
Crushed------------------do----	[e]8,400	[e]39,000	9,354	42,881	[e]10,000	[e]50,000
Dimension ----------------do----	[r] [e]64	[r] [e]11,688	73	13,724	[e]79	[e]14,928
Combined value of gem stones, peat, and values indicated by symbol W ---------	XX	898	XX	777	XX	7,395
Total---------------------	XX	[r]107,363	XX	117,205	XX	134,397
MICHIGAN						
Cement:						
Masonry ----- thousand short tons--	W	W	W	W	257	$17,026
Portland ----------------do----	W	W	W	W	4,713	216,120
Clays ---------------------do----	1,321	$5,052	1,477	$5,514	1,402	5,684
Gem stones----------------------	NA	[e]15	NA	[e]15	NA	25
Gypsum-------- thousand short tons--	1,534	10,304	1,772	11,883	1,979	11,052
Iron ore (usable) thousand long tons, gross weight--	13,263	W	12,629	W	10,957	W

See footnotes at end of table.

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

Mineral	1984 Quantity	1984 Value (thousands)	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
MICHIGAN—Continued						
Lime thousand short tons	622	$30,092	535	$24,790	556	$27,257
Peat do	227	4,341	282	5,414	298	6,170
Salt do	1,491	93,860	[r]927	[r]71,224	W	W
Sand and gravel:						
Construction do	36,071	76,540	[e]38,000	[e]93,000	42,514	91,886
Industrial do	3,400	33,060	3,345	25,469	3,343	29,493
Stone:						
Crushed do	[e]28,100	[e]92,000	30,685	95,953	[e]27,800	[e]83,900
Dimension do	[e]4	[r e]113	4	113	[e]6	[e]148
Combined value of bromine, calcium chloride (natural), copper (1985-86), gold (1985-86), iodine (1984-85), iron oxide pigments (crude), magnesium compounds, silver (1985-86), and values indicated by symbol W	XX	1,063,214	XX	[r]1,053,672	XX	764,089
Total	XX	[r]1,408,591	XX	[r]1,387,047	XX	1,252,850
MINNESOTA						
Gem stones	NA	[e]$5	NA	[e]$5	NA	$5
Iron ore (usable) thousand long tons, gross weight	35,602	1,561,516	34,977	1,430,353	28,779	1,017,261
Manganiferous ore short tons	68,019	W	--	--	--	--
Peat thousand short tons	24	W	34	1,720	W	W
Sand and gravel:						
Construction do	22,612	49,087	[e]25,000	[e]55,500	24,055	53,116
Industrial do	W	W	884	16,910	W	W
Stone:						
Crushed do	[e]8,900	[e]25,800	7,756	22,601	[e]8,300	[e]26,300
Dimension do	[r e]40	[r e]13,557	37	13,598	[e]28	[e]10,507
Combined value of clays, lime, and values indicated by symbol W	XX	26,470	XX	7,271	XX	20,438
Total	XX	[r]1,676,435	XX	1,547,958	XX	1,127,627
MISSISSIPPI						
Clays thousand short tons	[2]1,274	[r 2]$10,367	1,558	$34,864	[2]928	[2]$13,538
Gem stones	--	--	--	--	NA	1
Sand and gravel (construction) thousand short tons	12,205	34,955	[e]13,400	[e]42,000	15,080	42,809
Stone (crushed) do	[e]2,000	[e]5,800	1,582	4,282	[e]1,600	[e]4,400
Combined value of cement, clays (ball clay and fuller's earth, 1984, 1986), and sand and gravel (industrial)	XX	42,016	XX	21,647	XX	40,347
Total	XX	[r]93,138	XX	102,793	XX	101,095
MISSOURI						
Barite thousand short tons	W	W	47	$2,791	W	W
Cement:						
Masonry do	143	$7,033	139	6,630	167	$7,816
Portland do	3,981	178,225	3,669	159,757	4,642	179,184
Clays[2] do	1,575	14,666	1,545	10,271	1,321	6,650
Copper (recoverable content of ores, etc.) metric tons	5,818	8,575	13,410	19,797	W	W
Gem stones	NA	[e]10	NA	[e]10	NA	W
Iron ore (usable) thousand long tons, gross weight	1,370	W	1,110	W	803	W
Lead (recoverable content of ores, etc.) metric tons	278,329	156,766	371,008	155,955	319,900	155,481
Sand and gravel:						
Construction thousand short tons	7,967	19,364	[e]7,500	[e]20,000	9,746	24,065
Industrial do	614	8,129	535	7,330	517	6,230
Silver (recoverable content of ores, etc.) thousand troy ounces	1,401	11,406	1,635	10,044	1,459	7,982
Stone (crushed) thousand short tons	[e]41,600	[e]137,000	50,646	162,097	[e]51,200	[e]170,500
Zinc (recoverable content of ores, etc.) metric tons	45,458	48,707	49,340	43,908	37,919	31,767
Combined value of clays (fuller's earth), iron oxide pigments (crude), lime, stone (dimension), and values indicated by symbol W	XX	[r]142,104	XX	136,370	XX	158,910
Total	XX	[r]731,985	XX	734,960	XX	748,585

See footnotes at end of table.

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

Mineral	1984 Quantity	1984 Value (thousands)	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
MONTANA						
Clays ---------- thousand short tons--	229	$5,642	279	$8,296	222	$5,882
Copper (recoverable content of ores, etc.) metric tons--	W	W	15,092	22,281	W	W
Gem stones----------------------	NA	[e]450	NA	[e]400	NA	480
Gold (recoverable content of ores, etc.) troy ounces--	181,190	65,348	160,262	50,909	W	W
Lead (recoverable content of ores, etc.) metric tons--	W	W	846	356	W	W
Lime ---------- thousand short tons--	89	5,097	W	W	W	W
Sand and gravel (construction) ----do----	7,776	21,269	[e]9,000	[e]26,000	8,066	19,391
Silver (recoverable content of ores, etc.) thousand troy ounces--	5,653	46,018	4,010	24,630	4,773	26,110
Stone (crushed) --- thousand short tons--	[e]950	[e]2,400	[5]1,730	[5]5,044	[e] [5]2,200	[e] [5]6,200
Combined value of barite (1984-85), cement, graphite (1984), gypsum, iron ore (usable), molybdenum (1986), peat, phosphate rock, sand and gravel (industrial), stone (crushed traprock, 1985-86), stone (dimension), talc and pyrophyllite, vermiculite, and values indicated by symbol W ------------	XX	[r]93,777	XX	[r]62,166	XX	178,897
Total--------------------	XX	[r]240,001	XX	[r]200,082	XX	236,960
NEBRASKA						
Clays ---------- thousand short tons--	180	$556	244	$718	221	$668
Gem stones----------------------	NA	W	NA	[e]10	NA	10
Sand and gravel (construction) thousand short tons--	11,839	27,791	[e]11,600	[e]28,800	9,675	23,912
Stone (crushed) --------------do----	[e]4,500	[e]23,400	4,175	19,134	[e]4,000	[e]17,900
Combined value of cement, lime, sand and gravel (industrial), and value indicated by symbol W --------------------	XX	48,621	XX	51,308	XX	51,598
Total--------------------	XX	100,368	XX	99,970	XX	94,088
NEVADA						
Barite---------- thousand short tons--	615	$14,924	590	$10,904	184	$3,005
Clays[2]------------------do----	20	1,191	80	3,776	10	584
Gem stones----------------------	NA	[e]1,300	NA	[e]1,300	NA	213
Gold (recoverable content of ores, etc.) troy ounces--	1,020,546	368,068	1,276,114	405,369	2,098,929	772,909
Gypsum-------- thousand short tons--	1,192	8,860	1,207	8,942	1,236	8,221
Lead (recoverable content of ores, etc.) metric tons--	W	W	([3])	([3])	--	--
Mercury ----------- 76-pound flasks--	19,048	W	16,530	W	W	W
Perlite ---------------short tons--	W	W	W	W	4	122
Sand and gravel:						
Construction--- thousand short tons--	8,202	20,505	[e]9,500	[r] [e]24,880	12,197	35,692
Industrial ---------------do----	489	W	479	W	518	W
Silver (recoverable content of ores, etc.) thousand troy ounces--	6,477	52,727	4,947	30,383	6,409	35,056
Stone (crushed) --- thousand short tons--	[e]1,100	[e]4,700	1,334	6,218	[e]1,500	[e]7,000
Combined value of cement (portland), clays (fuller's earth and kaolin), copper, diatomite, fluorspar, iron ore (usable), lime, lithium minerals, magnesite, molybdenum (1984-85), salt, tungsten ore and concentrate (1984), and values indicated by symbol W ------------------------	XX	151,787	XX	[r]139,201	XX	114,529
Total--------------------	XX	624,062	XX	[r]630,973	XX	977,331
NEW HAMPSHIRE						
Sand and gravel (construction) thousand short tons--	5,637	$16,054	[e]6,300	[e]$19,800	8,418	$26,089
Stone:						
Crushed-----------------do----	[e]850	[e]2,700	1,612	6,434	[e]1,800	[e]5,900
Dimension ---------------do----	[r] [e]83	[r] [e]5,681	[r]80	[r]6,625	[e]82	[e]6,451
Combined value of other industrial minerals	XX	160	XX	134	XX	137
Total--------------------	XX	[r]24,595	XX	[r]32,993	XX	38,577

See footnotes at end of table.

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

Mineral	1984 Quantity	1984 Value (thousands)	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
NEW JERSEY						
Clays ---------- thousand short tons--	62	$611	130	$2,050	133	$2,066
Gem stones----------------------	NA	[e]1	NA	[e]1	NA	3
Peat ---------- thousand short tons--	5	128	W	311	W	542
Sand and gravel:						
Construction ---------------do----	9,545	31,878	[e]10,600	[e]36,700	13,999	53,746
Industrial ---------------do----	2,712	32,287	2,820	31,119	2,341	29,878
Stone (crushed) -------------do----	[e]13,500	[e]75,000	15,692	94,339	[e]15,300	[e]95,400
Combined value of other industrial minerals	XX	[r]16,183	XX	13,056	XX	4,613
Total--------------------	XX	[r]156,088	XX	177,576	XX	186,248
NEW MEXICO						
Clays ---------- thousand short tons--	67	$143	60	$161	60	$170
Gem stones----------------------	NA	[e]200	NA	[e]200	NA	200
Gold (recoverable content of ores, etc.) troy ounces--	W	W	45,045	14,309	39,856	14,677
Gypsum --------- thousand short tons--	318	1,622	350	1,570	W	W
Lead (recoverable content of ores, etc.) metric tons--	--	--	W	W	10	5
Perlite --------- thousand short tons--	416	14,115	[r]430	[r]14,896	433	13,727
Potassium salts -- thousand metric tons--	1,418	204,100	1,120	156,000	987	132,800
Pumice --------- thousand short tons--	132	1,269	152	1,114	255	2,370
Sand and gravel (construction) ----do----	8,363	22,389	[e]8,400	[e]22,800	8,471	25,862
Stone:						
Crushed-----------------do----	[e]4,700	[e]17,000	3,641	15,232	[e]3,900	[e]15,300
Dimension ---------------do----	[r][e]20	[r][e]185	20	277	[e]22	[e]378
Combined value of cement, copper, helium (Grade-A), iron ore (usable, 1986), mica (scrap), molybdenum, salt, silver, tungsten ore and concentrate (1984), and values indicated by symbol W ---------------	XX	374,855	XX	430,705	XX	406,586
Total--------------------	XX	[r]635,878	XX	[r]657,264	XX	612,075
NEW YORK						
Clays ---------- thousand short tons--	[2]543	[2]$2,435	700	$3,129	619	$3,075
Emery ----------------short tons--	W	W	W	W	2,878	W
Gem stones----------------------	NA	[e]30	NA	[e]30	NA	100
Salt ----------- thousand short tons--	5,644	123,755	[r]7,044	142,318	5,071	122,601
Sand and gravel:						
Construction ---------------do----	25,968	80,866	[e]28,000	[e]88,500	31,172	103,748
Industrial ---------------do----	25	260	W	W	59	1,164
Stone:						
Crushed-----------------do----	[e]33,100	[e]135,000	35,139	165,136	[e]40,600	[e]196,600
Dimension ---------------do----	[e]15	[r][e]3,072	16	3,666	[e]16	[e]3,002
Combined value of cement, clays (ball clay, 1984), garnet (abrasive), gypsum, lead, lime (1984-85), peat, silver, talc and pyrophyllite, titanium concentrate (ilmenite, 1984), wollastonite, zinc, and values indicated by symbol W --------------------	XX	265,873	XX	254,529	XX	247,272
Total--------------------	XX	[r]611,291	XX	657,308	XX	677,562
NORTH CAROLINA						
Clays ---------- thousand short tons--	2,327	$8,987	2,688	$10,477	2,658	$10,970
Feldspar --------------short tons--	510,275	13,994	490,993	13,351	526,672	15,568
Gem stones----------------------	NA	[e]50	NA	[e]50	NA	551
Gold (recoverable content of ores, etc.) troy ounces--	--	--	--	--	12	4
Mica (scrap) ----- thousand short tons--	79	3,762	80	3,726	89	4,641
Peat --------------------do----	W	W	W	W	15	W
Sand and gravel:						
Construction ---------------do----	6,312	18,159	[e]6,100	[e]19,500	7,543	23,127
Industrial ---------------do----	1,158	12,864	1,294	13,086	1,464	16,656
Stone:						
Crushed-----------------do----	[e]38,100	[e]168,000	41,771	194,818	[e]43,500	[e]206,500
Dimension ---------------do----	[r][e]35	[r][e]5,970	35	6,132	[e]41	[e]6,633

See footnotes at end of table.

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

Mineral	1984 Quantity	1984 Value (thousands)	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
NORTH CAROLINA—Continued						
Talc and pyrophyllite thousand short tons	87	$1,587	885	$1,604	83	$1,552
Combined value of lithium minerals, olivine, phosphate rock, and values indicated by symbol W	XX	r215,897	XX	r202,642	XX	180,221
Total	XX	r449,270	XX	r465,386	XX	466,423
NORTH DAKOTA						
Gem stones	NA	e$2	NA	e$2	NA	$2
Lime thousand short tons	60	5,912	56	5,562	74	7,359
Sand and gravel (construction) do	6,426	11,351	e6,900	e13,800	5,135	10,741
Combined value of clays, peat, salt, sand and gravel (industrial, 1986), and stone (crushed miscellaneous, 1985-86)	XX	4,529	XX	4,820	XX	2,700
Total	XX	21,794	XX	24,184	XX	20,802
OHIO						
Cement:						
Masonry thousand short tons	101	$8,092	110	$10,412	138	$11,540
Portland do	1,525	69,810	1,769	84,929	1,706	79,383
Clays do	1,960	10,473	2,114	10,581	2,833	11,515
Gem stones	NA	W	NA	e10	NA	10
Lime thousand short tons	1,859	87,951	1,730	84,142	1,648	81,103
Peat do	13	345	16	413	6	W
Salt do	W	W	r4,329	r130,964	4,115	126,757
Sand and gravel:						
Construction do	31,748	104,709	e33,000	e109,000	36,806	126,747
Industrial do	1,506	20,829	1,312	21,945	1,221	21,183
Stone:						
Crushed do	e38,500	e139,000	38,310	136,544	e39,300	e147,300
Dimension do	r e55	r e2,364	53	3,661	e36	e2,708
Combined value of abrasives, gypsum, and values indicated by symbol W	XX	108,240	XX	1,541	XX	1,738
Total	XX	r551,813	XX	r594,142	XX	609,984
OKLAHOMA						
Cement:						
Masonry thousand short tons	49	$3,506	43	$2,854	50	$3,198
Portland do	1,732	84,701	1,589	72,583	1,579	69,075
Clays do	979	2,498	997	2,338	993	2,329
Gem stones	NA	e2	NA	e2	NA	2
Gypsum thousand short tons	1,549	13,485	1,595	12,548	1,683	9,855
Sand and gravel:						
Construction do	10,984	26,582	e12,600	e32,300	10,366	24,585
Industrial do	W	W	W	W	1,203	16,454
Stone:						
Crushed do	e25,500	e86,000	31,173	98,811	e30,900	e102,100
Dimension do	r e9	r e584	11	836	e19	e913
Combined value of feldspar, iodine, lime, pumice, salt, tripoli, and values indicated by symbol W	XX	28,187	XX	29,335	XX	18,504
Total	XX	r245,545	XX	251,607	XX	247,015
OREGON						
Clays thousand short tons	189	$288	188	$285	204	$289
Gem stones	NA	e400	NA	e350	NA	350
Nickel (content of ore and concentrate) short tons	14,540	W	6,127	W	1,175	W
Sand and gravel (construction) thousand short tons	12,776	37,117	e12,500	e36,800	13,441	42,597
Stone (crushed) do	e12,500	e37,500	15,336	54,244	e15,100	e53,400
Talc and pyrophyllite do	(3)	66	(3)	30	(3)	41
Combined value of cement, diatomite, gold, lime, pumice, silver (1984), stone (dimension), and values indicated by symbol W	XX	45,031	XX	38,587	XX	29,755
Total	XX	120,402	XX	130,296	XX	126,432

See footnotes at end of table.

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

Mineral	1984 Quantity	1984 Value (thousands)	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
PENNSYLVANIA						
Cement:						
Masonry ----- thousand short tons--	298	$20,849	303	$20,970	391	$26,683
Portland ---------------do----	5,735	281,590	5,535	288,036	6,290	324,187
Clays[2] ---------------do----	963	4,050	1,142	5,293	1,234	5,061
Gem stones ----------------------	NA	[e]5	NA	[e]5	NA	5
Lime --------- thousand short tons--	1,620	90,182	1,492	85,269	1,417	81,234
Peat ---------------do----	24	693	21	602	19	532
Sand and gravel:						
Construction ------------do----	14,472	64,285	[e]17,000	[e]74,000	15,373	68,880
Industrial ------------do----	W	W	693	9,846	688	10,091
Stone:						
Crushed ---------------do----	[e]56,200	[e]228,000	64,765	310,859	[e]63,700	[e]317,100
Dimension -------------do----	[r][e]93	[r][e]7,026	51	8,214	[e]72	[e]8,100
Combined value of clays (kaolin), mica (scrap), tripoli (1986), and value indicated by symbol W ----------	XX	12,701	XX	1,380	XX	1,185
Total --------------------	XX	[r]709,381	XX	804,474	XX	843,058

Mineral	1984 Quantity	1984 Value (thousands)	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
RHODE ISLAND						
Sand and gravel:						
Construction --- thousand short tons--	1,483	$5,282	[e]1,200	[e]$4,600	2,269	$8,252
Industrial ------------do----	W	W	W	W	22	143
Stone (crushed) ------------do----	[e]1,000	[e]5,800	[5]1,135	[5]7,016	[e][5]1,000	[e][5]5,700
Combined value of other industrial minerals and values indicated by symbol W------	XX	[r]466	XX	576	XX	101
Total --------------------	XX	[r]11,548	XX	12,192	XX	14,196

Mineral	1984 Quantity	1984 Value (thousands)	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
SOUTH CAROLINA						
Cement (portland) - thousand short tons--	2,319	$103,891	2,207	$104,705	2,306	$109,529
Clays[2] ---------------do----	1,834	36,809	1,896	37,695	1,986	37,980
Gem stones ----------------------	NA	[e]10	NA	[e]10	NA	10
Manganiferous ore --------short tons--	20,404	W	19,882	W	14,320	W
Peat ---------- thousand short tons--	5	W	W	173	W	W
Sand and gravel:						
Construction ------------do----	5,845	17,097	[e]4,900	[e]14,000	7,200	19,783
Industrial ------------do----	882	14,889	794	14,092	800	14,081
Stone:						
Crushed ---------------do----	[e]17,900	[e]72,500	17,079	72,520	[e]18,200	[e]76,700
Dimension -------------do----	[r][e]8	[r][e]537	8	541	[e]8	[e]533
Combined value of cement (masonry), clays (fuller's earth), gold (1985-86), mica (scrap), silver (1985-86), vermiculite, and values indicated by symbol W ----------	XX	29,562	XX	32,193	XX	37,273
Total --------------------	XX	[r]275,295	XX	275,929	XX	295,889

Mineral	1984 Quantity	1984 Value (thousands)	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
SOUTH DAKOTA						
Cement:						
Masonry ----- thousand short tons--	5	$283	4	W	4	W
Portland ---------------do----	619	30,773	655	W	635	W
Clays[2] ---------------do----	119	343	117	$309	119	$375
Feldspar --------------short tons--	7,219	124	13,721	W	W	W
Gem stones ----------------------	NA	[e]70	NA	[e]70	NA	100
Gold (recoverable content of ores, etc.) troy ounces--	310,527	111,994	356,103	113,119	W	W
Gypsum -------- thousand short tons--	W	W	34	269	31	268
Sand and gravel (construction) ----do----	5,786	12,168	[e]6,400	[e]16,000	9,713	19,853
Silver (recoverable content of ores, etc.) thousand troy ounces--	50	407	63	388	W	W
Stone:						
Crushed ----- thousand short tons--	[e]3,800	[e]12,800	4,071	14,412	[e]3,600	[e]12,600
Dimension -------------do----	[r][e]57	[r][e]18,032	[r]51	[r]18,336	[e]55	[e]18,399
Combined value of beryllium concentrates, clays (bentonite), lime, mica (scrap), and values indicated by symbol W --------	XX	11,265	XX	[r]44,800	XX	181,291
Total --------------------	XX	[r]198,259	XX	[r]207,703	XX	232,886

See footnotes at end of table.

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

Mineral	1984		1985		1986	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
TENNESSEE						
Clays[2] ---------- thousand short tons--	1,165	$21,690	1,244	$25,913	1,164	$25,228
Gem stones--------------------	NA	[e]5	NA	[e]5	NA	W
Phosphate rock -- thousand metric tons--	1,368	33,275	1,233	[r]27,000	1,232	27,000
Sand and gravel:						
Construction---- thousand short tons--	6,304	19,830	[e]7,200	[e]22,000	7,360	24,592
Industrial ---------------do----	650	6,903	569	6,156	488	5,523
Stone:						
Crushed---------------do----	[e]36,200	[e]138,000	[5]37,939	[5]155,760	[e] [5]40,700	[e] [5]175,600
Dimension --------------do----	[r] [e]6	[r] [e]1,849	[r]6	[r]1,856	[e]6	[e]1,553
Zinc (recoverable content of ores, etc.) metric tons--	116,526	124,854	104,471	92,971	102,118	85,550
Combined value of barite, cement, clays (fuller's earth), copper, lead (1984-85), lime, pyrites, silver, stone (crushed granite, 1985-86), and value indicated by symbol W	XX	131,918	XX	141,109	XX	136,610
Total--------------------	XX	[r]478,324	XX	[r]472,770	XX	481,656
TEXAS						
Cement:						
Masonry ----- thousand short tons--	291	$24,409	263	$22,114	209	$15,790
Portland ---------------do----	10,423	557,421	10,242	532,494	8,883	412,697
Clays -----------------do----	[2]3,517	[2]17,091	4,107	28,059	[2]2,515	[2]11,724
Gem stones--------------------	NA	[e]175	NA	[e]175	NA	297
Gypsum-------- thousand short tons--	2,166	19,431	1,981	17,299	2,131	14,982
Lime ------------------do----	1,157	61,214	1,192	65,927	1,173	62,670
Salt -------------------do----	8,184	69,672	8,390	[r]84,249	8,520	62,996
Sand and gravel:						
Construction--------------do----	62,389	199,461	[e]57,800	[e]198,000	59,562	209,855
Industrial --------------do----	2,028	29,282	1,968	29,095	1,302	18,274
Stone:						
Crushed----------------do----	[e]89,200	[e]300,000	85,764	306,821	[e]84,200	[e]301,500
Dimension --------------do----	[r] [e]46	[r] [e]14,374	[r]36	[r]11,209	[e]49	[e]15,407
Sulfur (Frasch) -- thousand metric tons--	2,994	W	2,979	W	2,506	W
Talc and pyrophyllite thousand short tons--	240	4,125	261	5,245	283	6,456
Combined value of asphalt (native), clays (ball clay, 1986, fuller's earth and kaolin, 1984, 1986), fluorspar, helium (crude and Grade-A), iron ore (usable), magnesium chloride[7] (1984-85), magnesium compounds, magnesium metal[8] (1986), mica (scrap, 1984-85), sodium sulfate (natural), and values indicated by symbol W ----------	XX	419,861	XX	435,936	XX	579,340
Total--------------------	XX	[r]1,716,516	XX	[r]1,736,623	XX	1,711,988
UTAH						
Beryllium concentrates ------short tons--	6,030	$6	5,738	$6	6,533	$7
Cement (portland) - thousand short tons--	W	W	W	W	1,014	58,431
Clays -----------------do----	[2]315	[2]2,223	332	2,509	305	2,048
Gem stones--------------------	NA	[e]80	NA	[e]80	NA	96
Gold (recoverable content of ores, etc.) troy ounces--	W	W	135,489	43,039	W	W
Gypsum-------- thousand short tons--	277	2,671	413	4,033	470	3,671
Lime ------------------do----	297	16,471	225	11,912	232	13,079
Salt -------------------do----	1,246	28,651	[r]1,057	[r]30,013	1,112	31,830
Sand and gravel:						
Construction--------------do----	15,217	34,507	[e]14,000	[e]36,400	16,452	39,763
Industrial --------------do----	11	W	W	W	6	123
Stone (crushed) -------------do----	[e]5,200	[e]16,400	4,657	14,180	[e]4,500	[e]14,100
Vermiculite --------------do----	--	--	--	--	W	153
Combined value of asphalt (native), cement (masonry), clays (fuller's earth, 1984), copper, iron ore (usable, 1986), lead (1984), magnesium compounds, magnesium metal[8] (1986), molybdenum (1984-85), phosphate rock, potassium salts, silver, sodium sulfate (natural), stone (dimension), vanadium (1984, 1986), zinc (1984), and values indicated by symbol W ---------------	XX	[r]424,491	XX	[r]171,792	XX	210,755
Total--------------------	XX	[r]525,500	XX	[r]313,964	XX	374,056

See footnotes at end of table.

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

Mineral	1984 Quantity	1984 Value (thousands)	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
VERMONT						
Sand and gravel (construction) thousand short tons	3,802	$8,071	[e]2,700	[e]$7,000	4,834	$11,226
Stone:						
Crushed do.	[e]1,800	[e]7,000	1,689	7,468	[e]1,600	[e]7,600
Dimension do.	[r][e]111	[r][e]23,963	116	26,346	[e]105	[e]27,075
Combined value of asbestos, gem stones, and talc and pyrophyllite	XX	9,565	XX	9,040	XX	9,310
Total	XX	[r]48,599	XX	49,854	XX	55,211
VIRGINIA						
Clays thousand short tons	712	$6,004	814	$6,977	890	$7,700
Gem stones	NA	[e]20	NA	[e]20	NA	20
Iron oxide pigments (crude) short tons	W	W	2,280	W	W	W
Lime thousand short tons	562	24,799	633	28,103	624	27,362
Sand and gravel (construction) do.	8,860	37,359	[e]10,200	[e]42,000	11,670	46,488
Stone:						
Crushed do.	[e]47,200	[e]196,000	51,686	221,900	[e]52,000	[e]224,700
Dimension do.	[r][e]10	[r][e]3,066	10	3,136	[e]10	[e]3,128
Combined value of aplite, cement, gypsum, kyanite, sand and gravel (industrial), talc and pyrophyllite (1984-85), vermiculite, and values indicated by symbol W	XX	74,355	XX	79,140	XX	83,639
Total	XX	[r]341,603	XX	381,276	XX	393,037
WASHINGTON						
Cement:						
Masonry thousand short tons	W	W	W	W	6	$530
Portland do.	W	W	W	W	1,212	59,091
Clays do.	[2]292	[2]$1,598	243	$1,402	252	1,560
Gem stones	NA	[e]200	NA	[e]200	NA	200
Peat thousand short tons	W	W	12	292	W	W
Sand and gravel:						
Construction do.	23,369	61,070	[e]22,700	[e]62,300	26,342	76,387
Industrial do.	356	5,201	322	5,589	W	W
Stone:						
Crushed do.	[e]10,400	[e]31,700	9,543	31,052	[e]9,000	[e]34,100
Dimension do.	[r][e]1	[r][e]53	1	53	[e]1	[e]69
Combined value of barite (1984-85), calcium chloride (natural, 1985-86), clays (fire clay, 1984) diatomite, gold, gypsum, lime, magnesium metal[8] (1986), olivine, silver, talc and pyrophyllite (1984), and values indicated by symbol W	XX	102,855	XX	[r]120,719	XX	204,688
Total	XX	[r]202,677	XX	[r]221,607	XX	376,625
WEST VIRGINIA						
Clays thousand short tons	381	$3,410	331	$3,342	215	$470
Gem stones	--	--	--	--	NA	1
Salt thousand short tons	1,004	W	895	W	W	W
Sand and gravel (construction) do.	976	3,198	[e]900	[e]3,000	1,501	5,365
Stone (crushed) do.	[e]9,100	[e]37,300	9,393	38,348	[e]9,800	[e]37,500
Combined value of cement, lime (1984-85), sand and gravel (industrial), and values indicated by symbol W	XX	68,279	XX	60,719	XX	86,473
Total	XX	112,187	XX	105,409	XX	129,809
WISCONSIN						
Gem stones	--	--	--	--	NA	$15
Lime thousand short tons	373	$19,892	341	$19,001	350	19,715
Peat do.	9	W	10	W	9	W
Sand and gravel:						
Construction do.	17,785	38,245	[e]16,000	[e]36,000	24,913	59,325
Industrial do.	1,060	11,821	1,197	14,624	1,194	12,399

See footnotes at end of table.

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

Mineral	1984 Quantity	1984 Value (thousands)	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
WISCONSIN—Continued						
Stone:						
Crushed ______ thousand short tons__	[e]15,800	[e]$45,000	14,496	$42,380	[e]18,700	[e]$57,600
Dimension ______________do____	[r] [e]23	[r] [e]2,651	22	2,733	[e]23	[e]2,878
Combined value of abrasives, cement, and values indicated by symbol W ________	XX	11,527	XX	10,372	XX	12,600
Total____________________	XX	[r]129,136	XX	125,110	XX	164,532
WYOMING						
Clays _________ thousand short tons__	2,628	$67,921	2,302	$64,146	1,762	$51,823
Gem stones____________________	NA	225	NA	225	NA	225
Gypsum________ thousand short tons__	376	2,618	576	4,488	W	W
Lime __________________do____	W	W	W	W	25	1,689
Sand and gravel (construction) ____do____	4,586	13,372	[e]3,500	[e]11,000	3,377	10,977
Stone (crushed) _____________do____	[e]1,900	[e]7,600	[5]2,030	[5]7,329	[e] [5]1,700	[e] [5]5,900
Combined value of beryllium concentrates (1986), cement (masonry, 1986, and portland), helium (Grade-A, 1986), sodium carbonate (natural), stone (crushed granite, 1985-86), and values indicated by symbol W	XX	458,187	XX	465,275	XX	485,480
Total____________________	XX	549,923	XX	552,463	XX	556,094

[e]Estimated. [r]Revised. 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; value included with "Combined value" figure.
[3]Less than 1/2 unit.
[4]Partial total; excludes values that must be concealed to avoid disclosing company proprietary data.
[5]Excludes certain stones; value included with "Combined value" figure.
[6]Excludes salt in brines; value included with "Combined value" figure.
[7]Magnesium chloride for magnesium metal reporting discontinued in 1986.
[8]Magnesium metal (refinery production) not reported in 1984 and 1985.

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

(Thousand short tons and thousand dollars)

Area and mineral	1984[e] Quantity	1984[e] Value	1985 Quantity	1985 Value	1986[e] Quantity	1986[e] Value
American Samoa: Stone ___________________	NA	NA	([2])	1	([2])	400
Guam: Stone ________________________	345	2,280	548	3,731	700	3,300
Virgin Islands: Stone ____________________	249	2,397	214	2,405	200	1,500

[e]Estimated. NA Not available.
[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	1984 Quantity	1984 Value	1985 Quantity	1985 Value	1986 Quantity	1986 Value
Cement (portland) __________________	997	87,568	962	72,602	1,132	93,288
Clays ___________________________	128	266	118	264	111	223
Lime ___________________________	35	4,531	23	3,249	24	3,291
Salt ____________________________	--	--	[r]35	[r]735	40	880
Sand and gravel (industrial) ____________	43	W	--	--	31	624
Stone:						
Crushed ______________________	[e]5,813	[e]27,675	5,493	25,799	[e]5,400	[e]26,000
Dimension _____________________	W	W	W	W	--	--
Total[2] ____________________	XX	[r]120,040	XX	[r]102,649	XX	124,306

[e]Estimated. [r]Revised. 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	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
METALS				
Aluminum:				
Ingots, slabs, crude ---- metric tons--	347,292	$441,598	209,794	$282,958
Scrap ---- do----	374,646	350,669	350,858	333,187
Plates, sheets, bars, etc ---- do----	167,874	411,337	180,057	442,681
Castings and forgings ---- do----	12,408	74,498	6,902	59,979
Aluminum sulfate ---- do----	5,698	1,178	2,749	1,180
Other aluminum compounds ---- do----	32,390	27,829	29,486	28,847
Antimony, metals and alloys, crude ---- short tons--	362	876	595	1,210
Bauxite including bauxite concentrate thousand metric tons--	56	6,407	69	12,946
Beryllium ---- pounds--	119,428	6,375	79,556	7,394
Bismuth, metals and alloys ---- do----	268,669	603	92,906	415
Cadmium metal ---- metric tons--	86	342	38	188
Chromium:				
Ore and concentrate:				
Exports ---- thousand short tons--	101	4,600	92	4,143
Reexports ---- do----	4	670	1	511
Ferrochromium ---- do----	10	7,688	6	5,693
Cobalt (content) ---- thousand pounds--	627	r7,167	631	4,726
Copper:				
Ore, concentrate, composition metal, unrefined (copper content) ---- metric tons--	168,024	175,307	194,137	215,931
Scrap ---- do----	134,300	132,386	136,422	123,138
Refined copper and semimanufactures ---- do----	r102,293	r454,357	86,645	427,359
Other copper manufactures ---- do----	7,883	17,522	9,583	20,799
Ferroalloys not elsewhere listed:				
Ferrophosphorus ---- short tons--	49,674	5,776	38,377	4,393
Ferroalloys, n.e.c ---- do----	14,498	24,581	10,029	11,561
Gold:				
Ore and base bullion ---- troy ounces--	1,078,369	334,331	1,440,680	512,065
Bullion, refined ---- do----	2,888,309	919,433	3,172,239	1,207,783
Iron ore ---- thousand long tons--	5,033	240,557	4,482	204,738
Iron and steel:				
Pig iron ---- short tons--	31,614	3,543	47,238	4,442
Iron and steel products (major):				
Steel mill products ---- do----	929,954	855,078	923,822	856,633
Other steel products ---- do----	200,387	465,672	167,211	442,960
Iron and steel scrap: Ferrous scrap including rerolling materials, ships, boats, other vessels for scrapping thousand short tons--	10,191	940,416	11,994	1,081,626
Lead:				
Ore and concentrate ---- metric tons--	9,987	4,503	4,380	1,491
Pigs, bars, anodes, sheets, etc ---- do----	r27,344	20,977	12,601	13,997
Scrap ---- do----	59,949	12,963	58,998	14,921
Magnesium, metal and alloys, scrap, semimanufactured forms, n.e.c ---- short tons--	40,322	113,600	43,992	122,378
Manganese:				
Ore and concentrate ---- do----	56,040	4,286	41,966	3,278
Ferromanganese ---- do----	6,927	4,762	4,323	2,650
Silicomanganese ---- do----	3,089	1,359	2,004	687
Metal ---- do----	5,162	7,242	5,146	7,892
Molybdenum:				
Ore and concentrate (molybdenum content) thousand pounds--	63,859	247,690	49,153	136,006
Metal and alloys, crude and scrap ---- do----	574	2,365	1,000	3,111
Wire ---- do----	546	6,130	494	7,671
Semimanufactured forms, n.e.c ---- do----	408	8,390	486	9,119
Powder ---- do----	369	2,298	854	2,821
Ferromolybdenum ---- do----	1,262	2,698	332	929
Compounds ---- do----	23,769	46,109	17,063	24,997
Nickel:[1]				
Primary (unwrought commercially pure, anodes, ferronickel, powder and flakes) ---- short tons--	24,354	96,503	3,083	19,416
Wrought (bars, rods, angles, shapes, sections; plates, sheets, strip; tubes, pipes, blanks, fittings, hollow bar; wire) do----	8,155	89,289	7,443	69,836
Compound catalysts and waste and scrap ---- do----	18,920	49,516	12,743	25,643
Platinum-group metals:				
Ore and scrap ---- troy ounces--	362,384	76,993	368,748	103,332
Palladium, rhodium, iridium, osmiridium, ruthenium, osmium (metal and alloys including scrap) ---- do----	339,254	56,116	277,772	56,753
Platinum (metal and alloys) ---- do----	187,013	54,052	104,155	41,722
Rare-earth metals: Ferrocerium and pyrophoric alloys metric tons--	23	317	29	319
Selenium ---- kilograms--	154,122	1,431	161,007	1,452
Silicon:				
Ferrosilicon ---- short tons--	12,969	12,671	11,331	8,306
Silicon carbide, crude and in grains (including reexports) do----	5,186	7,446	4,254	7,197

See footnotes at end of table.

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

Mineral	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
METALS —Continued				
Silver:				
Ore, concentrate, waste, sweepings thousand troy ounces	12,145	$79,086	15,002	$85,795
Bullion, refined do	12,611	81,746	10,109	56,785
Tantalum:				
Ore, metal, other forms thousand pounds	491	19,265	463	15,792
Powder do	143	15,188	160	14,172
Tin:				
Ingots, pigs, bars, etc.: Exports metric tons	1,478	16,744	1,547	9,742
Tinplate and terneplate do	155,119	85,000	219,074	91,793
Titanium:				
Ore and concentrate short tons	27,759	6,953	5,314	1,414
Unwrought and scrap metal do	6,992	17,475	6,679	12,870
Intermediate mill shapes and mill products, n.e.c do	3,395	70,423	3,251	70,167
Pigments and oxides do	103,201	112,870	115,447	156,335
Tungsten (tungsten content):				
Ore and concentrate metric tons	124	831	34	242
Carbide powder do	661	15,734	349	9,268
Alloy powder do	1,449	33,331	951	19,779
Vanadium:				
Ore and concentrate (vanadium content) thousand pounds	5	9	177	772
Pentoxide, etc do	3,053	6,300	3,088	6,810
Ferrovanadium do	908	4,791	1,025	4,647
Zinc:				
Slabs, pigs, or blocks metric tons	1,011	1,525	1,938	3,533
Sheets, plates, strips, other forms, n.e.c do	776	1,973	721	1,513
Waste, scrap, dust (zinc content) do	45,984	22,080	70,211	34,907
Semifabricated forms, n.e.c do	r2,677	r3,503	2,660	3,356
Ore and concentrate do	23,264	8,216	3,269	1,590
Zirconium:				
Ore and concentrate short tons	16,855	3,965	17,474	4,567
Oxide do	1,048	3,332	1,817	4,010
Metals, alloys, other forms do	1,153	51,558	1,190	63,134
INDUSTRIAL MINERALS				
Abrasives (includes reexports):				
Industrial diamond, natural or synthetic:				
Powder or dust thousand carats	51,593	81,806	51,163	89,812
Other do	3,291	29,530	3,564	30,313
Diamond grinding wheels do	553	6,603	464	5,597
Other natural and manufactured metallic abrasives and products	XX	[2]89,716	XX	[2]101,452
Asbestos:				
Exports:				
Unmanufactured metric tons	45,075	16,366	46,897	14,401
Products	XX	193,476	XX	162,851
Reexports:				
Unmanufactured metric tons	581	123	384	119
Products	XX	r283	XX	1,045
Barite: Natural barium sulfate short tons	5,876	692	6,969	1,021
Boron:				
Boric acid do	49,457	21,598	42,178	23,562
Sodium borates, refined do	623,375	151,000	624,057	161,000
Bromine compounds thousand pounds	61,000	23,400	28,000	23,900
Calcium:				
Other calcium compounds including precipitated calcium carbonate short tons	49,000	25,000	26,833	15,000
Chloride do	26,143	6,343	18,168	3,962
Dicalcium phosphate do	58,600	43,000	51,113	42,000
Cement: Hydraulic and clinker do	97,897	21,478	58,556	9,024
Clays:				
Kaolin or china clay thousand short tons	1,381	174,204	1,583	213,373
Bentonite do	640	44,973	581	44,607
Other do	759	90,694	749	93,182
Diatomite do	120	28,519	131	32,180
Feldspar, leucite, nepheline syenite short tons	9,280	680	12,000	1,024
Fluorspar do	9,671	1,063	16,215	1,801
Gem stones (including reexports):				
Diamond thousand carats	2,378	571,300	2,527	787,700
Pearls	XX	3,600	XX	2,600
Other	XX	r96,400	XX	111,700
Graphite, natural short tons	r8,357	r3,125	7,754	3,416
Gypsum:				
Crude, crushed or calcined thousand short tons	83	13,021	155	15,481
Manufactured, wallboard and plaster articles	XX	13,398	XX	13,324
Helium million cubic feet	439	25,316	432	16,200

See footnotes at end of table.

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

Mineral	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
INDUSTRIAL MINERALS —Continued				
Lime short tons	19,383	$5,155	16,448	$4,500
Lithium compounds:				
Lithium carbonate thousand pounds	13,916	19,006	11,579	15,978
Lithium hydroxide do	7,853	13,709	6,388	11,141
Other lithium compounds do	5,608	12,453	3,092	8,060
Magnesium compounds:				
Magnesite, dead-burned short tons	24,805	5,529	23,746	5,488
Magnesite, crude, caustic-calcined, lump or ground do	21,567	9,773	22,801	13,295
Mica:				
Waste, scrap, ground thousand pounds	17,378	2,370	14,892	2,230
Block, film, splittings do	82	159	98	196
Manufactured, cut or stamped, built-up do	NA	5,103	NA	4,502
Mineral-earth pigments, iron oxide, natural and synthetic short tons	29,720	27,574	28,841	30,830
Nitrogen compounds (major) thousand short tons	10,799	1,553,387	7,754	NA
Phosphate rock thousand metric tons	r9,136	r263,631	7,848	211,701
Phosphatic fertilizers:				
Phosphoric acid do	716	141,162	700	110,010
Superphosphates do	5,524	176,515	5,223	155,861
Diammonium phosphates do	6,131	1,048,322	4,120	641,385
Elemental phosphorus metric tons	17,131	27,024	20,266	33,310
Pigments and compounds: Zinc oxide (metal content) do	359	1,005	791	1,124
Potash:				
Potassium chloride do	699,770	NA	708,357	NA
Potassium sulfate do	91,000	NA	155,608	NA
Quartz, crystal:				
Cultured thousand pounds	185	3,723	324	5,686
Natural do	60	290	74	411
Salt:				
Crude and refined thousand short tons	904	15,988	1,165	16,928
Shipments to noncontiguous territories do	23	5,196	24	6,725
Sand and gravel:				
Construction:				
Sand do	997	6,212	674	5,446
Gravel do	516	2,723	492	2,392
Industrial sand do	866	22,580	849	20,363
Sodium compounds:				
Sodium carbonate do	r1,747	r173,937	2,049	241,238
Sodium sulfate do	119	11,899	111	10,183
Stone:				
Crushed do	2,372	29,347	2,921	36,957
Dimension do	NA	13,835	NA	14,623
Sulfur, crude thousand metric tons	1,365	189,248	1,895	251,664
Talc, crude and ground thousand short tons	237	14,282	234	16,302
Total[3]	XX	r13,080,000	XX	11,558,000

[r]Revised. NA Not available. XX Not applicable.
[1]Not comparable to prior years owing to regrouping of nickel forms.
[2]Silicon carbide (crude and refined) has been deducted and is shown separately elsewhere in this table.
[3]Data may not add to totals shown because of independent rounding.

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

Mineral	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
METALS				
Aluminum:				
Metal metric tons	868,674	$1,017,453	1,348,816	$1,682,907
Scrap do	127,501	108,625	162,317	141,702
Plates, sheets, bars, etc do	423,769	847,476	455,531	914,305
Aluminum oxide (alumina) thousand metric tons	r3,827	r735,238	3,603	574,210
Antimony:				
Ore and concentrate (antimony content) short tons	6,638	12,381	5,855	5,892
Sulfide including needle or liquated do	167	256	576	596
Metal do	5,129	10,983	7,940	15,242
Oxide do	10,620	20,765	13,521	21,529
Arsenic:				
White (As_2O_3 content) metric tons	16,472	14,059	25,728	16,347
Metallic do	407	2,150	395	2,649
Bauxite, crude and dried thousand metric tons	r7,158	NA	6,456	NA
Beryllium ore short tons	1,646	1,427	1,510	1,324
Bismuth, metals and alloys (gross weight) pounds	1,998,865	10,172	2,489,634	6,895
Cadmium metal metric tons	1,988	4,122	3,174	6,208
Calcium metal pounds	492,244	1,395	566,170	1,310
Cesium compounds and chloride do	50,537	1,595	37,487	1,161
Chromium:				
Ore and concentrate (Cr_2O_3 content) thousand short tons	176	20,170	214	21,657
Ferrochromium (gross weight) do	331	r156,748	388	172,694
Ferrochromium-silicon do	4	2,085	9	5,743
Metal do	4	19,615	4	21,647
Cobalt:				
Metal thousand pounds	16,613	181,379	11,669	83,295
Oxide (gross weight) do	246	2,258	511	4,202
Salts and compounds (gross weight) do	1,413	4,431	805	2,669
Columbium ore do	2,899	4,673	2,854	4,541
Copper (copper content):				
Ore and concentrate metric tons	2,869	1,739	4,232	2,593
Matte do	3,997	6,997	702	573
Blister do	12,979	15,529	34,545	60,236
Refined in ingots, etc do	377,725	491,798	501,984	677,010
Scrap do	23,014	25,680	27,216	31,646
Ferroalloys not elsewhere listed, including spiegeleisen short tons	r5,096	r25,019	3,896	18,588
Gallium kilograms	7,961	3,447	17,202	6,954
Germanium do	14,841	8,829	12,911	7,526
Gold:				
Ore and base bullion troy ounces	1,865,022	587,002	1,948,996	677,337
Bullion, refined do	6,360,977	2,109,475	13,800,451	5,016,558
Hafnium short tons	1	185	(1)	76
Indium thousand troy ounces	980	3,480	1,380	4,633
Iron ore (usable) thousand long tons	15,771	r452,267	16,743	460,643
Iron and steel:				
Pig iron short tons	338,258	50,619	294,967	42,482
Iron and steel products (major):				
Steel mill products do	24,278,482	9,565,642	20,515,304	7,984,816
Other products do	1,211,146	1,308,921	1,157,893	1,211,251
Scrap including tinplate thousand short tons	r611	r46,480	724	49,073
Lead:				
Ore, flue dust, matte (lead content) metric tons	2,649	979	4,604	1,344
Base bullion (lead content) do	760	398	142	114
Pigs and bars (lead content) do	r131,353	r53,864	140,221	59,172
Reclaimed scrap, etc. (lead content) do	3,168	r1,212	3,290	1,471
Sheets, pipes, shot do	1,981	2,517	1,344	1,825
Magnesium:				
Metal and scrap short tons	4,866	10,303	5,191	12,007
Alloys (magnesium content) do	3,651	12,774	1,808	7,008
Sheets, tubing, ribbons, wire, other forms (magnesium content) do	754	2,010	2,210	5,556
Manganese:				
Ore (35% or more contained manganese) do	386,859	22,561	463,242	23,122
Ferromanganese do	366,874	104,389	395,650	120,482
Ferrosilicon-manganese (manganese content) do	109,719	51,423	131,425	58,839
Metal do	8,566	9,052	9,668	9,800
Mercury:				
Compounds pounds	329,889	1,625	316,224	1,395
Metal 76-pound flasks	18,890	5,337	20,187	4,176

See footnotes at end of table.

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

Mineral	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
METALS —Continued				
Molybdenum:				
Ore and concentrate (molybdenum content) thousand pounds	112	$566	1,120	$3,057
Waste and scrap (gross weight) do	NA	2,830	NA	2,870
Metal:				
Unwrought (molybdenum content) do	145	2,370	191	2,510
Wrought (gross weight) do	94	2,301	102	2,701
Ferromolybdenum (gross weight) do	1,424	3,721	1,599	3,626
Material in chief value molybdenum (molybdenum content) do	2,239	7,329	1,102	3,284
Compounds (gross weight) do	3,815	6,678	4,650	9,091
Nickel:				
Pigs, ingots, shot, cathodes short tons	97,779	446,009	99,017	407,210
Plates, bars, etc do	10,100	89,660	6,590	53,894
Slurry do	68,210	101,101	9,170	19,281
Scrap do	5,552	16,430	6,795	19,581
Powder and flakes do	12,753	67,717	10,342	51,051
Ferronickel do	36,528	60,253	37,901	53,672
Oxide do	5,079	20,722	2,868	4,372
Platinum-group metals:				
Unwrought:				
Grains and nuggets (platinum) troy ounces	20,827	6,807	10,465	4,758
Sponge (platinum) do	1,464,645	542,133	1,713,971	780,382
Sweepings, waste, scrap do	530,724	62,342	737,813	95,466
Iridium do	20,972	9,615	30,368	13,517
Palladium do	1,396,810	174,333	1,387,131	174,856
Rhodium do	201,028	173,310	179,068	195,666
Ruthenium do	162,887	16,474	176,580	13,649
Other platinum-group metals do	15,701	4,707	32,010	9,217
Semimanufactured:				
Platinum do	78,206	23,946	94,655	44,766
Palladium do	84,492	9,532	114,596	14,376
Rhodium do	145	73	1	3
Other platinum-group metals do	13,157	2,422	519	59
Rare-earth metals:				
Ferrocerium and other cerium alloys kilograms	113,385	1,302	95,262	1,154
Monazite metric tons	5,694	1,984	2,960	1,106
Metals including scandium and yttrium kilograms	3,185	285	19,558	1,837
Rhenium:				
Metal including scrap pounds	4,943	1,225	5,495	2,617
Ammonium perrhenate (rhenium content) do	3,325	669	12,188	2,149
Selenium and selenium compounds (selenium content) kilograms	400,658	8,358	462,646	9,550
Silicon:				
Metal (over 96% silicon content) short tons	51,801	83,367	40,852	65,180
Ferrosilicon do	155,421	74,019	223,031	100,578
Silver:				
Ore and base bullion thousand troy ounces	3,533	20,180	5,516	30,926
Bullion, refined do	137,398	855,550	125,365	688,296
Sweepings, waste, doré do	11,671	76,218	14,008	78,962
Tantalum ore thousand pounds	737	8,187	905	7,713
Tellurium (tellurium content) kilograms	30,050	871	13,935	911
Thallium pounds	2,655	50	5,302	358
Tin:				
Concentrate (tin content) metric tons	[r]1,616	[r]10,640	3,936	13,693
Dross, skimmings, scrap, residue, tin alloys, n.s.p.f. do	877	2,804	1,121	1,899
Tinfoil, powder, flitters, etc	XX	3,290	XX	1,280
Tin compounds metric tons	827	5,164	860	5,165
Titanium:				
Ilmenite[2] short tons	798,632	66,821	827,489	81,563
Rutile do	179,663	43,967	174,820	52,214
Metal do	5,479	39,408	5,346	36,097
Ferrotitanium and ferrosilicon titanium do	483	982	681	1,421
Pigments do	196,213	206,809	202,674	240,058
Tungsten ore and concentrate (tungsten content) metric tons	4,746	36,706	2,522	13,840
Vanadium (vanadium content):				
Ferrovanadium thousand pounds	1,557	7,757	1,189	6,423
Pentoxide do	22	180	824	3,564
Vanadium-bearing materials do	605	535	4,027	5,720

See footnotes at end of table.

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

Mineral	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
METALS —Continued				
Zinc:				
Ore and concentrates (zinc content) metric tons	90,186	$33,626	75,786	$19,096
Blocks, pigs, slabs do	610,900	508,003	665,126	487,030
Sheets, etc do	3,559	2,757	3,811	3,048
Fume (zinc content) do	--	--	11	2
Waste and scrap do	3,247	1,848	4,521	1,937
Dross and skimmings do	4,942	2,419	6,087	3,098
Dust, powder, flakes do	8,681	10,781	7,446	8,260
Manufactured	XX	713	XX	1,206
Zirconium:				
Ore including zirconium sand short tons	43,787	4,599	75,799	7,836
Metal, scrap, compounds do	4,202	24,962	3,616	18,974
INDUSTRIAL MINERALS				
Abrasives:				
Diamond (industrial) thousand carats	46,222	127,191	45,991	110,648
Other	XX	255,686	XX	294,125
Asbestos metric tons	142,431	44,093	108,352	26,537
Barite:				
Crude and ground thousand short tons	2,127	82,913	767	28,858
Witherite short tons	142	74	147	78
Chemicals do	32,907	19,978	31,603	21,733
Boron:				
Boric acid (contained boron oxide) do	6,000	5,121	3,000	3,824
Colemanite (contained boron oxide) thousand short tons	33,000	24,620	16,000	8,770
Ulexite do	31,000	11,120	42,000	17,766
Bromine (contained in compounds) thousand pounds	17,079	11,065	18,815	9,734
Calcium chloride:				
Crude short tons	75,381	9,059	143,328	14,403
Other do	2,355	1,908	2,098	1,264
Cement: Hydraulic and clinker thousand short tons	14,487	437,429	16,319	468,993
Clays short tons	40,902	5,981	38,398	7,501
Cryolite do	16,596	10,003	11,344	6,959
Feldspar:				
Crude do	936	1,126	568	474
Ground and crushed do	16	25	683	68
Fluorspar do	552,959	49,639	552,785	45,675
Gem stones:				
Diamond thousand carats	8,151	3,006,762	9,192	3,459,931
Emeralds do	2,741	139,000	2,757	152,396
Other	XX	534,113	XX	566,325
Graphite, natural short tons	52,737	16,186	42,790	15,758
Gypsum:				
Crude, ground, calcined thousand short tons	9,924	64,331	9,562	65,432
Manufactured do	XX	91,091	XX	115,735
Iodine, crude thousand pounds	4,971	26,761	3,028	17,199
Lime:				
Hydrated short tons	48,827	3,407	57,842	4,108
Other do	145,230	8,810	142,865	8,129
Lithium:				
Ore do	4,716	1,277	13,327	3,616
Compounds do	1,402	5,774	2,095	9,166
Magnesium compounds:				
Crude magnesite do	1,350	332	37	15
Lump or ground caustic-calcined magnesia do	65,709	10,407	78,742	11,493
Refractory magnesia, dead-burned, fused magnesite, dead-burned dolomite do	179,207	32,075	213,135	38,906
Compounds do	36,751	10,085	39,807	11,038
Mica:				
Waste, scrap, ground thousand pounds	20,057	2,920	21,962	3,549
Block, film, splittings do	1,684	1,080	1,867	654
Manufactured, cut or stamped, built-up do	978	3,154	2,106	4,859
Mineral-earth pigments, iron oxide:				
Ocher, crude and refined short tons	26	22	604	78
Siennas, crude and refined do	270	49	144	73
Umber, crude and refined do	4,921	795	5,855	1,071
Vandyke brown do	404	140	572	293
Other natural and refined do	1,026	561	845	619
Synthetic do	33,151	20,999	28,754	19,382
Nepheline syenite:				
Crude do	920	62	2,970	205
Ground, crushed, etc do	331,684	11,373	295,836	11,075
Nitrogen compounds (major) including urea thousand short tons	8,544	880,348	7,903	777,906

See footnotes at end of table.

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

Mineral	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
INDUSTRIAL MINERALS —Continued				
Peat:				
Fertilizer-grade ---------- short tons	452,018	$54,244	540,729	$68,054
Poultry- and stable-grade ---------- do	25,370	3,606	12,367	1,452
Phosphates, crude and apatite thousand metric tons	34	1,593	528	22,265
Phosphatic fertilizers:				
Fertilizer and fertilizer materials ---------- do	30	5,929	69	8,351
Elemental phosphorus ---------- do	2	3,530	2	3,548
Other ---------- do	3	492	2	473
Pigments and salts:				
Lead pigments and compounds ---------- metric tons	16,272	12,468	21,270	12,932
Zinc pigments and compounds ---------- do	52,310	48,244	57,317	47,006
Potash ---------- do	7,570,900	499,100	6,933,800	385,100
Pumice:				
Crude or unmanufactured ---------- short tons	781	198	3,488	297
Wholly or partly manufactured ---------- do	357	103	509	204
Manufactured, n.s.p.f ----------	XX	218	XX	512
Quartz crystal (Brazilian lascas) thousand pounds	173	99	52	51
Salt ---------- thousand short tons	6,207	65,593	6,665	79,709
Sand and gravel:				
Industrial sand ---------- do	81	1,513	88	1,014
Other sand and gravel ---------- do	246	1,572	205	1,412
Sodium compounds:				
Sodium carbonate ---------- do	56	8,089	106	15,023
Sodium sulfate ---------- do	[r]195	14,492	188	13,829
Stone:				
Crushed ---------- do	2,725	10,209	2,864	10,902
Dimension ----------	XX	[r]294,246	XX	379,724
Calcium carbonate fines thousand short tons	281	1,432	351	1,548
Strontium:				
Minerals ---------- short tons	37,552	3,321	33,236	3,396
Compounds ---------- do	[r]7,458	[r]5,713	8,495	5,871
Sulfur and compounds, sulfur ore and other forms, n.e.s ---------- thousand metric tons	2,104	199,240	1,347	142,220
Talc, unmanufactured ---------- thousand short tons	47	9,532	52	8,715
Total[3] ----------	XX	[r]29,380,000	XX	31,693,000

[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	1985 World production[1]	1985 U.S. production	1985 U.S. percent of world production	1986[p] World production[1]	1986[p] U.S. production	1986[p] U.S. percent of world production
METALS, MINE BASIS						
Antimony (content of ore and concentrate) short tons	61,833	W	NA	66,020	W	NA
Arsenic trioxide[2] ---------- metric tons	54,731	2,200	4	55,456	--	--
Bauxite[3] ---------- thousand metric tons	84,310	674	1	85,938	510	1
Beryl ---------- short tons	8,973	5,738	64	9,874	6,533	66
Bismuth ---------- thousand pounds	10,498	W	NA	8,965	W	NA
Chromite ----------	11,630	--	--	11,394	--	--
Cobalt (content of ore and concentrate) thousand pounds	80,229	--	--	79,700	--	--
Columbium-tantalum concentrate (gross weight) ---------- do	84,184	--	--	78,876	--	--
Copper (content of ore and concentrate) thousand metric tons	8,088	1,106	14	8,156	1,147	14

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	1985			1986[p]		
	World production[1]	U.S. production	U.S. percent of world production	World production[1]	U.S. production	U.S. percent of world production
METALS, MINE BASIS —Continued						
Gold (content of ore and concentrate) thousand troy ounces	48,673	2,427	5	50,937	3,733	7
Iron ore (gross weight) thousand long tons	839,865	48,751	6	847,775	38,825	5
Lead (content of ore and concentrate) thousand metric tons	3,389	424	13	3,239	353	11
Manganese ore (gross weight)	26,912	--	--	26,716	--	--
Mercury thousand 76-pound flasks	196	17	9	176	W	NA
Molybdenum (content of ore and concentrate) thousand pounds	216,364	108,409	50	206,192	93,976	46
Nickel (content of ore and concentrate)	884	6	1	864	1	(4)
Platinum-group metals[2] thousand troy ounces	7,938	W	NA	7,834	W	NA
Silver (content of ore and concentrate) do	421,041	39,433	9	419,781	34,220	8
Tin (content of ore and concentrate) metric tons	188,653	W	NA	180,237	W	NA
Titanium concentrates (gross weight):						
Ilmenite	3,793	W	NA	3,750	W	NA
Rutile	414	W	NA	439	W	NA
Tungsten ore and concentrate (contained tungsten) metric tons	46,535	996	2	42,474	780	2
Vanadium (content of ore and concentrate) short tons	33,299	W	NA	32,800	W	NA
Zinc (content of ore and concentrate) thousand metric tons	6,857	252	4	6,853	216	3
METALS, SMELTER BASIS						
Aluminum (primary only) do	15,351	3,500	23	15,314	3,037	20
Cadmium metric tons	18,634	1,603	9	18,257	1,486	8
Cobalt short tons	57,981	--	--	60,645	--	--
Copper smelter (primary and secondary)[5] thousand metric tons	8,585	1,191	14	8,554	1,196	14
Iron, pig (shipments)	555,416	49,963	9	546,833	44,287	8
Lead, smelter (primary and secondary)[6] thousand metric tons	5,587	1,103	20	5,413	981	18
Magnesium (primary)	362	150	41	359	138	38
Nickel[7]	807	36	4	810	2	(4)
Selenium[8] kilograms	1,175,868	W	NA	1,073,984	W	NA
Steel, raw	790,036	[9]88,259	11	780,966	[9]81,606	10
Tellurium[8] kilograms	97,007	W	NA	85,815	W	NA
Tin metric tons	196,633	[10]3,000	2	189,933	[10]3,213	2
Zinc (primary and secondary) thousand metric tons	6,894	334	5	6,784	316	5
INDUSTRIAL MINERALS						
Asbestos do	4,678	57	1	4,522	51	1
Barite	6,597	[11]739	11	5,404	[11]297	5
Boron minerals	3,383	1,269	38	3,534	1,251	35
Bromine thousand pounds	839,982	[11]320,000	38	817,080	[11]310,000	38
Cement, hydraulic	1,055,738	[12]78,859	7	1,099,894	[12]79,916	7
Clays:						
Bentonite[2]	9,592	[11]3,195	33	9,241	[11]2,813	30
Fuller's earth[8]	2,612	[11]2,059	79	2,436	[11]1,910	78
Kaolin[2]	24,594	[11]7,793	32	24,933	[11]8,549	34
Corundum short tons	10,204	--	--	10,160	--	--
Diamond thousand carats	65,603	--	--	91,833	--	--
Diatomite	2,003	635	32	1,972	628	32
Feldspar	4,496	700	16	4,631	735	16
Fluorspar	5,372	66	1	5,367	78	1
Graphite short tons	672,609	--	--	672,837	--	--
Gypsum	93,839	14,726	16	96,556	15,789	16
Iodine, crude thousand pounds	28,015	W	NA	28,333	W	NA
Lime	123,496	[11,12]15,713	13	121,831	[11,12]14,498	12
Magnesite	15,727	W	NA	13,615	W	NA
Mica (including scrap and ground) thousand pounds	557,649	275,100	49	579,146	296,300	51
Nitrogen, N content of ammonia	96,978	13,238	14	95,946	11,499	12
Peat	266,304	839	(4)	271,839	886	(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	1985			1986[p]		
	World production[1]	U.S. production	U.S. percent of world production	World production[1]	U.S. production	U.S. percent of world production
INDUSTRIAL MINERALS —Continued						
Perlite	1,802	[11]518	29	1,798	[11]507	28
Phosphate rock (gross weight) thousand metric tons	146,664	50,835	35	137,063	38,710	28
Potash (K_2O equivalent) do	29,051	1,296	4	28,248	1,202	4
Pumice[8]	12,085	[11]508	4	11,520	[11]554	5
Salt	191,565	[11 12]40,102	21	192,222	[11 12]36,703	19
Sodium compounds, natural and manufactured:						
Sodium carbonate	31,129	8,511	27	31,363	8,438	27
Sodium sulfate	4,838	835	17	4,738	798	17
Strontium[8] short tons	182,401	--	--	183,044	--	--
Sulfur, all forms thousand metric tons	54,587	11,609	21	54,161	11,087	20
Talc and pyrophyllite	8,661	1,269	15	8,529	1,302	15
Vermiculite[8]	556	[11]314	56	570	[11]317	56

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

[1]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. percent 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, and emery, decreased in 1986. Shipments of processed tripoli increased slightly in quantity and 20% in value. Production of garnet, a common iron-aluminum-silicate mineral, decreased 12% in quantity and value. There was a 4% increase in the quantity and an 11% increase in the value of refined garnet shipped when compared with 1985 shipments, a new record high. Production of crude special silica stone decreased 7% in quantity and slightly in value, and shipments of finished special silica stone products decreased slightly in quantity and increased 229% in value. Production of emery, an impure aluminum oxide, increased 77% in quantity and increased 269% in value of product mined and shipped.

Table 1.—Salient U.S. abrasives statistics

	1982	1983	1984	1985	1986
Natural abrasives production by producers:					
Tripoli (crude) short tons	112,928	111,020	124,482	W	117,174
Value thousands	$653	$649	$699	W	$918
Special silica stone[1] short tons	1,285	1,101	1,290	1,157	1,073
Value thousands	$553	$482	$602	$515	$501
Garnet[2] short tons	27,303	29,767	29,647	36,727	32,296
Value thousands	$2,321	$2,533	$2,487	$2,973	$2,603
Emery short tons	W	W	W	W	2,878
Value thousands	W	W	W	W	W
Manufactured abrasives[3] short tons	418,224	[4]418,153	[4]531,264	[4]478,897	[4]482,860
Value thousands	$167,471	[4]$167,430	[4]$203,231	[4]$171,974	[4]$173,858
Foreign trade (natural and artificial abrasives):					
Exports (value) do	$174,126	$192,794	$191,003	$191,272	$207,624
Reexports (value) do	$22,650	$24,111	$27,248	$23,845	$26,747
Imports for consumption (value) do	$245,048	$289,865	$381,694	$382,877	$404,773

W Withheld to avoid disclosing company proprietary data.
[1]Includes grindstones, oilstones, and whetstones. 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 U.S. and Canadian production and value of aluminum-zirconium oxide.

The nonmetallic manufactured abrasives industry, which includes only silicon carbide and fused aluminum oxide in the reported statistics, experienced a slight decrease in quantity and a slight increase in value of shipments. The average unit values of these shipments, including high-purity fused aluminum oxide, increased from those of 1985.

The metallic abrasives industry, which includes the primary producers of steel shot and grit, chilled and annealed iron shot and grit, plus cut wire shot manufacturers, reported a 6% increase in quantity and a slight decrease in value shipped from the 1985 shipments.

U.S. exports of diamond grit and powder was approximately 46.8 million carats, a 6% decrease from the record high of 1985.

Total imports of abrasive materials increased 6% in value. Imports of industrial diamond decreased 13% in value, and the quantity was essentially unchanged. Imported stone decreased 6% in quantity and 20% in value with an average price of $7.24 per carat, a 15% decrease from that of 1985. Imports from Ireland of synthetic grit, dust, and powder decreased 5% in quantity but accounted for 72% of the imports in this category. The average value of the synthetic grit, dust, and powder imported from Ireland increased from $1.49 to $1.53 per carat. Total exports plus reexports of abrasive materials increased 9% in value.

Domestic Data Coverage.—Domestic production data for abrasive materials are developed by the Bureau of Mines from six separate, voluntary surveys. Of the 67 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 diamond were essentially unchanged from those of 1985 in quantity at 54.7 million carats of loose material, but increased 8% in value to $120.1 million. The diamond content of diamond wheels, exports plus reexports, was 463,519 carats, a decrease of 16%; the declared value decreased 15% to $5.6 million. The total value of abrasive materials, exports plus reexports, increased 9% to $234.4 million.

Industrial diamond imports totaled 46 million carats of loose material valued at $110.6 million; the quantity was essentially the same as that of 1985, but the value decreased 13%. Imports of synthetic dust and powder were unchanged at 29.6 million carats; however, the value decreased slightly to $1.29 per carat. Natural dust and powder imports increased 8% to 7.3 million carats; the value remained unchanged at $1.08 per carat. Imports of natural stones plus miners' diamonds declined 6% to 8.9 million carats; the value decreased 15% to $7.24 per carat. Imports from Ireland accounted for 72% of the quantity of synthetic dust and powder and 49% of the total quantity of industrial diamond. The Republic of South Africa, the largest U.S. source of industrial diamond stones, furnished 42% of the quantity imported and 58% of the value. The Republic of South Africa's share of total U.S. industrial diamond imports decreased to 9% of the quantity and 35% of the value.

The value of abrasive materials imported increased 6% to $404.8 million. Imports by category as a percentage of value were industrial diamond and diamond products, 30%; abrasive coated paper, cloth, etc., 26%; fused aluminum oxide, 17%; silicon carbide, 10%; and other, 17%. The value of net imports increased slightly to $170 million.

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

(Thousands)

Kind	1985 Quantity	1985 Value	1986 Quantity	1986 Value
NATURAL				
Industrial diamond, natural or synthetic, powder or dust _ carats__	49,725	$78,235	46,839	$83,853
Industrial diamond, natural or synthetic, other ________do____	1,556	10,227	1,669	10,444
Emery, natural corundum, pumice in blocks _________pounds__	1,918	833	2,374	1,061
MANUFACTURED				
Artificial corundum (fused aluminum oxide) __________do____	24,531	15,004	21,836	18,963
Silicon carbide, crude or in grains ________________do____	10,004	7,147	8,386	7,110
Carbide abrasives, n.e.c______________________do____	1,420	1,005	327	509
Other refined abrasives _____________________do____	21,152	12,364	23,896	14,287
Grinding and polishing wheels and stones:				
Diamond __________________________ carats__	552	6,544	451	5,358
Polishing stones, whetstones, oilstones, hones, similar stone number__	726	2,208	1,086	2,416
Wheels and stones, n.e.c ____________________pounds__	3,445	19,343	4,459	21,295
Abrasive paper and cloth, coated with natural or artificial abrasive materials____________________________do____	10,405	33,576	11,455	36,365
Grit and shot including wire pellets ______________do____	16,172	4,786	13,964	5,963
Total _______________________________	XX	191,272	XX	207,624

XX Not applicable.

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

(Thousands)

Kind	1985 Quantity	1985 Value	1986 Quantity	1986 Value
NATURAL				
Industrial diamond, natural or synthetic, powder or dust _ carats__	1,868	$3,571	4,324	$5,959
Industrial diamond, natural or synthetic, other ________do____	1,735	19,303	1,895	19,869
Emery, natural corundum, pumice in blocks _________pounds__	30	13	--	--
MANUFACTURED				
Artificial corundum (fused aluminum oxide) __________do____	57	40	23	17
Silicon carbide, crude or in grains ________________do____	367	299	122	87
Grinding and polishing wheels and stones:				
Diamond __________________________ carats__	1	59	13	239
Polishing stones, whetstones, oilstones, hones, similar stone ___________________________ number__	7	16	4	2
Wheels and stones, n.e.c ____________________pounds__	55	266	111	453
Abrasive paper and cloth, coated with natural or artificial abrasive materials________________________________do____	45	278	90	121
Total _______________________________	XX	23,845	XX	26,747

XX Not applicable.

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

(Thousands)

Kind	1985 Quantity	1985 Value	1986 Quantity	1986 Value
Emery, flint, rottenstone, tripoli, crude or crushed ___short tons__	24	$475	3	$2,187
Silicon carbide, crude_________________________do____	56	22,854	76	30,046
Aluminum oxide, crude _______________________do____	152	60,444	142	55,884
Other crude artificial abrasives__________________do____	14	4,570	7	719
Abrasives, ground, grains, pulverized or refined:				
Silicon carbide ___________________________do____	6	9,007	7	10,558
Aluminum oxide___________________________do____	18	13,982	17	13,805
Emery, corundum, flint, garnet, other, including artificial abrasives ____________________________do____	2	5,343	2	7,330

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

(Thousands)

Kind	1985 Quantity	1985 Value	1986 Quantity	1986 Value
Papers, cloths, other materials wholly or partly coated with natural or artificial abrasives	(1)	$78,219	(1)	$106,704
Hones, whetstones, oilstones, polishing stones number	7,102	1,757	3,147	1,745
Abrasive wheels and millstones:				
Burrstones manufactured or bound up into millstones short tons	(2)	14	(2)	20
Solid natural stone wheels number	429	300	816	550
Diamond do	420	10,477	807	10,553
Abrasive wheels bonded with resins pounds	11,208	16,891	10,733	19,642
Other	(1)	16,299	(1)	18,829
Articles not specifically provided for:				
Emery or garnet	(1)	554	(1)	327
Natural corundum or artificial abrasive materials	(1)	8,367	(1)	10,251
Other n.s.p.f	(1)	4,094	(1)	4,275
Grit and shot, including wire pellets pounds	6,757	1,478	--	--
Diamond, natural and synthetic:				
Diamond dies number	14	561	13	700
Crushing bort carats	390	568	252	338
Natural industrial diamond stones do	8,174	74,433	8,436	61,808
Miners' diamond do	[3]1,271	6,019	472	2,645
Powder and dust, synthetic do	29,633	38,860	29,570	38,018
Powder and dust, natural do	6,754	7,311	7,261	7,839
Total	XX	382,877	XX	404,773

XX Not applicable.
[1]Quantity not reported.
[2]Less than 1/2 unit.
[3]Includes 111,000 carats of synthetic miners' diamond in 1985.

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, increased slightly in quantity and increased 20% in value. The value increased 33% for filler material but 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.

Processed Minerals Inc., a division of Canadian Pacific Railroad Co., acquired American Tripoli at yearend.

Prices quoted in the Engineering and Mining Journal, December 1986, for tripoli and amorphous silica were as follows:

Tripoli, paper bags, carload lots, f.o.b., in cents per pound:	
White, Elco, IL: Air floated through 200 mesh	3.55
Rose and cream, Seneca, MO, and Rogers, AR:	
Once ground	2.90
Double ground	2.90
Air float	3.15
Amorphous silica, 50-pound, paper bags, f.o.b. Elco, IL, in dollars per ton:	
Through 200 mesh, 90% to 95%	$71.00
Through 200 mesh, 96% to 99%	72.00
Through 325 mesh, 98% to 99.4%	78.00
Through 325 mesh, 99.5%	95.00
Through 400 mesh, 99.9%	128.00
Below 15 micrometers, 99%	137.00
Below 10 micrometers, 99%	164.00
Below 8 micrometers, 99%	196.00

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

Use		1982	1983	1984	1985	1986
Abrasives	short tons	35,798	38,073	40,812	40,022	36,584
Value	thousands	$2,477	$3,203	$3,738	$3,670	$3,590
Filler	short tons	55,314	65,138	65,941	68,800	73,908
Value	thousands	$4,557	$6,077	$6,989	$6,452	$8,588
Other	short tons	--	--	--	--	W
Value	thousands	--	--	--	--	W
Total	short tons	[3]91,111	103,211	106,753	108,822	110,492
Total value	thousands	$7,034	$9,280	$10,727	$10,122	$12,178

W Withheld to avoid disclosing company proprietary data.
[1]Includes amorphous silica and Pennsylvania rottenstone.
[2]Partly estimated.
[3]Data do not add to total shown because of independent rounding.

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. In 1986, the United States was a net exporter of hones, whetstones, and oilstones. Exports plus reexports totaled $2.4 million, imports were $1.7 million, and apparent U.S. consumption was $4.1 million.

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.

Arkansas accounted for 79% of the value and 83% of the total quantity of special silica stone products sold or used by U.S. producers.

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

Year	Quantity (short tons)	Value (thousands)
1982	713	$5,360
1983	602	3,814
1984	683	3,975
1985	443	1,452
1986	437	4,771

[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 1986

Company and location	Type of operation	Product
Arkansas Oilstone Co.: Hot Springs, AR	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.
Malvern, AR (inactive)	Quarry	Crude novaculite.
Washita Mountain Whetstone Co.: Lake Hamilton, AR	Stone cutting and finishing	Whetstones and oilstones.

GARNET

The United States continued to be the largest garnet producer, 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. Four domestic producers were active in 1986, 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, 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. (IGE), near Rangeley in Oxford County, ME, produced a range of garnet products that were used mostly in sandblasting and water filtration. IGE completed improvements in processing facilities and changes in product line that significantly increased production capacity. These changes in product line were driven by changes in market demand.

Production of crude garnet concentrates decreased 12% in quantity and value. The quantity of refined garnet sold or used increased 4% and the value increased about 11% compared with that of 1985.

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

Year	Quantity (short tons)	Value (thousands)
1982	26,660	$5,549
1983	30,300	5,970
1984	27,672	5,677
1985	30,634	6,102
1986	31,856	6,748

CORUNDUM AND EMERY

Corundum.—The value of imported crude corundum was $23,577, and the value of imported natural corundum articles was $10.3 million. The domestic demand was met by imports and the withdrawal from industry stocks of imported crude material. The stocks, which have constituted the major source of domestic supply in recent years, were made up almost entirely of materials imported from Zimbabwe through the Republic of South Africa in 1979. One firm in Massachusetts held these stocks of imported materials, and the same firm accounted for over one-half of the consumption of domestically processed crude corundum. Corundum was used as a tumbling medium and in grinding and polishing optical components.

The major U.S. sources of imported corundum articles by value were Canada, 52%; Ireland, 14%; and Italy, 8%.

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 1985, production of emery in Turkey was reported as 17,249 short tons, and production in Greece was reported to be 8,520 short tons. General Abrasives Co. imported emery from Turkey and Greece, processed it at its Westfield, MA, facility, and distributed the product.

Table 9.—Natural corundum: World production, by country[1]

(Short tons)

Country	1982	1983	1984	1985[p]	1986[e]
India	1,494	787	487	550	550
South Africa, Republic of	68	54	23	[2]11	[2]10
U.S.S.R.[e]	9,500	9,600	9,600	9,600	9,600
Uruguay[e]	50	55	55	44	--
Zimbabwe	9,606	5,644	([3])	([3])	--
Total	20,718	16,140	10,165	10,205	10,160

[e]Estimated. [p]Preliminary.
[1]Table includes data available through June 24, 1986.
[2]Reported figure.
[3]Revised to zero.

INDUSTRIAL DIAMOND

The four domestic firms producing synthetic industrial diamond were E. I. du Pont de Nemours & Co. Inc., Industrial Diamond Div., Gibbstown, NJ; General Electric Co., 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. Secondary production of industrial diamond, as reclaimed from used drill bits, diamond tools, and from wet and dry diamond-containing waste, was estimated to be 4.62 million carats.

The General Services Administration (GSA) awarded contracts for converting some chromite and metallurgical-grade manganese ore to high-carbon ferrochromium and high-carbon ferromanganese, respectively. Congress authorized continuation of this upgrading program and specified minimum annual conversion for fiscal years 1987 through 1993. Industrial diamonds in excess of stockpile goals continued to be sold in support of the program to upgrade ferroalloys.

Table 10.—U.S. imports for consumption of industrial diamond (excluding diamond dies)

(Thousand carats and thousand dollars)

Year	Quantity	Value
1982	19,127	85,837
1983	24,877	88,617
1984	43,710	113,632
1985	46,222	127,191
1986	45,991	110,648

Table 11.—U.S. imports for consumption of industrial diamond, by country[1]

(Thousand carats and thousand dollars)

Country	Natural industrial diamond stones (including glazers' and engravers' diamond, unset)				Miners' diamond[2]				Powder and dust, synthetic				Powder and dust, natural			
	1985		1986		1985		1986		1985		1986		1985		1986	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Australia	1	24	72	154	--	--	--	--	--	--	11	10	--	--	--	--
Belgium-Luxembourg	726	13,808	970	8,132	200	102	20	281	723	151	330	853	572	411	1,084	801
Canada	144	255	71	121	(3)	4	--	--	119	58	38	36	976	250	1,118	1,904
China	--	--	4	6	--	--	--	--	4	7	--	--	22	11	--	--
Congo	14	277	8	22	--	--	--	--	--	--	--	--	--	--	--	--
France	1	51	2	85	--	--	12	18	94	45	40	12	--	--	--	--
Germany, Federal Republic of	2	98	1	40	(3)	121	23	102	579	887	181	251	70	83	174	344
Ghana	--	--	71	232	--	--	--	--	--	--	--	--	--	--	--	--
Greece	--	--	--	--	--	--	--	--	676	333	857	446	--	--	--	--
Hong Kong	9	77	6	142	--	--	--	--	13	8	--	--	--	--	--	--
Iran	--	--	247	165	--	--	5	12	--	--	82	173	--	--	--	--
Ireland	763	1,622	330	1,199	941	4,952	113	727	22,348	33,380	21,205	32,351	1,702	3,152	982	1,369
Israel	11	672	138	190	(3)	3	3	11	15	52	148	56	90	30	55	54
Italy	--	--	90	28	--	--	(3)	15	--	--	337	108	--	--	3	48
Japan	18	616	46	1,462	--	--	--	--	2,800	1,604	4,281	2,119	158	128	1,316	419
Mexico	--	--	10	84	5	43	--	--	--	--	1	5	--	--	1	1
Netherlands	94	1,487	151	1,191	6	97	--	--	(3)	22	--	--	8	8	19	139
South Africa, Republic of	3,881	44,594	3,556	37,622	1	42	5	5	49	59	64	194	749	1,162	611	382
Switzerland	7	261	20	793	(3)	116	--	--	341	532	426	379	784	528	461	581
U.S.S.R.	--	--	--	--	--	--	--	--	--	--	62	17	442	130	--	--
United Kingdom	2,417	8,168	1,975	6,418	81	129	89	378	1,583	1,297	1,136	609	445	352	923	1,016
Venezuela	37	1,142	8	978	3	134	--	--	--	--	(3)	3	--	--	--	--
Zaire	--	--	571	1,672	7	43	198	1,070	--	5	13	26	583	890	381	728
Other Africa, n.e.c	8	314	38	319	(3)	3	--	--	--	--	43	20	--	--	--	--
Other	40	966	51	753	26	230	4	26	289	420	314	353	152	177	133	53
Total[4]	8,174	74,433	8,436	61,808	1,271	6,019	472	2,645	29,633	38,860	29,570	38,018	6,754	7,311	7,261	7,839

[1]Excludes 390,400 carats of crushing bort from Belgium-Luxembourg, Canada, Japan, the Republic of South Africa, and the United Kingdom in 1985, and 251,600 carats from Belgium-Luxembourg, Japan, and the Netherlands in 1986.
[2]Includes 111,000 carats of synthetic miners' diamonds in 1985.
[3]Less than 1/2 unit.
[4]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

The National Defense Stockpile of industrial diamonds, as of December 31, 1986, was 22 million carats of crushing bort; however, the 10.6 million carats of stones exceeded the proposed goal of 7.7 million carats. Available for disposal, from enabling legislation effective October 1, 1984, was 2.9 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 has been issued.

Exports plus reexports of industrial diamond dust and powder, natural and synthetic, were down slightly in quantity from the 1985 record high of 51.6 to 51.2 million carats; however, the value increased 10% to $89.8 million. Exports plus reexports of stone totaled 3.6 million carats valued at $30.3 million.

The United States remained the largest consumer of natural industrial diamond. Apparent consumption of natural and synthetic grit, dust, and powder was estimated to be 68.7 million carats, and apparent consumption of natural stones was estimated to be 6.9 million carats.

WORLD REVIEW

De Beers Consolidated Mines Ltd.'s sales of diamonds through the Central Selling Organization in 1986 were reported to be $2.56 billion compared with $1.83 billion in 1985, an increase of 40%.

Angola.—The Government of Angola liquidated Companhia de Diamantes de Angola, the state-owned diamond mining company, and stopped mining diamonds. The Government formed a new corporation called Empresa Nacional de Diamantes de Angola to oversee Angolan diamond operations. Under the new system, Angola's diamond-bearing areas would be parceled into concessions and allocated to foreign companies. The Angolan civil war significantly disrupted the production of diamonds. Production decreased from 1.5 million carats in 1979 to approximately 0.3 million carats in 1986. The average price decreased from $158 per carat in 1980 to $45 per carat in 1986. Production costs increased greatly because the mining areas are not secured and all equipment, supplies, and personnel must be airlifted to mines.[2]

Australia.—Argyle Diamond Mines Joint Venture completed the first year of production from the AK-1 lamproite pipe. The production of 29.2 million carats exceeded the planned production of 25 million carats.

Freeport Bow River Properties Inc. and Gem Exploration and Minerals Ltd. completed trial mining and feasibility studies on the Bow River alluvial diamond deposit. Plans were announced for construction of a mine and processing plant.

Australian Ores & Minerals Ltd. Div. and De Beers, Afro-West Mining Ltd. and Aracca Petroleum Corp., and Ashton Mining Ltd. all continued exploration and testing of their diamond projects.

Ghana.—Ghana Consolidated Diamonds Ltd. began mining operations in January in the Birin Valley. The operations were established as the main source of gravel for milling, to replace the almost depleted Akwatia deposits. The continued use of obsolete inefficient machinery resulted in a decrease in the number of carats produced. Gold was recovered as a byproduct of the diamond production.

The Government of Ghana published the Minerals and Mining Law of 1986, which modified existing laws. It ruled that all minerals in their natural state in Ghana shall be vested in the Provisions National Defense Council for and on behalf of the people of Ghana. The Government also shall have the right of preemption of all minerals recovered in Ghana or any waters controlled by Ghana.

Guinea.—Bridge Oil Ltd. reported that Aredor Guinea S.A. diamond production was 203,788 carats, an increase of 54% compared with 1985 production. Feasibility and design work was completed for a gold recovery system to recover gold from the diamondiferous gravel.

Indonesia.—Australia-based Pelsart Resources NL, part of the Parry Corp., negotiated a joint venture with Ashton Mining NL to explore for diamonds in the Pujon area of central Kalimantan. Alluvial diamonds have been found in this area for many years. The source of the diamonds and the delineation of the extent of the diamond-bearing alluvials is the primary objective of the exploration.

Acorn Securities Ltd. of Australia reported that the joint venture, 65% Acorn, 15% Keymead Ltd. of London, and 20% P.T. Aneka Tambang—the Indonesian state-owned mining company, was exploring alluvial diamond claims in the Danan Seran area of southern Kalimantan and completed a successful sampling program. Results to date yielded 992 stones weighing 144.76 carats. The stones ranged in size from 0.01 to 2.31 carats, and 19 of the stones exceeded 1.0 carat.

Table 12.—Diamond (natural): World production, by country and type[1]

(Thousand carats)

Country	1982			1983			1984			1985[p]			1986[e]		
	Gem	Industrial	Total	Gem	Industrial	Total	Gem	Industrial	Total	Gem[2]	Industrial	Total	Gem[2]	Industrial	Total
Angola	915	310	1,225	775	259	1,034	[r][e]652	250	902	[r][e]464	250	714	240	10	250
Australia	274	183	457	3,720	2,480	6,200	3,415	2,277	5,692	4,242	2,828	7,070	[3]13,145	[3]16,066	[3]29,211
Botswana	1,165	6,604	7,769	4,829	5,902	10,731	5,810	7,104	12,914	[r][e]6,318	[r][e]6,317	12,635	[3]9,610	3,500	13,110
Brazil	80	450	530	80	450	530	200	550	750	[r][e]233	[r][e]217	450	300	250	550
Central African Republic	186	91	277	230	65	295	236	101	337	245	105	350	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	68	616	684	34	306	340	35	[r][e]311	346	65	585	650	60	540	600
Guinea	13	27	[e]40	23	17	[e]40	44	3	47	123	9	132	[3]190	[3]14	[3]204
Guyana[e]	4	7	11	5	5	10	6	8	14	4	7	11	3	6	[3]9
India	11	2	13	12	2	14	13	2	15	14	2	16	14	2	16
Indonesia[e]	3	12	15	5	22	27	5	22	27	5	22	27	5	22	27
Ivory Coast	--	--	--	--	--	--	--	--	--	--	--	--	4	6	10
Lesotho	39	3	42	--	--	--	--	--	--	--	--	--	--	--	--
Liberia	170	263	433	132	198	330	108	132	240	66	72	138	[3]63	[3]189	[3]252
Namibia	963	51	1,014	915	48	963	884	46	930	[r][e]865	[r][e]45	910	900	50	950
Sierra Leone	203	87	290	242	103	345	240	105	[e]345	[r][e]243	[r]106	349	215	100	315
South Africa, Republic of:															
Finsch Mine	847	3,003	3,850	1,765	3,278	5,043	1,714	3,184	4,898	1,770	3,184	4,954	1,800	3,172	4,972
Premier Mine	615	1,845	2,460	800	1,844	2,644	765	1,785	2,550	820	1,864	2,684	834	1,869	2,703
Other De Beers properties[4]	1,359	906	2,265	1,400	569	1,969	1,452	593	2,045	1,500	569	2,069	1,529	567	2,096
Other	521	58	579	589	66	655	585	65	650	460	35	495	472	57	529
Total	3,342	5,812	9,154	4,554	5,757	10,311	4,516	5,627	10,143	4,550	5,652	10,202	4,635	5,665	10,300
Swaziland	--	--	--	--	--	--	7	10	17	[r][e]9	[r][e]12	21	17	23	40
Tanzania	100	120	[e]220	183	78	261	[r][e]193	[r][e]84	277	[r][e]207	[r][e]89	[r][e]296	210	90	300
U.S.S.R.[e]	2,100	8,500	10,600	3,700	7,000	10,700	4,300	6,400	10,700	4,400	6,400	10,800	4,400	6,400	10,800
Venezuela	99	394	[e]493	45	234	279	40	232	272	35	[r][e]180	215	40	195	235
Zaire	308	5,856	6,164	3,355	8,627	11,982	5,169	13,290	18,459	[r][e]5,493	[r][e]14,124	19,617	4,661	18,643	[3]23,304
World total	10,243	30,188	40,431	23,039	32,353	55,392	26,073	37,354	63,427	27,781	37,822	65,603	39,157	52,676	91,833

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

[1]Table includes data available through June 2, 1987. 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 (1982-86), the Central African Republic (1983-85), Guinea (1984-86), 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]Other De Beers Group output from the Republic of South Africa includes Kimberley Pool, Koffiefontein Mine, and the Namaqualand Mines.

South Africa, Republic of.—De Beers decided to switch from the long-established block caving system to sublevel caving in the Dutoitspan and Bultfonteen Mines. The project would extend the economic life of both mines and would reduce labor costs. The two mines share a common shaft system. Both mines were developed about 100 years ago.

Syria.—The Syrian Ministry of Oil and Mineral Resources confirmed the existence of a project to exploit diamond deposits discovered in the Homs area.[3]

Zaire.—Diamond production set a record high for the second consecutive year. Production was 23,303,739 carats, an increase of about 19%. The average price per carat was $8.26, well above the $7.90 per carat floor price established by the agreement entered into with De Beers in 1985.

The Government of Zaire signed a contract for the evaluation of each of the Government's shipment of diamonds. The Government has blocked all shipments of diamonds where the evaluation was higher than the De Beers contract price. De Beers had to yield to the valuation either by making a competitive offer or lose the purchase and thereby allow a shipment to be sold outside of De Beers' influence.

TECHNOLOGY

New technology for producing diamond film coatings was used to produce the first commercial product with a thin diamond coating. Japanese firms began marketing a tweeter speaker manufactured by Sony Corp. with a diamond-coated cone for improving the fidelity of sound reproduction. The process for diamond coating involves the use of methane. A mixture of methane and hydrogen pass through a microwave discharge and form an electrically charged plasma that is used to coat the substrate. Additional uses of the technology could include the manufacture of long-wearing tools and bearings coated with diamond, new optical systems, scratchproof lenses and windows, a new generation of high-speed solid-state devices impervious to radiation, and long-lasting razor blades.[4]

A U.S. diamond sawblade manufacturer introduced a new concept in diamond segments as the result of a 10-month development project. The L-shaped diamond segment is said to offer up to 40% reduction in grinding and polishing time in dimension stone production. The metal bond layer contained high-strength synthetic diamond in the size range 20/30-60/80 U.S. mesh. The outer layer also contained high concentrations of diamond. The design results in better blade alignment and tracking during the cut. The manufacturer claimed the arrangement also reduced stress on the blade because the surface area of the segment in contact with the work area is reduced.[5]

Controlled comparison tests, conducted at De Beers Technical Service Centre, between conventional masonry cutoff blades and those containing a high-quality processed natural diamond indicated the processed natural diamond blades had 18 times the life of the conventional cutoff blades. The same tests indicated the blades with the processed natural diamond had a sawing rate improvement of 4.6 times the conventional blades with standard natural grit.[6] A new thermally stable (up to 1,200° C) polycrystalline diamond (PCD) cutting element for rotary core drilling could have significant impact on exploration drilling. Tests of the new PCD bit indicated penetration rates three or four times that of impregnated bits and the life expectancy of the PCD bit was the same as an impregnated bit. The bit was tested in hard gabbro of 240-megapascal compressive strength.[7] Stonecutting chain saws using PCD were reported to have cut tool costs at several Italian marble quarries by up to 60% compared with conventional helicoidal wire. The chains incorporated PCD rock cutters that consist of a 0.7- or 1.0-millimeter-thick layer of PCD backed by tungsten carbide substrate. Since the carbide wears preferentially, the sharp diamond cutting edge is maintained throughout the life of the cutter.[8] A U.S. firm recently introduced a multilayer PCD-coated carbide insert capable of withstanding extreme impact force. The insert is intended for applications in percussion bits and roller bits. Field results obtained by substitution of PCD-enhanced inserts for standard tungsten carbide-cobalt inserts in percussion bits demonstrated that throughout their accepted life (which, depending on the applications, can be from 10 to 50 times that of standard inserts), PCD inserts exhibit virtually no wear. When the inserts finally do fail, it is by fatigue-induced fracture. The tests were conducted in rocks with compressive strengths of 25,000 pounds per square inch (17 megapascals) and 28,200 pounds per square inch (194 megapascals).[9]

MANUFACTURED ABRASIVES

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

At the end of 1986, four firms were producing fused aluminum oxide at eight plants in the United States and Canada. Production was at 45% of furnace capacity. Reported production of high-purity material decreased 7% in quantity and slightly in value compared with that of 1985. Production of regular material decreased 11% in quantity and 7% in value to 135,301 tons and $43.3 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 21,000 tons, an increase of 12% compared with that of 1985.

The fused aluminum oxide facilities of Sohio Electro Minerals Co., at Niagara Falls, NY, and Niagara Falls, Ontario, Canada, were sold to Sandbright Investment Ltd. In December, Sandbright sold the facilities to Washington Mills Abrasive Co. of North Grafton, MA.

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 decreased in both tonnage and value compared with that of 1985.

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 54% of furnace capacity. Output during the year increased 10% to 124,000 tons and value increased 13%. Abrasive use accounted for 38% of the output, metallurgical use accounted for 51% of output, refactory use was 9%, and other uses totaled 2%. Yearend stocks totaled 18,146 tons, an increase of 35% compared with that of 1985. Silicon Metals Products Ltd., Elberton, GA, and Northern Recovery Systems Inc., Barre, VT, both recovered silicon carbide from the stonecutting industry. The recovered silicon carbide was sold for metallurgical and refractory uses.

Sohio Electro Minerals sold the silicon carbide manufacturing facilities at Shawinigan Falls, Quebec, Canada, to Sandbright Investment. In December, Sandbright sold the same facilities to Norton Co. of Worcester, MA.

The National Defense Stockpile, as of December 31, 1986, contained 249,867 tons of crude fused aluminum oxide and 50,786 tons of abrasive grain fused aluminum oxide. Silicon carbide stocks were 80,550 tons, and the goal was 29,000 tons.

Metallic abrasives were produced by 12 firms in 13 plants in the United States. Steel shot and grit were 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, and cut wire shot. The following six States, in decreasing order of quantity, supplied 100% of the total sold or used steel shot and grit: Michigan, Pennsylvania, Ohio, 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.

Wheelabrator-Frye Inc. began to dismantle the metallic abrasives plant at Miskawaka, IN, which had been idle since 1983.

Kennecott sold The Pangborn Co., a manufacturer of metallic abrasives, to Kenmare Capital Corp. in September 1986. In October, Pangborn announced that it closed its metallic abrasives manufacturing facilities at Butler, PA, and converted the plant to a warehouse. Pangborn will continue to market steel shot and grit under its brand name, but the material will be purchased from other manufacturers.

Two U.S. firms developed and started to market cutting tool inserts made from silicon carbide whisker-reinforced ceramic material.[10] The ceramics were made by dispersing the whiskers in a matrix of fine-grained aluminum oxide. The new ceramic materials provided increased strength, thermal conductivity, and shock resistance, and operated at temperatures approaching 2,000° C. Tools made from the materials were ideal for working Inconel, nickel-based alloys and ultrahard steels.[11]

A U.S. firm developed a new ceramic aluminum oxide abrasive. The new material is manufactured using a process based on controlled crystallization of alumina from a solution, followed by filtration, roasting, and grading. The process results in crystals with few inherent fractures, and because of the reduction in fractures, it is reported to be between two and three times tougher than other forms of alumina.[12]

[1]Physical scientist, Division of Industrial Minerals.
[2]Jewelers' Circular-Keystone. Gemstones. V. 157, No. 11, Nov. 1986, p. 159.
[3]Mining Journal (London). Development. V. 308, No. 7903, Feb. 6, 1987, p. 95.
[4]Science. Research News. V. 234, No. 4779, Nov. 28, 1986, pp. 1074-1076.
[5]Industrial Minerals (London). Processing Equipment. No. 224, May 1986, p. 74.
[6]———. Processing Equipment. No. 225, June 1986, p. 82.
[7]World Mining Equipment. V. 10, No. 3. Mar. 1986, pp. 20-21.
[8]Megadiamond Industries Inc. Technol. Update, v. 11, No. 1, Jan. 1987, p. 6.
[9]H. T. Hall Inc. Percussion Drilling With Polycrystalline Diamond-Enhanced Inserts. (Contributions by J. D. Crockett, B. L. Campbell, and D. R. Hall.)
[10]Cutting Tool Engineering. An Industry Profile—Greenleaf Corporation. V. 39, No. 1, Feb. 1987, pp. 54-57.
[11]———. Product Report. V. 38, No. 6. Dec. 1986, p. 49.
[12] Toon, S. Abrasive Minerals. Ind. Miner. (London), No. 231, Dec. 1986, pp. 53-73.

Table 13.—Crude artificial abrasives manufacturers in 1986

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 14.—Producers[1] of metallic abrasives in 1986

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

(Thousand short tons and thousand dollars)

Kind	1982	1983	1984	1985	1986
Silicon carbide[1]	112	109	137	113	124
Value	$54,507	$52,016	$57,125	$42,563	$48,064
Aluminum oxide (abrasive grade)[1]	132	137	177	169	151
Value	$45,975	$50,565	$63,818	$54,061	$50,584
Aluminum-zirconium oxide	8	W	W	W	W
Value	$4,600	W	W	W	W
Metallic abrasives[2]	166	172	217	197	208
Value	$62,389	$64,849	$82,288	$75,349	$75,210
Total	418	[3]418	[3]531	[3]479	[3]483
Total value	$167,471	[3]$167,430	[3]$203,231	[3 4]$171,974	[3]$173,858

W Withheld to avoid disclosing company proprietary data.
[1]Includes 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 16.—End uses of crude silicon carbide and aluminum oxide (abrasive grade) in the United States and Canada, as reported by producers

Use	1985			1986		
	Quantity (short tons)	Value (thousands)	Yearend stocks (short tons)	Quantity (short tons)	Value (thousands)	Yearend stocks (short tons)
SILICON CARBIDE						
Abrasives	46,664	$18,451	6,245	47,248	$19,973	9,858
Metallurgical	53,433	19,018	5,448	63,293	22,719	5,545
Refractories and other	12,508	5,094	1,703	13,407	5,372	2,743
Total	112,605	42,563	13,396	123,948	48,064	18,146
ALUMINUM OXIDE						
Regular: Abrasives plus refractories[1]	152,401	46,705	16,993	135,301	43,347	18,961
High purity	16,422	7,356	1,769	15,251	7,237	2,058
Total	168,823	54,061	18,762	150,552	50,584	21,019

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

Table 17.—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)	
1985:					
Chilled iron shot and grit	W	W	W	W	W
Annealed iron shot and grit	W	W	W	W	W
Steel shot and grit	182,655	$54,404	187,381	$70,647	237,000
Other[3]	17,713	7,584	10,088	4,702	41,100
Total	200,368	61,988	197,469	75,349	XX
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

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 items indicated by symbol W.

Aluminum[1]

By Patricia A. Plunkert and Deborah A. Kramer[2]

Domestic primary aluminum production decreased significantly from that of 1985 owing to smelter shutdowns. In addition, expiration of labor contracts led to work stoppages at many primary smelters, disrupting production for as long as 5 months. The tolling of alumina into metal by independent firms for major foreign and domestic metal companies continued, as approximately 580,000 tons of domestic primary smelting capacity was committed to tolling operations. Foreign sources of aluminum supplied an even larger share of the U.S. market in 1986, as imports reached their highest level in the last 35 years. World primary aluminum smelter capacity decreased slightly in 1986. Although Japan and the United States decreased their annual capacity significantly, these reductions were offset by capacity expansions in Australia, Brazil, Canada, and France.

Advances in aluminum-lithium alloy technology increased their potential for use in future aerospace applications. Although these alloys were in limited production, a range of standard mill products was available for evaluation and testing in sizes similar to those of products made of conventional high-strength aerospace alloys. In addition, silicon carbide-reinforced aluminum metal matrix composites were used in advanced technology applications, and commercial production of ultrahigh-purity aluminum metal was achieved for use in the manufacture of integrated circuits.

April 1986 marked the 100th anniversary of the filing of the formal patent application for the electrolytic reduction of aluminum that permitted, for the first time, the mass commercial production of the world's most abundant metal.

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 11 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)

	1982	1983	1984	1985	1986
United States:					
Primary production	3,274	3,353	4,099	3,500	3,037
Value	$5,485,121	$5,754,298	$7,319,844	$6,249,614	$5,422,993
Price: Producer list, ingot, average cents per pound	76.0	77.8	81.0	81.0	[1]81.0
Secondary recovery[2]	1,466	1,564	1,760	1,762	1,773
Exports (crude and semicrude)	748	776	734	908	753
Imports for consumption (crude and semicrude)	878	1,091	1,477	1,420	1,967
Aluminum industry shipments[3]	5,090	5,857	[r]6,552	[r]6,382	[p]6,543
Consumption, apparent	4,370	5,035	5,279	5,174	5,143
World: Production	[r]13,433	[r]13,908	15,707	[p]15,351	[e]15,314

[e]Estimated. [p]Preliminary. [r]Revised.
[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.—Under Section 111 of the Clean Air Act, the Environmental Protection Agency was required to review standards of performance for new, modified, or reconstructed stationary sources every 4 years. A review of the existing standards of performance for primary aluminum reduction plants (40 CFR 60, Subpart 5) was completed. The review indicated that revisions to the total fluoride emission standards promulgated in June 1980 were not necessary at this time. The limits for total fluoride emissions remained as follows: 1.0 kilogram per ton of aluminum produced for potroom groups at Soderberg plants, 0.95 kilogram per ton of aluminum produced for potroom groups at prebake plants, and 0.05 kilogram per ton of aluminum equivalent for anode bake plants. However, under no circumstances were total fluoride emissions from potroom groups allowed to exceed 1.3 kilograms per ton of aluminum produced at Soderberg anode plants and 1.25 kilograms per ton of aluminum produced at prebaked anode plants.[3]

The Department of Defense Authorization Act, 1987 (Public Law 99-661), signed by the President on November 14, 1986, stated that no action may be taken before October 1, 1987, to implement or administer any change in a stockpile goal in effect on October 1, 1984, that results in a reduction in the quality or quantity of any strategic and critical material to be acquired for the National Defense Stockpile (NDS). Therefore, as of December 31, 1986, the NDS goal for aluminum metal remained at 700,000 short tons, and the stockpile inventory was 2,080 short tons of aluminum metal.

DOMESTIC PRODUCTION

Primary.—Domestic primary aluminum production decreased to about 3 million tons in 1986. Permanent closure of primary smelting capacity and work stoppages from June through October contributed to the decline in U.S. production. Domestic primary aluminum production capacity was reduced to 4 million tons because of the closure of Reynolds Metals Co.'s 83,000-ton-per-year smelter at Listerhill, AL, and Consolidated Aluminum Corp.'s 131,000-ton-per-year smelter at New Johnsonville, TN. In addition, Aluminum Co. of America (Alcoa) permanently closed annual capacity of 78,000 tons at Massena, NY; 40,000 tons at Alcoa, TN; and 105,000 tons at Rockdale, TX. Kaiser Aluminum & Chemical Corp. reportedly wrote off 131,000 tons per year of capacity at its idle Chalmette, LA, smelter. By yearend 1986, the operating capacity of U.S. primary smelters was about 71.8% with 1.14 million tons of the 4 million tons of annual capacity shut down, compared with 66.4% of the 4.7 million tons operational at yearend 1985. The status of the primary industry at yearend 1986 was 2 smelters permanently closed, 3 smelters temporarily closed, 16 operating at reduced capacity, and 6 operating at full capacity.

Expiration of labor contracts with the Aluminum, Brick, and Glass Workers International Union (ABGWIU) and the United Steelworkers of America (USWA) led to work stoppages at many primary smelters, disrupting production for as much as 5 months. Despite talks between the ABGWIU, USWA, Alcoa, and Reynolds Metals to negotiate a master labor contract for both producers before the expiration deadline of May 31, no agreement was reached. After rejecting a proposal that included wage and benefit cuts of about $1.15 per hour, about 15,000 Alcoa employees at 15 plants in 8 States walked off their jobs on June 1. Workers at Reynolds Metals' plants elected to continue work under the terms of the expired contract. Although salaried workers reportedly continued to operate Alcoa's smelters during the walkout, the plants operated at reduced levels. The Vancouver, WA, plant was idled; three and one-half potlines were shut down at Wenatchee, WA; one potline was shut at Massena, NY; two potlines were shut at Evansville, IN; and one-half potline was shut at Badin, NC. After an agreement was reached between the unions and management, a 3-year contract was ratified that called for a wage and benefit reduction of $0.95 per hour. Employees at Alcoa's plants, except Massena, NY, and Evansville, IN, returned to work on July 10. Reynolds Metals' employees also were covered by the new contract. After initial rejection of the master contract, employees at Massena, NY, and Evansville, IN, accepted the contract after some local issues were settled; about 1,500 employees returned to work at Massena on August 1, and about 2,600 employees returned to work at Evansville on August 21. By the end of August, one idled potline reportedly was restarted at

Evansville, to bring the total number of potlines in operation to five, and Wenatchee returned to its full five-potline operation.

Employees at Alcan Aluminum Corp.'s Sebree, KY, primary smelter walked off the job on June 8 after rejecting a contract that called for about $3.20 per hour in wage and benefit concessions. Alcan Aluminum employees had been working without a contract since the last one expired on January 31. Although salaried employees continued to operate the smelter, one potline reportedly was shut during the labor walkout. About 450 workers returned to their jobs on October 31 after management and the ABGWIU successfully negotiated a 3-year contract with about $2.30 per hour in wage and benefit concessions.

Ormet Corp. employees stopped work on July 1 when a contract proposal calling for $4.50 per hour in wage and benefit cuts was rejected by USWA members. Employees had been working without a contract since the previous 3-year contract expired on May 31. Salaried personnel reportedly continued to operate the smelter at a reduced level, idling three of the six potlines that had been operating. About 1,500 union employees ratified a 43-month contract, which called for wage and benefit concessions totaling $4.60 per hour, and returned to their jobs on October 31.

Workers at Alumax Inc.'s Eastalco smelter in Frederick, MD, walked off their jobs on July 31, after the previous labor contract expired. Management reportedly held negotiations with the USWA before the contract expiration, but no contract details were available. Alumax reportedly continued to operate Eastalco with salaried personnel at about 75% of capacity, the same operating capacity as that before the employees stopped work. Employees returned to work on October 19 after ratifying a 3-year contract that called for $0.91 per hour in wage and benefit cuts and some work rule changes. In separate negotiations, employees at Alumax's Intalco smelter in Ferndale, WA, agreed to extend the old contract for 1 year, and employees remained on the job.

After a contract proposal that included wage and benefit cuts equivalent to about $4.50 per hour was rejected, employees at Commonwealth Aluminum Corp.'s Goldendale, WA, primary smelter reportedly were locked out of the facility when their contract expired on July 31. During the lockout, salaried personnel operated the smelter at about 60% of its annual capacity, the same level as it had been operated before the lockout. USWA employees and management negotiated a 3-year contract with wage and benefit concessions totaling $2.60 per hour, and union employees ratified the contract and returned to work on October 7.

Workers at Noranda Aluminum Inc.'s New Madrid, MO, smelter walked off their jobs on September 1, after the expiration of their contract on August 31. The employees rejected a contract proposal that included wage and benefit cuts of about 14.6%. Although salaried employees continued to operate the plant, it reportedly was operating at a rate of 116,000 tons per year, compared with the 185,000-ton-per-year rate at which it had been operating. Noranda and the USWA successfully negotiated a 3-year contract that would reduce the average hourly labor cost by $2.49, and about 350 employees returned to work on October 3.

In addition to work stoppages at primary smelters, 350 employees at Norandal USA Inc.'s rolling mill in Scottsboro, AL, walked off their jobs on June 4, but returned to work on July 1 after a new 3-year contract was negotiated between Norandal and the USWA. About 750 ABGWIU employees stopped work on July 14 at Reynolds Metals' foil, powder, and extrusion plants in Louisville, KY, and 170 employees stopped work at Reynolds Metals' Longview, WA, rod and cable plant on July 15. After reportedly accepting a contract similar to the master contract ratified by Alcoa's and the remainder of Reynolds Metals' employees, workers at these two plants returned to their jobs on August 14.

On June 16, the Bonneville Power Administration (BPA) announced the availability of a variable power rate for its Direct Service Industries (DSI) customers, which included the aluminum producers of the Pacific Northwest. The variable power rate linked the smelters' power costs directly to the price of aluminum. The new proposal stated that a year-round baseline power rate, which was at 22.8 mills per kilowatt hour (mills/kW•h), would be in effect when primary aluminum ingot was priced between two pivot points. Below the lower pivot point, set at 61 cents per pound in the first year and 59 cents per pound thereafter, the power rate would drop 1 mill/kW•h for every 1 cent per pound drop in the ingot price. This decrease would continue until the power cost hit a predetermined floor level. This floor cost was initially set at 15 mills/kW•h and would rise 1 mill/kW•h every 2 years during the variable rate's 10-year duration. When primary ingot was priced above the upper pivot point, which was set at 72 cents per pound, power costs would increase 0.75 mill/kW•h for every 1-cent-per-pound increase in ingot price, until a ceiling of 28.6 mills/kW•h was reached. The ingot price to be used to calculate power costs would be the average Metals Week U.S. transaction price for the month that was 3 months prior. In July, six primary aluminum producers with smelters in the Pacific Northwest signed contracts with BPA to have their smelters' entire power load under the variable power rate. At the end of July, the Federal Energy Regulatory Commission gave an interim approval of the variable rate, and the rate could take effect on August 1.[4]

In January, 95,000 tons of annual primary aluminum capacity reportedly was restarted at Noranda's New Madrid, MO, smelter. This capacity included one 63,500-ton-per-year potline that had been idled since January 1985 and one-half of a potline, idled since November. Capacity was restarted because an agreement between Associated Electric Corp. and Noranda reduced the power rates on these potlines from 22.25 mills/kW•h to 19.25 mills/kW•h for 1 year. A third 77,000-ton-per-year potline reportedly had a separate contract with Associated Electric to supply power at 37 mills/kW•h, but because of heavy shutdown penalties, this potline remained operating.

In January 1986, the Maryland Public Service Commission approved a rate surcharge by Potomac Edison Co. to increase power costs to over 26 mills/kW•h for Alumax's Eastalco smelter in Frederick, MD. The plant was paying 24 mills/kW•h until October 1985, when the rate was increased to 24.8 mills/kW•h. Under a separate agreement with Potomac Edison, on May 1, 1986, Eastalco reportedly began increasing its power usage during the offpeak hours between 10 p.m. and 7 a.m. and on Sundays to take advantage of a 6-month experiment under which Eastalco would pay lower rates for power used during these offpeak hours.

Under an agreement that was approved April 22 by the Ohio Public Utilities Commission, retroactive to January 1, Kaiser reportedly did not have to pay for electricity that it did not use at its Ravenswood, WV, aluminum smelter and fabricating plant. The agreement between Kaiser and Ohio Power Co. reduced the demand charge the Ravenswood facility paid to Ohio Power's Muskingum River Station from 384 megawatts (MW) to 237 MW. This reportedly resulted in a 4-mill/kW•h reduction in power costs and brought Kaiser's costs, in mills/kW•h, from the midtwenties to the low twenties. In addition, as long as the London Metal Exchange (LME) price for aluminum ingot remained below the pivot price of 62.5 cents per pound in fourth quarter 1985 dollars, Kaiser paid the reduced rate. If the LME pivot price was passed in any month, Kaiser paid the original demand charge. If the LME price reached 65 cents per pound, Kaiser began paying a surcharge of 1.5 mills/kW•h. This surcharge increased in stages as the price increased.

During 1986, the amount of primary aluminum produced from alumina on a tolling basis increased in the United States. Four plants (Columbia Falls, MT; Hannibal, OH; The Dalles, OR; and Mount Holly, SC) reportedly committed an annual capacity of 580,000 tons of primary metal to tolling operations. The Columbia Falls Aluminum Co., which purchased the Columbia Falls, MT, smelter from ARCO Metals Co. in 1985, reportedly signed contracts in May 1986 with Norsk Hydro A/S of Norway and The Broken Hill Pty. Co. Ltd. (BHP) of Australia to toll-convert alumina at Columbia Falls. A 3-year contract was signed with Norsk Hydro to toll enough alumina to keep 60% of Columbia Falls' 163,000-ton-per-year capacity operating. The remaining 40% of the plant's annual capacity was covered under a 3- to 5-year contract between Columbia Falls Aluminum and BHP. Although the duration of the BHP contract was considered to be 3 to 5 years, either partner reportedly could renegotiate terms after 3 years. Before the long-term contracts were signed, Columbia Falls Aluminum was tolling alumina for both Norsk Hydro and BHP under short-term agreements that were to expire at the end of July.

Ormet reportedly was purchased in September in a leveraged buyout from Consolidated Aluminum and Revere Copper and Brass Inc. by an investor group, Ohio River Associates Inc. Under terms of the purchase agreement, in the first year of operation, Ohio River Associates would receive about 14,000 tons of the plant's projected 245,000-ton output, and Consolidated Aluminum's and Revere's shares of the remainder would be 66% and 34%, respectively, representing their former shares of the ownership and production. Ohio River Associates' share would increase to 34,000 tons in the second year and 68,000 tons in the third year, with Consolidated Aluminum and Revere continuing to receive the same portions of the remainder. In the fourth year of operation, the smelter's entire output would belong to Ohio River Associates. In addition, Clarendon Ltd., a U.S.-associated trading company of Marc Rich and Co., reportedly completed a 3-year tolling agreement with Revere to assume Revere's share of Ormet's production.

In September, Northwest Aluminum, a group headed by a former executive director of BPA for DSI companies, reportedly completed a lease-buy agreement with Martin Marietta Corp. for The Dalles, OR, smelter, which was idled since December 1984. Northwest Aluminum will lease the smelter for 3 to 5 years, and at the end of the lease, it will have an option to purchase the smelter. Successful negotiations of a 5-year labor contract with the USWA earlier in 1986, in which labor costs were reduced in exchange for profit sharing, were cited by Northwest Aluminum as partially responsible for the reopening of the plant. The company also signed up for BPA's new variable power rate. The Dalles was planned to operate as a tolling facility with Clarendon supplying alumina to fill the plant's initial operating capacity. In December, one 40,500-ton-per-year potline was reopened.

Clarendon also reportedly entered into a multiyear agreement with Alumax to toll alumina at the company's Mount Holly, SC, smelter. The agreement, signed in May, would commit one-half of Mount Holly's 181,000-ton-per-year capacity to tolling alumina for Clarendon.

Commonwealth Aluminum announced in November that it planned to close its Goldendale, WA, smelter by yearend because of heavy accumulated losses over the previous 2 years. Goldendale had not operated at its full 168,000-ton-per-year capacity since the third potline was idled in March 1985. Shutdown of Goldendale was delayed in December, reportedly to allow time for Commonwealth Aluminum to evaluate offers from potential buyers.

In October, Alcoa reportedly signed a letter of agreement with Vanalco Inc., a subsidiary of Bay Resources Corp., an investment and consulting firm, to purchase Alcoa's Vancouver, WA, smelter. The Vancouver plant was closed after union contract negotiations failed early in June. No timetable was given for restarting the facility, but Vanalco reportedly expected to phase in two to three of the smelter's five potlines during the first year of operation. Vanalco initially planned to operate the smelter as an independent producer of extrusion billet and foundry ingot.

After acquiring 21.5% of the outstanding shares in Kaiser, a group of investors, headed by Joseph A. Frates, reportedly offered shareholders $21.50 per share, with $8.00 in cash and $13.50 in securities, in an attempt to gain control of the company in March. When shareholders rejected the offer, the Frates group increased its buyout offer to $28 per share in April. The Frates group withdrew this proposal after Kaiser's annual meeting on April 29, when a proposal to elect Frates' slate of officers to Kaiser's board of directors was defeated by shareholders. By the beginning of November, the Frates group increased its stake in Kaiser to 30.27%. At the end of November, Kaiser's board of directors proposed to give control of the company to investor Alan Clore, who was in a joint venture with the Frates group. Under terms of the proposal, Kaiser reportedly agreed in principle to form a new holding company, with Clore naming the majority of the new company's board of directors. In addition, the plan called for Clore to purchase 8.2 million shares of convertible, exchangeable preferred stock in the new company for $140 million, along with restricted warrants for 2 million shares of common stock. Clore was expected to be managing partner of the joint venture between Clore and the Frates group, while Frates was expected to retain a 20% nonvoting equity interest.

In October, AMAX Inc. acquired full ownership of Alumax in a buyout of Mitsui & Co., which owned 45% of Alumax, and Nippon Steel Corp., which owned 5% of Alumax. Under the terms of the acquisition, Mitsui exchanged a portion of its interest for 4 million shares of Alumax preferred stock, worth about $100 million, which was convertible to AMAX common stock. AMAX acquired the remaining Mitsui interest and the interest held by Nippon Steel for $335 million in cash.

As part of its efforts to concentrate on aluminum businesses that were expected to offer the highest return on investments, Alcoa restructured its operating units into five business groups, Alcoa Packaging Systems Group, Alcoa Aerospace & Industrial Products Group, Alcoa Metals & Chemicals Group, Alcoa Materials Science Group, and Alcoa International Group. In addition, the company continued to invest in nonaluminum industries including ceramics, fiberoptic communication systems, and packaging materials. Alcoa announced that it was installing a 64-inch continuous coil-coating line at its rolling mill in Evansville, IN. The facility, scheduled to be operational in August 1987, would be used to coat aluminum can end stock.

Alcoa planned a $25 million expansion of its Alcoa Laboratories to provide new facilities for advanced materials and manufacturing research for Alcoa Defense Systems, a unit of Alcoa Materials Science Group. Plans for the expansion, to be completed in mid-1987, included remodeling the existing building for materials research, construction of an impact physics laboratory, and building a composite materials research and manufacturing laboratory. Limited production of Alcoa's aluminum-lithium alloy, Alithalite alloy 2090, reportedly was shipped from its new casting facility in Merwyn, PA, by the end of the first quarter of 1986. When fully operational, the facility was expected to have the capacity to pour three 20,000-pound aluminum-lithium ingots simultaneously.

In October, Alcoa reportedly became the first U.S. producer and supplier of ultrapure aluminum (99.999+%). Ultrapure aluminum is used in the manufacture of integrated circuits because of its low thorium and uranium content. Four grades of ultrapure aluminum, to be marketed under the name "Ultimet Aluminum," were to be produced by a patented Alcoa process at the company's New Kensington, PA, plant. All grades were available in 30- and 50-pound ingots as well as in 5- and 9-inch-diameter billets.[5]

In September, Alcan Rolled Products Co. announced that it was discontinuing production of bright-trim aluminum sheet products and coated building products at its Warren, OH, rolling mill. The company cited a drop in demand for automotive and appliance trim and replacement of coated building products by competing lower cost materials, such as vinyl and pressed hardboard, as reasons for discontinuing the product lines.

Consolidated Aluminum announced that it was reorganizing its fabrication operations into three independent subsidiaries. Effective January 1, 1987, the operations would become subsidiaries of Alusuisse of America, the U.S. holding company of Swiss Aluminium Ltd. (Alusuisse). Following the reorganization, Consolidated Aluminum's operations would consist of the Hannibal, OH, sheet mill; Jackson, IN, foil and coated products operation; and Alusuisse Products, the company's sales import organization. The composite materials and ceramic foam businesses would be divided to form separate subsidiaries.

Commonwealth Aluminum announced a $20 million modernization of the hot rolling line at its mill in Lewisport, KY. The modernization, which was scheduled to be completed in the fourth quarter of 1987, would convert the entire line to computerized control, leading to improvements in control of gauge, profile, surface defects, and temperatures. The 200,000-ton-per-year plant produced nonheat-treated sheet, plate, and coil and some rigid container stock.

The Novamet Aluminum Div. of Inco Alloys International Inc. reportedly planned to construct a new plant for the commercial-scale manufacture of mechanically alloyed aluminum alloys in Pittsboro, NC. The 400,000-pound-per-year plant was scheduled to be completed in the first quarter of 1987. Initial production at the plant will focus on the manufacture of corrosion-resistant alloys for marine applications, a lightweight alloy for airframe forgings, and aluminum-base composite materials.

Alusuisse Flexible Packaging Inc. reportedly will invest $32 million in the construction of a state-of-the-art flexible packaging plant in Shelbyville, KY. Initial production, scheduled for mid-1987, would be concentrated on pouches, wraps, and lids for food containers and pharmaceutical packaging that uses aluminum foil and paper or film. A three-phase plant development was planned with full operation scheduled for 1992.

Cabot Corp. reportedly sold its aluminum master alloy business to the Harbour Group for an undisclosed sum. The sale included two plants in Henderson, KY, and Wenatchee, WA, as well as its 50% interest in a plant in the Netherlands.

ARCO Metals announced that it would supply an instrument cover for a missile guidance system, manufactured from a metal matrix composite, to a U.S. defense contractor. The composite was a silicon carbide-reinforced aluminum alloy, and 1,200 missiles would require four 1.25-pound covers each. These covers reportedly would replace beryllium in this application at considerable cost savings.

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

Company	Yearend capacity (thousand metric tons) 1985	1986	1986 ownership (percent)
Alcan Aluminum Corp.:[1]			
Sebree, KY	163	163	Alcan Aluminium Ltd., 100%.
Alumax Inc.:[2]			
Ferndale, WA (Intalco)	254	254	AMAX Inc., 100%.
Frederick, MD (Eastalco)	160	160	Do.
Mount Holly, SC	181	181	Do.
Total	595	595	
Aluminum Co. of America:			
Alcoa, TN	200	160	Aluminum Co. of America, 100%.
Badin, NC	115	115	Do.
Evansville, IN (Warrick)	270	270	Do.
Massena, NY	205	127	Do.
Rockdale, TX	310	205	Do.
Vancouver, WA	110	110	Do.
Wenatchee, WA	205	205	Do.
Total	1,415	1,192	
Columbia Falls Aluminum Co.:[3]			
Columbia Falls, MT	163	163	Montana Aluminum Investors Corp., 100%.
Commonwealth Aluminum Corp.:[4]			
Goldendale, WA	168	168	Comalco Pty. Ltd., 100%.
Consolidated Aluminum Corp.:			
New Johnsonville, TN	131	--	Swiss Aluminium Ltd., 100%.
Kaiser Aluminum & Chemical Corp.:			
Chalmette, LA[5]	236	105	Kaiser Aluminum & Chemical Corp., 100%.
Mead, WA (Spokane)	200	200	Do.
Ravenswood, WV	148	148	Do.
Tacoma, WA	73	73	Do.
Total	657	526	
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:[6]			
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.:[7]			
Scottsboro, AL	105	105	Revere Copper and Brass Inc., 100%.
Reynolds Metals Co.:			
Listerhill, AL	183	--	Reynolds Metals Co., 100%.
Longview, WA	191	191	Do.
Massena, NY	114	114	Do.
Troutdale, OR	118	118	Do.
Total	606	423	
Grand total	4,706	4,038	

[1]Purchased from ARCO Metals Co. in 1985.
[2]AMAX Inc. purchased 45% from Mitsui & Co. and 5% from Nippon Steel Corp. in Nov. 1986.
[3]Purchased from ARCO Metals Co. in 1985.
[4]Purchased from Martin Marietta Aluminum Inc. in 1985.
[5]Kaiser Aluminum & Chemical Corp. wrote off 131,000 tons of annual capacity in Nov. 1986.
[6]Northwest Aluminum signed a lease-purchase agreement for The Dalles smelter with Martin Marietta Corp. in 1986.
[7]Revere Copper and Brass Inc. filed for bankruptcy in 1982.

Secondary.—Wabash Alloys Inc., a division of Avondale Industries Inc., announced plans to construct a new secondary aluminum smelter in Tennessee. Initial capacity would be 18,000 tons per year, but the plant capacity could be expanded to 54,000 tons per year. Wabash Alloys operated two facilities in Wabash, IN, and Cleveland, OH, and the new Tennessee smelter would be equipped with new melting technology and energy-saving equipment, similar to those installed in the Wabash and Cleveland plants. The Tennessee facility reportedly would rely on scrap suppliers that were servicing the Indiana plant.

In April, Timco Corp., a subsidiary of TST

Inc., reportedly completed construction of a 200,000-pound, gas-fired reverberatory furnace at its secondary smelter in Fontana, CA. Use of this furnace could increase the plant's capacity to 10 million pounds of secondary products per month. Timco acquired the Fontana plant from American Can Co. in 1984 and also operated a secondary smelter in Long Beach, CA.

Advanced Aluminum Products Inc. reportedly planned to construct two additional minimills designed to process aluminum alloy scrap into alloy sheet. One of the new plants would be built in the southeastern United States and one in the southwestern United States. Construction on the southeastern plant was planned to begin in 1987, while construction on the southwestern plant was planned for 1988. The addition of these two plants, combined with Advanced Aluminum's recently completed minimill plant in Hammond, IN, would bring the company's total scrap processing capacity to 3 million pounds per year. The Hammond plant reportedly began operation in February 1986 and processed 40 million pounds of scrap in the year.

U.S. Reduction Co. reportedly leased a portion of a U.S. Die Casting & Development Co. aluminum scrap melting plant in Sheffield, AL, and planned to produce 1,000 to 1,500 recycled scrap ingot sows from aluminum borings and turnings for internal use and resale.

A group of investors acquired the Cleveland, OH, secondary smelter of Alumax Recycling Group Inc. The investors were reportedly operating the smelter under the name of Apex International Alloys Inc. and planned to make some improvements in the plant, which produced foundry and die-cast ingot. Before the acquisition, production at the smelter reportedly was 50 to 55 million pounds per year.

Rochester Smelting & Refining Co. Inc. reportedly ceased operation of its secondary aluminum smelter in Rochester, NY, at yearend. The company cited sluggish business among industries that the plant served and labor problems as reasons for closing the 30-million-pound-per-year secondary ingot plant. In August, Hall Aluminum Co. filed for protection from its creditors under Chapter 11 of the Bankruptcy Code. The plant reportedly was producing 2.5 million pounds of ingot per month in July, and the company cited a drop in the price of secondary ingot in the spring as the reason for bankruptcy filing. Creditors were expected to receive 35 to 40 cents per dollar that they were owed. Hall Aluminum was reported to have secured debts of $1.8 million and unsecured debts of $2.1 million.

CONSUMPTION

Apparent consumption of aluminum metal decreased slightly in 1986 compared with that of 1985. The containers and packaging industry continued to be the dominant end-use market, accounting for almost 28% of total shipments.

Metal Container Corp., a subsidiary of Anheuser-Busch Inc., reportedly purchased the Carson, CA, aluminum beverage can manufacturing plant from Metal Box Plc. of the United Kingdom for $41 million. Capacity of this facility was estimated to be 1 billion cans per year. Metal Container also operated can manufacturing plants in Jacksonville, FL, Columbus, OH, and Arnold, MO, and these plants reportedly produced 4 billion cans per year for Anheuser-Busch. The company was estimated to consume 12 billion cans annually. In addition, Anheuser-Busch awarded a multiyear contract to Metal Container to supply aluminum beer cans to its new Fort Collins, CO, brewery. Metal Container planned to construct a $20 million can manufacturing plant in Windsor, CO, to supply the cans. The plant was scheduled to be completed in 1988 and would supply 700 million cans to the brewery.

Ball Corp. announced plans to double the aluminum can end capacity at its Golden, CO, plant by early 1987 to 2.5 billion can ends per year. The $16 million expansion would provide additional supply for soft drink can manufacturers in the Western United States. Can ends would be shipped for assembly with can bodies from the company's Fairfield, CA, plant.

In July, Triangle Industries Inc. reportedly reached an agreement to purchase American Can's packaging division for $570 million. Triangle Industries already owned National Can Corp. and was the largest domestic beverage can manufacturer. With the acquisition, Triangle Industries would be the largest metal can manufacturer in the world and the second largest U.S. food can manufacturer.

Pechiney Corp. reportedly acquired the

aluminum aerosol can manufacturing operations of International Container Corp., in Waterbury, CT. The facility, which began operating in 1984, had a capacity of 30 million containers per year and would become part of Pechiney-Cebal Corp. In May, Pechiney-Cebal reportedly began commercial production at an aluminum aerosol can manufacturing plant in East Granby, CT, with an annual capacity of 30 million containers. The company planned to double capacity at the East Granby plant with the addition of a second manufacturing line in the spring of 1987.

Alcoa reportedly developed an electrophoretic coating process that could be applied in aluminum food can manufacture. This technology would allow one of Alcoa's canmaker customers to construct a commercial-scale aluminum food can line. Until the new coating technology was developed, commercial aluminum can production was limited to shallow cans. The commercial-scale production facility was expected to be in production in 1987 at a rate of 900 cans per minute; this was reportedly twice the typical capacity for a three-piece-steel food can line. The Can Manufacturers Institute estimated that 27.9 billion food cans were produced in 1985, and this market had the potential to increase aluminum consumption by 1 billion pounds per year.

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
1985			
Secondary smelters	853,722	702,136	757,674
Primary producers	725,890	611,371	655,250
Fabricators	178,494	154,310	165,074
Foundries	93,680	78,209	84,163
Chemical producers	26,758	12,246	13,113
Total	1,878,544	1,558,272	1,675,274
Estimated full industry coverage	1,978,000	1,638,000	1,762,000
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

[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 1986

(Metric tons)

Class of consumer and type of scrap	Stocks, Jan. 1	Net receipts[2]	Consumption	Stocks, Dec. 31
Secondary smelters:				
New scrap:				
Solids	16,356	225,137	227,134	14,359
Borings and turnings	6,823	133,655	134,561	5,917
Dross and skimmings	4,323	52,102	50,003	6,422
Other[3]	922	64,284	61,648	3,558
Total	28,424	475,178	473,346	30,256
Old scrap:				
Castings, sheet, clippings	7,000	160,824	160,479	7,345
Aluminum-copper radiators	1,217	14,890	15,024	1,083
Aluminum cans	[r]1,408	[4]76,228	[4]75,527	2,109
Other[5]	34	17,895	17,494	435
Total	[r]9,659	269,837	268,524	10,972
Sweated pig	7,358	66,475	66,999	6,834
Total secondary smelters	[r]45,441	811,490	808,869	48,062
Primary producers, foundries, fabricators, chemical plants:				
New scrap:				
Solids	22,461	464,560	472,656	14,365
Borings and turnings	106	28,354	28,317	143
Dross and skimmings	386	10,673	10,608	451
Other[3]	5,473	37,725	40,588	2,610
Total	28,426	541,312	552,169	17,569
Old scrap:				
Castings, sheet, clippings	914	61,002	61,070	846
Aluminum-copper radiators	28	1,601	1,580	49
Aluminum cans	10,781	430,828	425,478	16,131
Other[5]	1,742	15,212	15,480	1,474
Total	13,465	508,643	503,608	18,500
Sweated pig	296	19,201	17,909	1,588
Total primary producers, etc	42,187	1,069,156	1,073,686	37,657
All scrap consumed:				
New scrap:				
Solids	38,817	689,697	699,790	28,724
Borings and turnings	6,929	162,009	162,878	6,060
Dross and skimmings	4,709	62,775	60,611	6,873
Other	6,395	102,009	102,236	6,168
Total new scrap	56,850	1,016,490	1,025,515	47,825
Old scrap:				
Castings, sheet, clippings	7,914	221,826	221,549	8,191
Aluminum-copper radiators	1,245	16,491	16,604	1,132
Aluminum cans	[r]12,189	507,056	501,005	18,240
Other	1,776	33,107	32,974	1,909
Total old scrap	[r]23,124	778,480	772,132	29,472
Sweated pig	7,654	85,676	84,908	8,422
Total of all scrap consumed	[r]87,628	1,880,646	1,882,555	85,719

[r]Revised.
[1]Includes imported scrap. According to reporting companies, 6.26% of total receipts of aluminum-base scrap, or 117,652 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)

	1985		1986	
	Production	Net shipments[1]	Production	Net shipments[1]
Die-cast alloys:				
13% Si, 360, etc. (0.6% Cu, maximum)	111,361	111,042	104,153	104,419
380 and variations	279,892	278,868	278,692	279,004
Sand and permanent mold:				
95/5 Al-Si, 356, etc. (0.6% Cu, maximum)	26,475	27,474	26,706	26,548
No. 12 and variations	W	W	W	W
No. 319 and variations	43,940	44,720	48,391	48,263
F-132 alloy and variations	12,116	12,419	8,237	8,326
Al-Mg alloys	292	410	84	86
Al-Zn alloys	5,154	4,955	5,087	4,913
Al-Si alloys (0.6% to 2.0% Cu)	5,593	5,490	5,213	5,390
Al-Cu alloys (1.5% Si, maximum)	1,807	2,113	1,450	1,465
Al-Si-Cu-Ni alloys	1,012	1,012	1,064	1,048
Other	664	653	833	838
Wrought alloys: Extrusion billets	97,168	96,929	106,297	103,949
Miscellaneous:				
Steel deoxidation	27,735	28,010	27,146	27,716
Pure (97.0% Al)	168	168	823	667
Aluminum-base hardeners	1,236	1,275	745	730
Other[2]	14,504	14,305	20,694	20,179
Total	629,117	629,843	635,615	633,541
Less consumption of materials other than scrap:				
Primary aluminum	45,034	--	47,808	--
Primary silicon	25,028	--	26,223	--
Other	2,227	--	3,091	--
Net metallic recovery from aluminum scrap and sweated pig consumed in production of secondary aluminum ingot[3]	556,828	XX	558,493	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)

	1982	1983	1984	1985	1986
Primary production	3,274	3,353	4,099	3,500	3,037
Change in stocks:[1] Aluminum industry	+184	+547	-388	+312	+108
Imports	878	1,091	1,477	1,420	1,967
Secondary recovery:[2]					
New scrap	884	953	935	912	989
Old scrap	782	820	825	850	784
Total supply	6,002	6,764	6,948	6,994	6,885
Less total exports	748	776	734	908	753
Apparent aluminum supply available for domestic manufacturing	5,254	5,988	6,214	6,086	6,132
Apparent consumption[3]	4,370	5,035	5,279	5,174	5,143

[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	1984[r]		1985		1986[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	1,828	26.0	1,862	26.9	1,926	27.7
Building and construction	1,300	18.5	1,375	19.8	1,433	20.6
Transportation	1,375	19.5	1,383	20.0	1,409	20.3
Electrical	681	9.7	642	9.3	629	9.1
Consumer durables	502	7.1	484	7.0	544	7.8
Machinery and equipment	377	5.4	377	5.4	385	5.5
Other markets	279	4.0	264	3.8	258	3.7
Statistical adjustment	+210	2.9	-5	-.1	-41	-.6
Total to domestic users	6,552	93.1	6,382	92.1	6,543	94.1
Exports	488	6.9	546	7.9	413	5.9
Grand total	7,040	100.0	6,928	100.0	6,956	100.0

[p]Preliminary. [r]Revised.

Source: The Aluminum Association Inc.

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

(Metric tons)

	1985	1986[p]
Wrought products:		
Sheet, plate, foil	3,290,826	3,397,401
Rod, bar, pipe, tube, shapes	1,267,269	1,335,274
Rod, wire, cable	356,803	337,327
Forgings (including impacts)	67,464	43,646
Powder, flake, paste	48,655	65,566
Total	5,031,017	5,179,214
Castings:		
Sand	92,528	77,218
Permanent mold	167,844	154,725
Die	698,169	748,842
Other	52,044	51,419
Total	1,010,585	1,032,204
Grand total	6,041,602	6,211,418

[p]Preliminary.
[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)

	1985	1986
Sheet, plate, foil:		
Nonheat-treatable	54.4	54.4
Heat-treatable	3.6	3.7
Foil	7.3	7.5
Rod, bar, pipe, tube, shapes:		
Rod and bar (rolled and extruded)	1.7	1.7
Pipe and tube (extruded and drawn)	2.2	2.4
Extruded shapes	21.2	21.5
Rod, wire, cable:		
Rod and bar wire	1.0	1.0
Cable and insulated wire	6.1	5.5
Forgings (including impacts)	1.3	1.3
Powder, flake, paste	1.2	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 2.35 million tons at yearend 1985 to about 2.24 million tons at yearend 1986.

PRICES

In August, Metals Week discontinued the publication of a producer list price for 99.5%-pure aluminum ingots. Through July, the producer price held steady at 81 cents per pound.

The December 1985 average monthly market price for aluminum ingot, usually 99.7% pure, as published by Metals Week, was 50 cents per pound. The average for the month of January 1986 rose to 55.2 cents. The monthly average continued to increase and reached a high for the year of 61.6 cents per pound in March. Prices softened in the spring, remained relatively stable in the summer, and decreased again in the fall. In December, the monthly average market price was 52.8 cents per pound.

Both the LME and New York Commodity Exchange (COMEX) prices for aluminum futures followed the same general trend as the market prices. However, the LME cash price, as published by Metals Week, began the year at about 4 cents per pound lower than the U.S. market price. By March, the difference in prices had risen to almost 9 cents per pound. This differential began to decrease, and by December, the difference in prices had fallen to about 1.5 cents per pound. COMEX prices, compared with U.S. market prices, were usually 2 to 4 cents lower per pound for metal with short delivery dates. COMEX prices with longer delivery dates began the year about 2 cents higher per pound than U.S. market prices. However, beginning in March, these prices also dropped below the U.S. market price. Producer U.S. transaction prices, as published by Metals Week, were usually slightly below the U.S. market price throughout the year. 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
1985: Annual average	46.45	47.06	50.54	47.85	48.81	49.04
1986:						
January	53.75	54.35	57.01	50.77	55.25	55.63
February	53.57	54.14	56.94	50.57	56.82	56.89
March	57.78	58.18	60.17	52.98	61.57	61.72
April	55.16	55.41	56.38	52.82	59.35	60.64
May	54.17	54.16	54.58	52.81	57.77	58.71
June	53.83	53.89	54.66	53.66	56.74	58.28
July	51.64	52.04	53.50	50.94	54.12	54.56
August	51.97	52.23	53.51	51.22	54.49	54.96
September	52.89	53.34	54.56	54.70	55.40	56.76
October	51.36	51.76	52.78	52.70	53.57	54.12
November	49.28	49.69	51.09	51.34	52.56	52.83
December	49.74	50.22	51.32	51.41	52.84	53.10
Annual average	52.93	53.28	54.71	52.18	55.87	56.52

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

Source: Metals Week.

Buying prices of old sheet and cast aluminum scrap, quoted by American Metal Market, ranged from a high of about 41 cents per pound in March to a low of about 30 cents per pound in late May and early June. Used beverage can (UBC) scrap, processed and delivered to producers, was bought throughout the year at a range of 32 to 45 cents per pound. Secondary aluminum ingot prices followed a price trend similar to that of primary aluminum. Secondary aluminum alloy 360 began the year at about 62 to 63 cents per pound. In mid-March, alloy 360 reached a high for the year of 71 to 72 cents per pound and closed the year at 58 to 59 cents per pound. Alloy 413 was about 1 to 2 cents per pound higher than alloy 360, and alloy 380 was about 2 to 3 cents per pound lower than alloy 360.

FOREIGN TRADE

Exports of all forms of aluminum from the United States decreased substantially from the 1985 level. Exports of crude metals and alloys showed the most dramatic decrease, declining to a level less than two-thirds that of 1985. Although total exports to Japan in 1986 dropped 18% compared with those of 1985, Japan remained the major recipient of U.S. aluminum materials.

Imports for consumption of aluminum in all forms increased significantly compared with those of 1985 and reached their highest level in the last 35 years. Imports of crude metals and alloys increased 55% compared with those of 1985. Canada remained the major shipping country to the United States, supplying slightly more than one-half of the total imports in 1986.

U.S. tariff rates in effect during 1986 for aluminum products from countries with most-favored-nation status were as follows:

Item	TSUS No.	Import duty
Unwrought metal (in coils)	618.01	2.7% ad valorem.
Unwrought (other than Si-Al alloys)	618.02	.1 cent per pound.
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	1985 Quantity (metric tons)	1985 Value (thousands)	1986 Quantity (metric tons)	1986 Value (thousands)
Crude and semicrude:				
Metals and alloys, crude	347,292	$441,598	209,794	$282,958
Scrap	374,646	350,669	350,858	333,187
Plates, sheets, bars, etc	167,874	411,337	180,057	442,681
Castings and forgings	12,408	74,498	6,902	59,979
Semifabricated forms, n.e.c	5,656	32,984	5,584	32,632
Total	907,876	1,311,086	753,195	1,151,437
Manufactures:				
Foil and leaf	19,497	28,800	27,548	29,717
Powders and flakes	2,492	9,838	2,125	7,553
Wire and cable	5,619	15,358	2,912	11,088
Total	27,608	53,996	32,585	48,358
Grand total	935,484	1,365,082	785,780	1,199,795

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)
1985:								
Belgium-Luxembourg	55	$39	513	$2,956	2,934	$2,555	3,502	$5,550
Brazil	234	1,066	1,006	5,334	941	886	2,181	7,286
Canada	36,200	50,867	127,064	303,756	15,840	15,599	179,104	370,222
Chile	111	147	15	113	53	76	179	336
Colombia	33	113	1,598	3,766	21	333	1,652	4,212
France	156	399	425	3,299	322	318	903	4,016
Germany, Federal Republic of	288	856	1,556	9,833	4,844	4,342	6,688	15,031
Hong Kong	4,167	4,789	862	2,908	130	164	5,159	7,861
Israel	172	828	4,082	15,911	29	49	4,283	16,788
Italy	21	169	2,300	12,215	5,029	4,393	7,350	16,777
Japan	198,341	239,255	3,753	17,121	263,620	243,664	465,714	500,040
Korea, Republic of	21,065	24,729	1,485	4,420	783	770	23,333	29,919

See footnote at end of table.

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

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)
1985 —Continued								
Mexico	20,011	$27,786	22,958	$57,115	49,772	$53,891	92,741	$138,792
Netherlands	27,346	29,762	1,189	7,104	5,271	4,538	33,806	41,404
Spain	2	12	463	2,297	1,406	1,052	1,871	3,361
Taiwan	15,007	17,660	1,316	5,800	21,601	16,221	37,924	39,681
United Kingdom	1,414	2,170	2,923	17,046	1,581	1,556	5,918	20,772
Other[r]	22,669	40,951	12,430	47,825	469	262	35,568	89,038
Total	347,292	441,598	185,938	518,819	374,646	350,669	907,876	1,311,086
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
Chile	43	125	12	61	215	293	270	479
Colombia	62	170	1,661	3,836	5	15	1,728	4,021
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
Israel	328	1,749	1,456	7,046	56	129	1,840	8,924
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
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	8,782	14,924	12,802	45,698	1,226	1,226	22,810	61,848
Total	209,794	282,958	192,543	535,292	350,858	333,187	753,195	1,151,437

[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	1985: Quantity (metric tons)	1985: Value (thousands)	1986: Quantity (metric tons)	1986: Value (thousands)
Crude and semicrude:				
Metals and alloys, crude	868,674	$1,017,453	1,348,816	$1,682,907
Circles and disks	11,764	25,130	14,541	31,230
Plates, sheets, etc., n.e.c	344,943	721,308	373,056	755,070
Rods and bars	63,714	86,162	61,833	90,474
Pipes, tubes, etc	3,348	14,876	6,101	37,531
Scrap	127,501	108,625	162,317	141,702
Total	1,419,944	1,973,554	1,966,664	2,738,914
Manufactures:				
Foil	25,934	82,879	27,345	96,241
Leaf	([1])	108	([1])	163
Flakes and powders	4,480	7,593	3,507	6,211
Wire	4,238	8,123	3,215	9,893
Total	34,652	98,703	34,067	112,508
Grand total	1,454,596	2,072,257	2,000,731	2,851,422

[1]1985—aluminum leaf not over 30.25 square inches in area, 1,505,626 leaves, and aluminum leaf over 30.25 square inches in area, 68,118,504 square inches; and 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.

Source: Bureau of the Census.

Table 13.—U.S. imports for consumption 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)
1985:								
Argentina	25,307	$29,471	4,515	$7,308	--	--	29,822	$36,779
Australia	1,346	1,752	15,401	32,792	26	$70	16,773	34,614
Bahrain	12,403	15,520	1,081	1,099	--	--	13,484	16,619
Belgium-Luxembourg	935	1,433	33,006	48,769	509	469	34,450	50,671
Canada	675,705	773,060	48,162	97,007	101,736	86,593	825,603	956,660
France	876	1,456	23,156	53,820	--	--	24,032	55,276
Germany, Federal Republic of	3,219	11,302	17,783	43,589	646	598	21,648	55,489
Greece	20	27	3,252	5,348	--	--	3,272	5,375
Israel	1,494	1,672	2,442	9,916	326	295	4,262	11,883
Italy	42	43	10,385	18,738	252	214	10,679	18,995
Japan	1,660	2,817	143,815	329,232	4	7	145,479	332,056
Mexico	90	69	1,613	2,311	5,342	4,426	7,045	6,806
Netherlands	1,498	2,616	7,256	21,659	183	182	8,937	24,457
South Africa, Republic of	15,111	18,396	790	1,291	34	36	15,935	19,723
U.S.S.R.	1,599	2,241	--	--	6,822	6,058	8,421	8,299
United Arab Emirates	29,304	36,037	621	753	--	--	29,925	36,790
United Kingdom	3,078	4,415	8,838	24,647	2,673	2,376	14,589	31,438
Venezuela	7,517	7,924	54,294	63,331	6,723	5,718	68,534	76,973
Other[r]	87,470	107,202	47,359	85,866	2,225	1,583	137,054	194,651
Total	868,674	1,017,453	423,769	847,476	127,501	108,625	1,419,944	1,973,554
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
Bahrain	18,080	22,967	12,063	18,749	--	--	30,143	41,716
Belgium-Luxembourg	103	228	30,873	51,101	402	399	31,378	51,728
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
Greece	60	131	2,868	4,579	--	--	2,928	4,710
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
South Africa, Republic of	32,372	37,021	4,404	6,499	184	158	36,960	43,678
U.S.S.R.	5,530	5,017	--	--	19,906	18,571	25,436	23,588
United Arab Emirates	68,542	86,008	250	255	--	--	68,792	86,263
United Kingdom	1,745	3,105	11,476	35,607	927	930	14,148	39,642
Venezuela	69,182	75,215	54,145	71,031	6,532	6,079	129,859	152,325
Other	210,964	276,181	55,502	117,037	2,802	2,027	269,268	395,245
Total	1,348,816	1,682,907	455,531	914,305	162,317	141,702	1,966,664	2,738,914

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

Source: Bureau of the Census.

WORLD REVIEW

World primary aluminum production capacity decreased slightly in 1986. Although there were significant reductions of annual capacity in Japan and the United States, they were offset by capacity expansions in Australia, Brazil, Canada, and France. World production of primary aluminum was estimated to be essentially at the same level as that of 1985. Several U.S. and European companies announced plans to lower future primary aluminum ingot production and to place more emphasis on value-added products.

Primary aluminum inventories held by members of the International Primary Aluminum Institute (IPAI), which represent the bulk of stocks held outside the centrally planned economy countries, decreased from 2.188 million tons at yearend 1985 to 1.853 million tons at yearend 1986. IPAI reported that total metal inventories, including secondary aluminum, were 3.598 million tons at yearend 1986.

Australia.—In August, the Government of China through the China International Trust and Investment Corp. reportedly acquired a 10% share in the Portland, Victoria, aluminum smelter. As a result, Alcoa of Australia Ltd. reduced its share of the plant from 55% to 45%. Alcoa of Australia announced that the company was in discussions with potential buyers for a further part of its holding in the Portland smelter. The other shareholders in the Portland smelter were the Victoria State government (35%) and the First National Resource Trust (10%). Clarendon, an affiliate of Marc Rich, reportedly signed an agreement to take the aluminum output from First National's stake in the Portland smelter. The government of Victoria announced that it was negotiating contracts with a number of Japanese companies and Cargill Metals covering its 35% share of the plant's aluminum output. The first 150,000-ton-per-year potline of the Portland smelter was completed in November, and shipments reportedly began in December. The second potline was expected to be completed in July 1988 giving the smelter a planned total annual capacity of 300,000 tons.

Comalco Pty. Ltd. announced that it was terminating its joint venture with Showa Denko K.K. of Japan. The joint venture, Showa Aluminium Industries K.K. in Yokohama, Japan, was established in December 1982 and produced hot metal for wire rod production, alloys, and castings. Comalco turned over its 50% share in Showa Aluminium to the company's other parent, Showa Denko, effective March 31, 1986. In exchange, Comalco received Showa Denko's 20.6% share in New Zealand Aluminium Smelters Ltd. (NZAS) raising Comalco's equity to 79.4%. Japan's Sumitomo Chemical Co. Ltd. retained its 20.6% share in NZAS.

Bahrain.—Aluminium Bahrain Ltd. (ALBA) reportedly received the financing required for the two-stage modernization program of its aluminum smelter. The first phase was expected to add 25,000 tons of annual capacity by late 1988. The second phase, pending Government approval, was expected to add an additional 20,000 tons per year of capacity reportedly by improving the efficiency of the existing plant. The overall program, to be completed by 1991, reportedly would increase the smelter's annual capacity from its current 170,000 tons to 220,000 tons.

The Gulf Aluminium Rolling Mill Co. (GARMCO), a joint $100 million project of six Middle Eastern countries, was inaugurated in February. The GARMCO plant was constructed by Kobe Steel Ltd. of Japan. and is owned by the Governments of Bahrain, Iraq, Kuwait, and Saudi Arabia with 20% each and Oman and Qatar with 10% each. The rolling mill had a capacity of 40,000 tons per year and reportedly utilized aluminum ingots from ALBA to produce aluminum sheet, coil, and foil stock. GARMCO also announced plans to construct a 6,000-ton-per-year aluminum foil plant, adjacent to the rolling mill, by the end of 1988.

Brazil.—In March, Alcoa Alumínio S.A. opened a second potline at its Alumar smelter, increasing the annual capacity from 100,000 tons to 245,000 tons. Billiton Metais S.A., a partner in the Alumar smelter, announced late in the year that it would invest $150 million of the $240 million needed to construct a third potline, which was expected to come on-line in 1989 and would raise the capacity of the smelter to 380,000 tons per year.

Consorcio de Alumínio Albrás e Alunorte S.A. completed the first line of 240 pots at its smelter, increasing capacity to 160,000 tons per year. The project is 51% owned by the Brazilian Government's Cia. Vale do Rio Doce and 49% by a consortium of 33 Japanese companies, Nippon Amazon Aluminium Co. In November, Japan received its first shipment of aluminum ingot from the Albras smelter.

In March, the Government of Brazil allowed a 20% increase in industrial electricity rates only days after announcing an anti-inflation program that included a freeze on wages and prices. The increased power rates and low aluminum metal prices reportedly jeopardized the expansion plans for several aluminum smelters, including the Albras project, the Alumar smelter, and the Vale do Sul Alumínio S.A. smelter in Santa Cruz.

Canada.—A disagreement between management and labor curtailed production at Canadian Reynolds Metals Co. Ltd.'s Baie Comeau, Quebec, aluminum smelter. During the 4-week dispute, the plant reportedly was operated by nonunion personnel at about 50% of its 272,000-ton-per-year capacity. Workers were recalled on March 29 after an agreement was reached on a new 3-year contract.

The first potline of the 230,000-ton-per-year Aluminiere de Bécancour Inc. (ABI) aluminum smelter began operations in April. The second 115,000-ton-per-year potline was scheduled to begin operations in 1987. ABI was jointly owned by Pechiney, 50%; Alumax, 25%; and Société Générale de Financement du Quebec, 25%. In late

July, Reynolds Metals and Pechiney reportedly signed a letter of intent to form a partnership under which the two companies would evenly divide Pechiney's stake in the smelter. In October, Reynolds Metals announced that it planned to finance its entry into ABI by using $88 million generated from the sale of its 41% equity in Robertshaw Controls, an electronics firm in the United States.

The government of Ontario passed legislation that lifted the 10-year-old ban on the use of aluminum for soft-drink cans beginning September 1, 1987. Aluminum cans, as well as other nonrefillable containers, were required to reach a 50% recycling level within 18 months of their entry into the marketplace or the supplier would face fines and the imposition of a deposit on that type of container until the level was raised. Alcan Aluminium estimated that this law could open an annual market for about 18,000 to 20,000 tons of aluminum can body stock.

China.—Alcan Aluminium announced that a joint agreement was reached between Alcan Nikkei China and the China National Nonferrous Metals Industry Shenzhen Associated Corp. to establish an integrated aluminum extrusion and manufacturing plant in the Shenzhen Special Economic Zone of southern Guangdong Province. The joint venture, Nonfemet International Aluminium Co. Ltd., reportedly would have an extrusion press and associated anodizing facilities and would make and sell extrusions for the architectural, transportation, communications, and electronics industries, in both domestic and export markets. In addition to producing a range of aluminum windows and doors, the plant was expected to sell extrusion billets and dies. The operation was scheduled to come on-stream in about 2 years at an estimated cost of about $20 million.

Production began at the Guangdong Nonferrous Metal Processing Factory, a fully modernized aluminum window frame and door plant, in the Shake District of Guangzhou City. Production equipment and technology, which included a window and door assembly line, coloring apparatus, and extrusion and testing systems, were reportedly provided by Merban Americas Corp. of the United States at a cost of $6.85 million. Annual production capacity of alloy aluminum products was expected to be about 3,000 tons. The factory reportedly was planning a second phase of the project that, upon completion, would increase output to 8,000 tons.

A plant to produce pull-top aluminum cans, using an automatic production line imported from the United States, reportedly began operations in the economic development zone of Dalian during August. The North China Wusan Can Co. reported an annual production capacity of 100 million aluminum alloy can bodies and 250 million lids.

France.—The new 90,000-ton-per-year potline at Pechiney's Saint-Jean-de-Maurienne, Savoie, primary aluminum smelter, which started up at the end of March, became fully operational by yearend. The addition of the new line increased capacity at the plant to 130,000 tons per year.

As part of the company's restructuring program, Pechiney announced that production at its 113,000-ton-per-year Nogueres and 24,000-ton-per-year Riouperoux smelters would be phased out over the next 5 years.

The agreement on power rates signed by Pechiney and Électricité de France, a state-owned utility company, in 1985 for a 10- to 18-year period was replaced with a reportedly lower cost contract covering the next 5 to 8 years. The new contract reportedly contained an option for a one-third reduction in rates if Pechiney's smelters closed during the 3 months of winter.

Pechiney Cegedur, a subsidiary of Pechiney, opened a new aluminum powder plant at Hermillon. Initial production concentrated on propellant-quality pure aluminum and aluminum alloy powders, but the range of products reportedly would be extended later to include other nonferrous metal powders.

Germany, Federal Republic of.—Vereinigte Aluminiumwerke AG (VAW) announced plans to permanently close its 20,000-ton-per-year primary aluminum smelter at Luenen by the end of 1989.

Alusuisse announced plans to reduce primary aluminum capacity at its Rheinfelden smelter by 20,000 tons per year by yearend 1987. The decrease in primary capacity reportedly would be replaced by a similar increase in recycling capacity.

VAW reported plans to install a second rolling mill at its Grevenbroich facility that would increase production capacity for foil from 50,000 tons per year to 90,000 tons per year. The main feature of the planned expansion, which was scheduled for completion in 1987, was the ability to produce thin foil in widths of about 2,000 millimeters. Alunorf, jointly owned by Alcan Aluminium and VAW, announced that it planned to commission a new 170,000-ton-per-year cold-rolling mill by April 1987 that would produce aluminum foil sheet up to 2,130 millimeters wide. The wider aluminum foil was designed to meet the needs of the packaging industry, in particular the producers of the "tetrapak" soft drink containers, which coat the package foil with laminated paper. Because the paper mills could provide paper coil in excess of 2 meters wide, pressure had been placed on the aluminum sector to do likewise in order to improve package production efficiency.

Kaiser Aluminium Europe Inc. reported the sale of its minority interest in two European can manufacturing plants to Reynolds Metals. Kaiser Aluminium sold its 40% interest in the operations of Gerro Kaiser Dosenwerk GmbH & Co. KG in Recklinghausen and a 20% interest in Austria Dosen GmbH & Co. KG near Vienna, Austria.

Ghana.—Volta Aluminium Co. restarted the fourth of its five 40,000-ton-per-year potlines at the Tema smelter owing to an increase in power availability.

A 10,000-ton-per-year aluminum rolling mill in Tema was officially opened in September 1985. The plant was designed to produce aluminum sheet and strip for Ghana and neighboring West African countries.

Italy.—MCS-Aluminia, Italy's state-owned aluminum conglomerate, and Reynolds Metals announced an agreement that reportedly increased MCS-Aluminia's share of Italy's aluminum extrusion market. The agreement involved an exchange of shares between two companies that Reynolds Metals and MCS-Aluminia held in joint ownership. MCS-Aluminia was to take over 100% ownership of Reynolds Aluminia Italia S.p.A., which operated a 25,000-ton-per-year extrusion plant, Cisterna di Latina, increasing MCS-Aluminia's extrusion production capacity to 80,000 tons per year or about 35% of the Italian market. In return, Reynolds Metals was to take over MCS-Aluminia's 40% holding in Società Lavorazioni Industriali Metali S.p.A., which operated a sheet and foil plant at Fossa Nova.

Japan.—Showa Light Metal Co. Ltd. reported the permanent shutdown of the last remaining potline at the Chiba smelter in February. Showa Light Metal also announced that it would begin shipping part of a prebaked potline from its Chiba smelter to Baiyin, China, in March.

Sumitomo Aluminium Smelting Co. Ltd., a subsidiary of Sumitomo Chemical, reported the closure of its 82,000-ton-per-year aluminum smelter at Toyama in October. Sumitomo Chemical also announced plans to reorganize Sumitomo Aluminium into two subsidiaries, one to handle imports of aluminum ingots for sale in the country and the other to take over the casting facilities at Toyama. Sankyo Aluminium Co. announced a joint venture with Sumitomo Chemical to take over the casting facilities at Toyama in January 1987 to produce aluminum alloy billets from imported aluminum ingot. The new company would be named Toyama Alloy Co. Ltd.

Two other aluminum companies announced plans to close primary aluminum smelters during the first half of 1987. Ryoka Light Metal Industries Ltd. announced plans to close its 76,000-ton-per-year smelter at Sakaide, and Mitsui Aluminium Co. Ltd. announced that it planned to close its 144,000-ton-per-year Miike smelter. The smelter closures that took place in 1986 and those planned for 1987 reportedly would leave Japan with only one operating primary smelter by the end of 1987, Nippon Light Metal Co. Ltd.'s 64,000-ton-per-year smelter at Kambara.

On October 31, the Governments of Japan and the United States issued a statement of understanding concerning trade in aluminum between the two countries. The Government of Japan reported that it completed the necessary domestic procedures required to reduce the tariff rates on unwrought aluminum and on aluminum plate, sheet, and strip to 1% and 3%, respectively, effective January 1, 1988. In the interim, the Government of Japan informed the United States that it intended to reduce the tariff rates on unwrought aluminum from 9% to 5% and on aluminum plate, sheet, and strip from 9.2% to 6.1%, effective April 1, 1987. Both sides also agreed to establish an ad-hoc committee on U.S.-Japanese aluminum trade, which would meet twice annually, to consult on trade issues and market access in aluminum and aluminum products.

Nigeria.—Alcan Aluminium announced the sale of its 60% interest in Alcan Aluminium of Nigeria Ltd. and its sister company, Alcan Aluminium Products Ltd., to the Inlaks Group of Switzerland.

Alusuisse announced that it signed a letter of intent with Hallmark Beteiligungs AG, also of Switzerland, covering the sale of Nigalex, which produced extrusions for the construction industry, and Alumaco, which made products ranging from aluminum windows to refrigerators.

Norway.—In September, Norsk Hydro's aluminum division and Ardal og Sunndal Verk A/S (ASV Group), owned by the Government of Norway, formally announced the merger of the two companies. Norsk Hydro's initial share of the new company, Hydro Aluminium A/S, was 70% with an option for Norsk Hydro to increase its share to 90% at a later date. The merger of these two organizations gave the new company a total annual smelter capacity of about 600,000 tons.

In a letter of understanding signed with Alusuisse, Hydro Aluminium reportedly would acquire an additional 24.8% share in Sör-Norge Aluminium A/S (Soeral). Upon completion of the sale, each company would hold a 50% share in Soeral's 66,000-ton-per-year aluminum smelter in Husnes.

Norsk Hydro reportedly entered into negotiations with Alcan Aluminium to purchase five of Alcan Aluminium's extrusion plants in Western Europe. The plants, with a combined capacity of 70,000 tons per year, were in Raeren, Belgium; Luce and Pinon, France; Uphusen, Federal Republic of Germany; and Ornago, Italy. The purchase reportedly would increase Norsk Hydro's aluminum extrusion capacity to 150,000 tons per year.

South Africa, Republic of.—The Comprehensive Anti-Apartheid Act of 1986, signed by the President of the United States in October, banned the importation into the United States of material produced or manufactured by a parastatal organization of the Republic of South Africa. In November, the U.S. Department of State released a listing of companies, which it determined to be parastatal, that is companies in which the Government of the Republic of South Africa had more than a 50% stake or were in some way largely controlled or subsidized by the Government of the Republic of South Africa. Aluminum companies on the list included Aluminum Investment Co. Pty. Ltd., Alusaf (Pty.) Ltd., Alustang (Pty.) Ltd., and Atlantis Aluminum Pty. Ltd.

Alcan Aluminium reportedly reached an agreement in principle for the sale of its 24% interest in Hulett Aluminium Ltd. The sale would be to the Tongaat-Hulett Group, the majority owner of Hulett Aluminium.

Switzerland.—Alusuisse announced plans to cut its primary aluminum production capacity in Western Europe by about 30% over the next 2 to 3 years. Alusuisse reportedly decided to shift the emphasis of its business to downstream operations, such as foil, aerosol cans, and composites. As part of its capacity reduction program, Alusuisse announced that it intended to cut 12,000 tons of annual capacity at its Chippis smelter in Switzerland by yearend 1987.

U.S.S.R.—A 40,000-ton-per-year cold-rolling mill reportedly started up at the Kuybyshev Lenin metallurgical works. This mill was in addition to the 20,000-ton-per-year mill on the same site that was completed in 1980. Also, a new potline reportedly came on-stream at the Tadzhik plant in Soviet Central Asia, bringing capacity there to 260,000 tons per year.

United Arab Emirates.—The second primary aluminum smelter to be built in the United Arab Emirates was to be sited in Umm al-Qaiwain. The smelter was to be owned by Umm al-Qaiwain Aluminium Co. (Umalco), which is 75% owned by the Government of Umm al-Qaiwain and 25% owned by a London consortium comprised of Brown and Root UK Ltd., Balfour Beatty Ltd., Hawker Siddeley Power Engineering, and Ferrostaal of the Federal Republic of Germany. Alcoa had been retained to furnish the technology and technical services for the smelter that reportedly would have an initial capacity of 120,000 tons per year with the possibility of expansion to 240,000 tons per year. Construction was due to begin in early 1987 with an anticipated startup date of April 1989.

Kaiser Aluminum Technical Services Inc. reportedly was contracted to carry out an expansion program at Dubai Aluminium Co. Ltd. The program was expected to increase smelter capacity to 170,000 tons per year by 1989. The expansion reportedly would be achieved both by automating potlines using a proprietary system developed by Kaiser and by a program of retrofitting.

Venezuela.—Corporación Venezolana de Guayana (CVG) and the Fondo de Inversiones de Venezuela approved plans to expand primary aluminum production capacity to about 650,000 tons per year by 1989.

Aluminio del Caroní S.A. (ALCASA) reportedly would invest about $421 million for the construction of a fourth 84,000-ton-per-year potline that would raise capacity at its Cuidad Guayana smelter to about 220,000 tons per year. In addition, ALCASA announced plans to expand its Cuidad Guayana rolling mill by 20,000 tons per year to provide an annual capacity of 60,000 tons. Both of these expansion plans by ALCASA reportedly would be completed by 1989. Late in 1986, ALCASA reportedly began preliminary discussions with Pechiney on the possible use of Pechiney technology in the construction of a fifth potline at Cuidad Guayana that reportedly would increase smelter capacity by an additional 180,000 tons per year at a later date.

Industria Venezolana de Aluminio C.A.

(VENALUM) announced plans to add 110,000 tons of annual capacity at its San Felix smelter by the end of 1988.

Alusur, a new Venezuelan joint venture, announced plans to begin construction of a new 180,000-ton-per-year aluminum smelter near the Interalumina alumina refinery. Alusur was a joint-venture company composed of Suramericana de Aleaciones Laminados (Sural), 40%; Austria Metall AG, 40%; and CVG, 20%. Sural reportedly would purchase 60,000 tons per year of the smelter's output for use in its wire-rod manufacturing facility, with the remainder going to Alusur's other partners. The company projected that the plant would come on-stream in 1989.

Yugoslavia.—Boris Kidric Tvornica Glirice Aluminija announced plans to modernize and expand its aluminum smelter in Slovenia. The project, scheduled for completion in December 1988, reportedly would increase smelting capacity to 70,000 tons per year and would also include the upgrading of casting, quality control, and auxiliary facilities.

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

(Thousand metric tons)

Country	1982	1983	1984	1985[p]	1986[e]
Argentina	138	133	139	140	150
Australia	381	478	758	851	[2]882
Austria	94	94	96	94	94
Bahrain	171	172	177	177	178
Brazil	299	401	455	550	[2]762
Cameroon	79	77	73	86	85
Canada	1,065	1,091	1,227	1,282	1,360
China[e]	380	400	400	410	410
Czechoslovakia	34	36	32	[e]32	30
Egypt	141	140	170	209	[2]175
France	390	361	342	293	310
German Democratic Republic[e]	58	57	58	[r]60	60
Germany, Federal Republic of	723	743	777	745	765
Ghana	174	42	--	49	[2]125
Greece[3]	[e]135	136	136	125	130
Hungary	74	74	74	74	[2]74
Iceland	75	76	80	73	76
India[3]	217	204	269	260	225
Indonesia[3]	33	115	199	217	220
Iran	45	39	42	[e]42	42
Italy	233	196	230	221	[2]243
Japan[4]	351	256	287	227	[2]140
Korea, North[e]	10	10	10	10	10
Korea, Republic of[3]	15	13	18	18	[2]19
Mexico[3]	41	40	44	43	43
Netherlands	251	235	249	251	252
New Zealand	163	219	243	241	234
Norway	638	[r]713	765	712	[2]712
Poland[5]	43	44	46	47	48
Romania[6]	208	223	244	247	240
South Africa, Republic of	106	161	167	165	165
Spain	367	358	381	370	375
Suriname[7]	43	34	[e]23	[e]23	[2]29
Sweden	79	82	83	84	80
Switzerland	75	76	79	73	65
Taiwan[3]	10	--	--	--	--
Turkey	36	30	38	54	50
U.S.S.R.[e]	[r]1,900	2,000	2,100	2,200	2,300
United Arab Emirates: Dubai	149	151	155	[e]155	155
United Kingdom	241	252	288	275	270
United States	3,274	3,353	4,099	3,500	[2]3,037
Venezuela	274	335	386	[e]396	424
Yugoslavia[3]	220	258	268	[e]270	270
Total	[r]13,433	[r]13,908	15,707	15,351	15,314

[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 30, 1987.

[2]Reported figure.

[3]Primary ingot.

[4]Excludes high-purity aluminum containing 99.995% or more as follows, in metric tons: 1982—4,345; 1983—2,679; 1984—4,358; 1985—4,783; and 1986—8,236.

[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	1984	1985	1986[p]
North America:			
Canada	1,234	1,347	1,462
Mexico	45	45	45
United States	4,896	4,706	4,038
South America:			
Argentina	140	146	150
Brazil	519	629	869
Suriname	60	60	60
Venezuela	400	400	430
Europe:			
Austria	92	92	92
Czechoslovakia	60	60	60
France	333	333	423
German Democratic Republic	85	85	85
Germany, Federal Republic of	777	777	777
Greece	145	145	145
Hungary	76	76	76
Iceland	86	86	86
Italy	276	276	276
Netherlands	266	266	266
Norway	770	770	770
Poland	110	110	110
Romania	250	250	250
Spain	389	379	344
Sweden	82	82	82
Switzerland	86	86	86
U.S.S.R	2,490	2,550	2,640
United Kingdom	287	287	287
Yugoslavia	357	357	357
Africa:			
Cameroon	80	80	80
Egypt	166	170	170
Ghana	200	200	200
South Africa, Republic of	172	172	172
Asia:			
Bahrain	170	170	170
China	413	413	413
India	363	363	363
Indonesia	225	225	225
Iran	50	50	50
Japan	712	425	284
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	812	862	1,012
New Zealand	244	244	244
Total	18,215	18,071	17,946

[p]Preliminary.
[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 1983-90 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 1983-90 by smelter and country.

TECHNOLOGY

Intensive development work continued in the field of discontinuous silicon carbide-reinforced aluminum composites. The reasons for the interest reportedly were the remarkable properties of silicon carbide aluminum metal matrix composites and their potentially low production costs. The composites were as light as aluminum and possessed strength and stiffness comparable to titanium alloys. They could be extruded, cast, rolled, and forged with conventional equipment and possessed a low coefficient of thermal expansion. They reportedly retained strength and stiffness at up to 450° F. Even with limited production, prices of these composites were said to be competitive with titanium. In addition to aerospace applications, the automotive industry reportedly was evaluating the use of these composites for connecting rods and pistons, engine blocks, drive shafts, and frame and structural members.[6]

Research continued on the development of advanced aluminum alloys, such as aluminum-iron-cerium. A paper was published describing some of the recently developed alloy systems and some of the new metallurgical techniques used to produce them. Rapid solidification technology reportedly provided a means to develop aluminum-transitional metal systems by extending the range of solid solubility of the transition elements. New methods of heat treating were also studied as possible solutions to the problems of corrosion and cracking.[7]

An aluminum-carbon composite anode technology that reportedly had the potential to increase energy efficiency and to lower operation costs at alumina reduction plants was studied. Experimental work and engineering calculations for composite anode cells reportedly indicated that a specific energy consumption of 4 kilowatt hours per pound of aluminum produced might be attainable in retrofit Hall-Heroult plants. These results were preliminary and further evaluation on a pilot-plant scale was expected to be required.[8]

Researchers at Pechiney reported the development of a process that permits the extraction of liquid aluminum metal from drosses by simple compression. The company indicated that the recovery rate was better than other known processes and the cost was much lower. Industrial tests reportedly established that aluminum extraction by compression could be carried out on drosses of all major aluminum alloys and was compatible with standard remelt or alloying procedures of each casthouse or foundry evaluated. In addition, the metal extracted could be recycled immediately.[9]

A paper was published that outlined the operation of the Alcan Aluminum decoating plants for UBC in Greensboro, GA, and Oswego, NY.[10]

The Bureau of Mines reviewed the structural characteristics of crystalline phases and phase equilibria data for the sodium chloride-potassium chloride-aluminum chloride-sodium fluoride-potassium fluoride-aluminum flouride system, which encompasses a large number of molten salt fluxes currently used in aluminum recycling. The purpose of the report was to provide guidelines for research into the relationships between molten salt compositions and their physical properties, notably vapor pressures, densities, surface tensions, and viscosities, knowledge of which was essential to maximizing fluxing efficiencies and metal recovery and minimizing hazardous emissions and disposal problems. In addition, this report described experimental determinations of subsolidus compatibility relationships in the system. The compatibility diagram served to define the important compositional planes across which important changes in properties were likely to occur.[11]

Allied-Signal Corp. reportedly developed new aluminum alloys for high-temperature applications. The new alloys would contain between 6% to 12% iron, 1% to 3% silicon, 1% to 3% vanadium, and 0% to 3% zirconium depending on the properties required. The company expected that these alloys could be used for missile fins, aircraft airframe sheet, aircraft wheel forgings, and gas-turbine-engine components.

Lockheed-Georgia Co. reportedly was working with two companies, ARCO Chemical Co. and Avco Corp. to develop and test metal matrix composites to be used as fins in the next-generation advanced tactical fighter. ARCO Chemical developed an aluminum alloy reinforced with up to 40% silicon carbide whiskers. To form the alloy, silicon carbide was blended with aluminum powder and hot-compressed into cylindrical billets by powder metallurgy techniques. Avco developed an aluminum alloy reinforced with continuous ceramic fibers, 0.0056 inch in diameter. The metal matrix composite was formed by plasma spraying aluminum around drum-wound fibers. Properties of these two composite materials were to be compared and evaluated, and if proven to be comparable or superior to titanium, they could be substituted for titanium fins at weight savings of 20% to 30%.[12]

Alcoa announced the development of a new method for alloy separation of UBC scrap. Alloy 3004 was used for the can bodies and 5182 was used for the ends, and if the UBC scrap was melted, the resultant alloy required the addition of significant quantities of primary aluminum and other alloying elements before it would be suitable for can sheet. The Alcoa process takes advantage of a 90° F differential between the melting points of alloys 3004 and 5182; 5182 alloy melts at a lower temperature. After the UBC was partially shredded in a hammermill, it was treated in a rotary kiln operated at the lower end of the 5182 alloy melting range. At that temperature, the grain boundaries of the 5182 alloy weakened, causing the alloy to become brittle, and the alloy was fragmented by tumbling. The 3004 alloy was virtually unaffected by the process, and as a result, the 5182 alloy could be separated by screening the alloy mixture through a 0.265-inch screen.[13]

[1]All quantities in this chapter are given in metric tons unless otherwise indicated.

[2]Physical scientists, Division of Nonferrous Metals.

[3]Federal Register. Review of Standards of Performance for New Stationary Sources; Primary Aluminum Reduction Plants. V. 51, No. 238, Dec. 11, 1986, pp. 44643-44645.

[4]Metals Week. V. 57, No. 45, Nov. 10, 1986, pp. 9-10.

———. V. 57, No. 47, Nov. 27, 1986, pp. 9-10.

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Antimony

By Patricia A. Plunkert[1]

The production of primary antimony products increased compared with that of 1985 despite the closure of two antimony metal production facilities. Domestic mine production, however, decreased sharply as a result of the closure of the Sunshine Mine. Total imports of antimony materials reached their highest level in over 25 years. The President signed the Superfund Amendments and Reauthorization Act of 1986 in October, which extended the Superfund program for 5 years. In June, the General Services Administration (GSA) announced the initial offering of excess antimony metal from the National Defense Stockpile (NDS) as tender for its ferroalloy upgrading program.

The development of advanced technology applications for antimony continued in 1986. Indium antimonide infrared detector arrays were investigated for use in aircraft night-vision systems and in future space astronomy applications.

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 10 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)

	1982	1983	1984	1985	1986
United States:					
Production:					
Primary:					
Mine (recoverable antimony)	503	838	557	W	W
Smelter	12,282	14,557	17,639	16,449	17,978
Secondary	16,596	14,204	14,823	[r]15,030	15,029
Exports of metal, alloys, waste and scrap	830	304	511	362	595
Exports of antimony oxide	277	365	480	885	580
Imports for consumption	13,387	12,885	23,089	20,694	25,401
Reported industrial consumption, primary antimony	9,414	10,418	12,465	[r]11,697	10,956
Stocks: Primary antimony, all classes, Dec. 31	5,973	3,935	6,895	[r]6,040	6,130
Price: Average, cents per pound[1]	107.2	91.3	151.2	131.1	121.9
World: Mine production	61,131	[r]55,881	60,309	[p]61,833	[e]66,020

[e]Estimated. [p]Preliminary. [r]Revised. 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.—The Safe Drinking Water Act Amendments of 1986 (Public Law 99-339) was signed by the President on June 19, 1986. Antimony was 1 of 83 contaminants for which the Environmental Protection Agency was required to set maximum permissible levels in drinking water within 3 years.

On October 2, 1986, the President signed the Comprehensive Anti-Apartheid Act of 1986. Section 303(a) of the law stated that no article that is grown, produced, manufactured by, marketed, or otherwise exported by a parastatal organization of the Republic of South Africa may be imported into the United States except for those strategic minerals for which the President has certified to the Congress that the quantities essential for the economy or defense of the

United States are unavailable from reliable and secure suppliers. Section 504(a) required that the President submit a report to Congress not later than 90 days after the date of enactment of this legislation that detailed the extent to which the United States was dependent on imports from the Republic of South Africa of strategic and critical materials, such as antimony, as defined in the Strategic and Critical Materials Stock Piling Act. On October 27, 1986, the President signed Executive Order No. 12571 delegating the Secretary of State the authority to make this report.

The Superfund Amendments and Reauthorization Act of 1986 (Public Law 99-499) that extended and amended the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 was signed by the President on October 17, 1986. Antimony and antimony trioxide will continue to be taxed under the new law. The taxes, which are to be collected from producers and importers beginning January 1, 1987, were set at the old rates of $4.45 per short ton of antimony and $3.75 per ton of antimony trioxide. The taxes terminate on December 31, 1991.

On June 9, the GSA announced the initial offering of excess antimony metal from the NDS as tender for its program to upgrade stockpiled ferroalloys. Sales to the ferroalloy upgraders, Elkem Metals Co. and Macalloy Inc., and/or their agents were limited to 150 tons of antimony metal per month, not to exceed 1,000 tons per fiscal year. The total sale of excess antimony metal under this program during calendar year 1986 was 460 tons.

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 tons of antimony metal from the NDS. The law also stated that no action may be taken before October 1, 1987, to implement or administer any change in a stockpile goal in effect on October 1, 1984, that results in a reduction in the quality or quantity of any strategic and critical material to be acquired for the NDS.

GSA reported that Government stocks of antimony metal in the NDS at the end of 1986 totaled 37,379 tons of stockpile-grade material. The stockpile goal remained at 36,000 tons.

DOMESTIC PRODUCTION

MINE PRODUCTION

On April 17, Sunshine Mining Co. announced the closure of the Sunshine Mine that produced tetrahedrite, a complex silver-copper-antimony sulfide, one of the principal ore minerals in the Kellogg, ID, area. The company stated that the mine would remain closed until the facility could be operated on a profitable basis.

With the closure of Sunshine's mining operation, domestic mine production was limited to antimony produced by ASARCO Incorporated as a byproduct of the smelting of some domestic lead and silver ores and approximately 22 tons of high-grade, hand-sorted antimony ore shipped from two mines near Fairbanks, AK.

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

(Short tons of recoverable antimony)

Year	Produced	Shipped
1982	503	365
1983	838	878
1984	557	711
1985	W	W
1986	W	W

W Withheld to avoid disclosing company proprietary data.

SMELTER PRODUCTION

Primary.—Production of primary antimony products from domestic and imported materials increased compared with that of 1985. In 1986, antimony oxide production reached its highest level in over 25 years, whereas metal production was at its lowest level in over 25 years. The decrease in metal production was mainly the result of the closures of two primary metal production facilities in 1986.

In addition to the closure of its mining operations, Sunshine also ceased antimony metal production in 1986. Antimony metal had been produced as a byproduct of the treatment of tetrahedrite ore at Sunshine's refinery in Kellogg, ID.

On May 2, Asarco announced the indefinite closure of its antimony metal plant in El Paso, TX. The company reported that it was evaluating a new process at its East Helena, MT, smelter for the treatment of its Coeur Mine concentrates that were previously refined at El Paso. Under the process, the antimony contained in these concentrates reportedly would be mixed into the lead bullion produced at East Helena and shipped to Asarco's Omaha, NE, refinery where the antimony would be recovered as antimony oxide.

United States Antimony Corp. (USAC), which announced the closure of its antimony mining operation in 1985, reported the signing of an open-ended contract to purchase a minimum of 66 tons of antimony ore per month from China. The contract reportedly contained an option to increase the ore shipments to 132 tons per month. The imported ore was processed at USAC's refinery in Thompson Falls, MT.

The other producers of primary antimony products were Amspec Chemical Corp., Gloucester City, NJ; Anzon America Inc., Laredo, TX; Asarco, Omaha, NE; Chemet Co., Moscow, TN; Laurel Industries Inc., La Porte, TX; McGean Chemical Co. Inc., Cleveland, OH; and M & T Chemicals Inc., Baltimore, MD.

Table 3.—Primary antimony produced in the United States

(Short tons of antimony content)

Year	Class of material produced				Total
	Metal	Oxide	Residues	Byproduct antimonial lead	
1982	539	11,564	179	W	12,282
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

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

Secondary.—Old scrap, predominantly lead battery plates, was the source of most of the secondary output. New scrap, mostly in the form of drosses and residues from various sources, supplied the remainder. The antimony content of scrap was usually recovered and consumed as antimonial lead.

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)

	1985[r]	1986
KIND OF SCRAP		
New scrap: Lead- and tin-base	1,184	1,366
Old scrap: Lead- and tin-base	13,846	13,663
Total	15,030	15,029
FORM OF RECOVERY		
In antimonial lead	13,928	14,279
In other lead- and tin-base alloys	1,102	750
Total	15,030	15,029
Value (millions)	$39	$39

[r]Revised.

CONSUMPTION AND USES

Antimony compounds were used in plastics both as stabilizers and as flame retardants. Antimony stabilizers were used to retard heat and light degradation in plastics such as polyvinyl chloride. Antimony trioxide in an organic solvent was used to make fabrics, plastics, and other combustibles flame retardant. Several companies announced new product developments and enhancements in the use of antimony compounds as flame retardants.[2] Antimony was also used as a decolorizing and refining agent in some types of glass such as special optical glass.

Antimony metal alloyed with lead was used in lead-acid storage batteries, industrial chemical pumps and pipes, tank linings, roofing sheets, and cable sheaths. In these alloys, antimony increases strength and inhibits chemical corrosion. In 1986, the Battery Council International reported that the total domestic shipments of replacement and original equipment automotive batteries in the United States increased only slightly compared with those of 1985.

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

(Short tons of antimony content)

Year	Class of material consumed					Total
	Metal	Oxide	Sulfide	Residues	Byproduct antimonial lead	
1982	1,282	7,924	29	179	W	9,414
1983	1,245	8,867	23	283	W	10,418
1984	1,543	10,747	28	147	W	12,465
1985	[r]1,503	10,053	33	108	W	[r]11,697
1986	2,441	8,410	30	75	W	10,956

[r]Revised. 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	1982	1983	1984	1985	1986
Metal products:					
Ammunition	294	175	W	410	W
Antimonial lead	793	926	845	568	605
Bearing metal and bearings	143	143	182	[r]177	156
Cable covering	25	31	W	W	68
Castings	9	9	11	11	12
Collapsible tubes and foil	1	W	W	W	W
Sheet and pipe	26	43	80	W	40
Solder	124	154	232	[r]336	279
Type metal	11	10	31	31	9
Other	67	71	337	105	420
Total	1,493	1,562	1,718	[r]1,638	1,589
Nonmetal products:					
Ammunition primers	20	16	21	27	23
Ceramics and glass	1,358	1,252	1,292	1,187	1,027
Fireworks	6	4	7	4	4
Pigments	330	198	178	147	250
Plastics	1,050	993	1,108	998	975
Rubber products	221	70	21	25	41
Other	103	119	161	141	162
Total	3,088	2,652	2,788	2,529	2,482
Flame-retardant:					
Adhesives	179	184	343	310	170
Paper	103	133	159	111	1
Pigments	25	14	8	8	14
Plastics	3,312	4,441	5,858	5,529	4,979
Rubber	104	220	342	315	439
Textiles	1,110	1,212	1,249	1,257	1,282
Total	4,833	6,204	7,959	7,530	6,885
Grand total	9,414	10,418	12,465	[r]11,697	10,956

[r]Revised. 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	1982	1983	1984	1985	1986
Antimonial lead[1]	W	W	W	W	W
Metal	556	805	582	[r]807	956
Ore and concentrate	532	446	1,304	1,164	1,030
Oxide	4,711	2,614	4,926	3,954	4,019
Residues and slags	150	51	69	99	106
Sulfide	24	19	14	16	19
Total	5,973	3,935	6,895	[r]6,040	6,130

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

PRICES

At the beginning of 1986, the New York dealer price range for antimony metal, published by Metals Week, was $1.28 to $1.32 per pound. The quoted price range fluctuated throughout the year and reached a high of $1.36 to $1.41 per pound at the beginning of April. At yearend, the dealer price range was listed at $1.05 to $1.10 per pound.

Asarco's published price for high-tint antimony trioxide in lots of 40,000 pounds was $1.45 per pound at the beginning of the year. On February 19, the company announced a price increase to $1.50 per pound. The price remained at this level until mid-June when it was gradually decreased so that by yearend, Asarco's published price for antimony trioxide was $1.25 per pound.

Metal Bulletin (London) published European price quotations for antimony ore and concentrates. Both prices decreased steadily during the first 8 months of the year before beginning a gradual increase in late August. At yearend, the price range quotations were as follows: clean sulfide concentrates, 60% antimony content, $18.00 to $19.25 per metric ton unit (equivalent to $16.35 to $17.45 per short ton unit), and lump sulfide ore, 60% antimony content, $19.50 to $20.50 per metric ton unit (equivalent to $17.70 to $18.60 per short ton unit).

Table 8.—Antimony price ranges in 1986, by type

Type	Price per pound
Domestic metal[1]	$2.00
Foreign metal[2]	$1.05- 1.41
Antimony trioxide[3]	1.25- 1.50

[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

Exports of antimony oxide decreased significantly in 1986 but remained above the average export level for the previous 5-year period. In addition to exports of antimony oxide, the United States also exported 1,350 tons (gross weight) of other antimony compounds in 1986 with a value of $4.4 million. The Federal Republic of Germany, Venezuela, and the United Kingdom, in descending order of receipts, received 57% of these compounds, and the balance was divided among 25 other countries.

Total imports of antimony materials increased significantly compared with those of 1985 and reached their highest level in over 25 years. China, the Republic of South Africa, and Mexico, in descending order of shipments, accounted for approximately 70% of total U.S. antimony imports in 1986.

In 1986, the following source countries for antimony metal were eligible for special duty-free status under the Generalized System of Preferences: Bolivia, Chile, the Republic of Korea, Mexico, Peru, and Thailand.[3]

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

Country	1985 Gross weight (short tons)	1985 Value (thousands)	1986 Gross weight (short tons)	1986 Value (thousands)
Belgium-Luxembourg	99	$242	--	--
Canada	2	10	28	$83
Dominican Republic	4	15	--	--
Germany, Federal Republic of	2	3	26	41
India	59	223	--	--
Italy	--	--	1	30
Japan	48	34	130	278
Korea, Republic of	--	--	10	15
Mexico	41	103	29	49
Netherlands	11	30	14	24
Saudi Arabia	--	--	191	147
Spain	28	41	44	103
Taiwan	--	--	1	3
Trinidad	--	--	13	49
United Kingdom	21	76	31	84
Venezuela	1	2	30	68
Other	46	97	46	237
Total[1]	362	876	595	1,210

[1]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	1985 Gross weight (short tons)	1985 Antimony content[1] (short tons)	1985 Value (thousands)	1986 Gross weight (short tons)	1986 Antimony content[1] (short tons)	1986 Value (thousands)
Australia	4	3	$15	2	2	$9
Belgium-Luxembourg	1	1	4	14	12	53
Canada	368	305	1,051	319	265	916
Germany, Federal Republic of	123	102	260	48	40	146
India	6	5	28	13	11	56
Israel	2	2	4	--	--	--
Italy	139	115	538	111	92	423
Japan	25	21	78	10	8	25
Korea, Republic of	7	6	57	43	36	95
Mexico	59	49	87	42	35	117
Netherlands	3	2	6	--	--	--
Singapore	4	3	12	12	10	41
Taiwan	--	--	--	18	15	65
Turkey	--	--	--	23	19	74
United Kingdom	308	256	677	10	8	29
Uruguay	--	--	--	12	10	38
Venezuela	6	5	24	3	2	15
Other	r12	r10	r35	17	15	79
Total[2]	1,067	885	2,876	699	580	2,182

rRevised.
[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. import duties for antimony

Item	TSUS No.	Most favored nation (MFN) Jan. 1, 1986	Most favored nation (MFN) Jan. 1, 1987	Non-MFN Jan. 1, 1986
Ore	601.03	Free	Free	Free.
Needle or liquated	603.10	0.1 cent per pound	0.1 cent per pound	0.25 cent per pound.
Metal, unwrought	632.02	do	Free	2 cents per pound.
Antimony oxide	417.50	Free	do	Do.

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

Country	1985 Gross weight (short tons)	1985 Antimony content[1] (short tons)	1985 Value (thousands)	1986 Gross weight (short tons)	1986 Antimony content[1] (short tons)	1986 Value (thousands)
Antimony ore and concentrate:						
Bolivia	973	642	$1,349	741	470	$661
Canada	756	421	406	1	(2)	1
Chile	429	276	486	65	39	40
China	4,555	1,798	5,144	1,450	886	1,088
Guatemala	655	320	391	1,094	616	726
Guyana	--	--	--	54	33	32
Honduras	273	150	223	66	26	19
Hong Kong	22	14	25	850	387	484
Korea, Republic of	--	--	--	19	11	40
Malaysia	55	17	25	--	--	--
Mexico	4,000	2,055	1,948	5,541	2,913	2,255
Peru	--	--	--	70	40	56
Singapore	1,727	661	1,754	--	--	--
South Africa, Republic of	--	--	--	19	16	7
Taiwan	450	90	94	--	--	--
Thailand	443	181	406	779	366	386
United Kingdom	43	13	130	83	53	96
Total[3]	14,381	6,638	12,381	10,833	5,855	5,892
Antimony oxide:						
Belgium-Luxembourg	607	504	1,549	472	392	1,243
Bolivia	685	569	1,325	833	691	1,315
Brazil	92	76	194	--	--	--

See footnotes at end of table.

Table 12.—U.S. imports for consumption of antimony, by class and country —Continued

Country	1985 Gross weight (short tons)	1985 Antimony content[1] (short tons)	1985 Value (thousands)	1986 Gross weight (short tons)	1986 Antimony content[1] (short tons)	1986 Value (thousands)
Antimony oxide —Continued						
Canada	19	16	$65	--	--	--
Chile	--	--	--	221	183	$333
China	3,404	2,825	8,789	3,410	2,830	7,818
France	1,436	1,191	5,134	881	731	2,463
Germany, Federal Republic of	97	80	653	101	84	703
Hong Kong	482	401	1,281	1,155	959	2,566
Japan	7	6	35	1	1	14
Korea, Republic of	20	17	68	--	--	--
Mexico	--	--	--	27	22	28
Netherlands	--	--	--	38	32	92
South Africa, Republic of	3,534	2,933	785	5,889	4,888	3,884
Spain	--	--	--	56	46	138
Switzerland	31	26	126	--	--	--
Taiwan	--	--	--	195	162	365
United Kingdom	206	171	761	241	200	567
Total[3]	10,620	8,815	20,765	13,521	11,221	21,529
Antimony sulfide:[4]						
Austria	--	--	--	4	3	15
Belgium-Luxembourg	6	4	15	--	--	--
Canada	10	7	17	--	--	--
China	126	84	187	538	360	565
Germany, Federal Republic of	1	1	10	--	--	--
Hong Kong	--	--	--	20	13	8
Ivory Coast	24	16	26	--	--	--
Japan	(2)	(2)	1	--	--	--
Mexico	--	--	--	13	9	9
Total[3]	167	112	256	576	385	596

[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 13.—U.S. imports for consumption of antimony metal, by country

Country	1985 Gross weight (short tons)	1985 Value (thousands)	1986 Gross weight (short tons)	1986 Value (thousands)
Belgium-Luxembourg	1	$4	--	--
Bolivia	--	--	127	$229
Canada	1	175	(1)	109
Chile	--	--	65	117
China	3,398	8,617	4,634	9,828
France	(1)	4	--	--
Germany, Federal Republic of	(1)	30	20	107
Hong Kong	228	601	1,232	2,810
Japan	(1)	6	(1)	1
Korea, Republic of	--	--	154	403
Mexico	1,247	1,006	1,359	896
Netherlands	--	--	20	51
Peru	101	205	11	24
Spain	58	150	--	--
Taiwan	95	185	--	--
Thailand	--	--	58	117
U.S.S.R	--	--	236	502
United Kingdom	--	--	22	47
Total[2]	5,129	10,983	7,940	15,242

[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

The Bureau of Mines studied the potential availability of primary antimony from demonstrated resources in 21 mines and deposits in market economy countries. The 21 studied properties contained 550,700 tons of antimony as demonstrated resources, of which 335,000 tons was recoverable as antimony metal; another 1 million tons of antimony was contained in inferred resources. This report was one of a series of reports by the Bureau that analyzed the availability of selected minerals from domestic and foreign sources.[4]

Canada.—Durham Resources Inc. reported that its Lake George Mine in New Brunswick, which was reopened in June 1985, following a 3-year closure, operated at full production levels in 1986. At full capacity, the mill reportedly could process about 500 tons of ore per day and produce concentrates averaging 65% antimony content.

Guatemala.—Minas de Guatemala S.A. reported that production at its mines, which were reopened in 1985, had reached 2,000 tons of ore per month averaging 6% antimony. The mill was reportedly operating at 60% of its 150-ton-per-day capacity and producing 165 tons per month of concentrates grading 62% antimony. The company announced that it planned to increase concentrate production to 180 tons per month in the near future.

Japan.—Antimony trioxide production, mainly from imported material, was 10,667 tons, an increase of 17% compared with 1985 production levels. Antimony metal production decreased from 326 tons in 1985 to 213 tons in 1986.[5]

South Africa, Republic of.—A technical review of the history, occurrence, mining, and metallurgy of antimony at Consolidated Murchison Ltd. was published. World antimony markets were also discussed.[6]

Thailand.—The Government announced the approval of plans to build a new $1.7 million antimony smelter near Bangkok. The smelter reportedly will use domestic concentrates to produce antimony metal for export. The plant, to be operated by a new company, the New Siam Mineral Resources Co., was expected to have an annual capacity of 1,100 tons of antimony metal.

Yugoslavia.—Antimony deposits totaling 1.2 million tons of ore reportedly were located near Srebrenica in Bosnia-Hercegovina. Potentially, these deposits could yield about 900 tons of antimony per year. In 1986, there was reportedly only one antimony mine operating in Yugoslavia, the Zajica-Loznica Mine in Serbia with an annual production of about 1,100 tons of antimony.

Table 14.—Antimony: World mine production (content of ore unless otherwise specified), by country[1]

(Short tons)

Country	1982	1983	1984	1985[p]	1986[e]
Australia[2]	1,263	[r]593	1,267	[r,e]1,650	1,650
Austria	735	726	577	526	550
Bolivia	15,408	10,969	10,231	9,838	11,350
Canada[3]	--	--	610	[r,e]1,185	4,300
China[e]	13,200	16,500	16,500	16,500	16,500
Czechoslovakia	770	990	1,100	[e]1,100	1,000
France	340	122	--	--	--
Guatemala[e]	550	--	100	[r]1,170	1,200
Honduras[e]	--	--	[r]120	[r]100	110
Italy	374	--	269	546	330
Malaysia (Sarawak)	153	148	19	13	20
Mexico[4]	1,725	2,777	3,377	4,702	4,400
Morocco (content of concentrates)	998	500	1,071	[r,e]830	830
Pakistan	--	--	1	4	--
Peru (recoverable)	814	786	741	655	740
South Africa, Republic of (content of concentrates)	10,070	6,947	8,201	8,150	8,200
Spain	506	539	643	273	220
Thailand	734	1,315	2,172	1,367	1,400
Turkey	1,189	926	1,121	1,210	1,200
U.S.S.R.[e]	9,900	10,000	10,300	10,400	10,500

See footnotes at end of table.

Table 14.—Antimony: World mine production (content of ore unless otherwise specified), by country[1] —Continued

(Short tons)

Country	1982	1983	1984	1985[p]	1986[e]
United States[5]	503	838	557	W	W
Yugoslavia	1,672	1,047	[e]1,050	[e]1,400	1,300
Zimbabwe (content of concentrates)	227	158	282	214	220
Total	61,131	[r]55,881	60,309	61,833	66,020

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Table includes data available through May 26, 1987.
[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]Antimony content of ores for export plus antimony content of antimonial lead and other smelter products produced.
[5]Production from antimony mines; excludes amount produced as a byproduct of domestic lead ores.

TECHNOLOGY

Northrop Corp. announced the development of a semiconductor chip that reportedly provided well-defined television images of night-operating aircraft at ranges of more than 10 miles. The indium antimonide array absorbed infrared radiation and electronically converted it into a television picture for display on a monitor in a cockpit or control center. Northrop reported that the suitability of the new chip for daytime use had been validated and that flight tests of night-vision applications were to begin late next year.[7]

Researchers at the National Aeronautics and Space Administration Ames Research Center published a paper describing a technology-development program to advance the capabilities of integrated infrared detector arrays for low-background astronomical research from space. The goal of the program was to characterize available devices and provide an understanding of sensor technologies from which a number of infrared array-based instrument concepts could be drawn for both near-term and future space astronomy applications. Indium antimonide arrays and silicon antimonide direct read-out arrays were among the devices tested.[8]

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[1]Physical scientist, Division of Nonferrous Metals.
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[4]Palencia, C. M., and C. P. Mishra. Antimony Availability—Market Economy Countries. BuMines IC 9098, 1986, 20 pp.
[5]Japan Metal Journal. V. 17, No. 11, Mar. 16, 1987, p. 7.
[6]Davis, D. R., D. B. Paterson, and D. H. C. Griffiths. Antimony in South Africa. J. S. Afr. Inst. Min. Metall., v. 86, No. 6, June 1986, pp. 173-193.
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Asbestos

By Robert L. Virta[1]

U.S. apparent consumption of asbestos declined in 1986. Shipments from domestic mines decreased 11% and imports for consumption decreased 24% from those of 1985. 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

	1982	1983	1984	1985	1986
United States:					
Production (sales):					
Quantity metric tons	63,515	69,906	57,422	57,457	51,437
Value[1] thousands	$24,917	$27,866	$24,238	$20,485	$17,367
Exports and reexports (unmanufactured):					
Quantity metric tons	58,771	54,634	39,919	45,656	47,281
Value thousands	$19,713	$19,683	$18,346	$16,489	$14,520
Exports and reexports of asbestos products:					
Value do	$127,867	$129,582	$163,347	$193,765	$163,896
Imports for consumption (unmanufactured):					
Quantity metric tons	241,737	196,387	209,963	142,431	108,352
Value thousands	$64,925	$57,956	$64,749	$44,093	$26,537
Consumption, apparent[2] metric tons	246,500	217,000	226,000	162,000	119,627
World: Production do	[r]4,559,495	[r]4,728,867	4,659,115	[p]4,678,287	[e]4,522,045

[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.—On January 29, 1986, the EPA announced a proposed ruling that would immediately ban the manufacture, importation, and processing of certain asbestos construction materials (asbestos-cement pipe and fittings, roofing felt, flooring felt, felt-backed sheet flooring, vinyl asbestos floor tile, and asbestos clothing) under section 6 of the 1976 Toxic Substances Control Act.[2] In addition, the mining and importation of asbestos and the importation of asbestos products not directly banned would be placed under a permit system. The permit system would limit the mining and importation of asbestos to 30% of the 1981, 1982, and 1983 average values and would phase out asbestos use within 10 years.

The Occupational Safety and Health Administration (OSHA) enacted a ruling, effective July 21, that limits worker exposure to asbestos, tremolite, anthophyllite, and actinolite to 0.2 fiber per cubic centimeter per 8-hour work period.[3] OSHA also required employee training and medical surveillance when exposure levels exceed 0.1 fiber per cubic centimeter. A 9-month administrative stay was placed on that portion of the ruling covering the nonasbestiform varieties of tremolite, anthophyllite, and actinolite.[4]

Worker exposure to the nonasbestiform varieties was limited to 2.0 fibers per cubic centimeter by the administrative stay.

The EPA enacted a ruling, effective June 9, that limits asbestos exposures for State and local government employees who were not protected by OSHA regulations or by State plans approved under the Occupational Safety and Health Act.[5] Exposures for workers engaged in the removal, enclosure, or encapsulation of any friable material containing more than 1% asbestos are limited to 2.0 fibers per cubic centimeter per 8-hour period.

The Consumer Product Safety Commission issued an enforcement policy for household products to which asbestos is intentionally added.[6] The policy, effective December 23, requires warning labels to be placed on asbestos-containing products that are likely to release asbestos fibers when handled or used.

The EPA announced a final ruling establishing effluent limitation guidelines for the discharge of conventional pollutants into navigable waters by specified industrial dischargers.[7] No changes were made to previous effluent limitation guidelines for asbestos manufacturing. Previous guidelines set no limitations on effluent discharge with regard to best conventional pollutant control technology except for solvent recovery, where the best conventional technology is required to control total suspended solids and pH.

On October 22, the Asbestos Hazard Emergency Response Act of 1986 was signed into law.[8] The act requires EPA to develop regulations for inspecting public and private school buildings for asbestos-containing materials, evaluating the risk that these materials represent, recommending corrective action and an air monitoring protocol, and issuing disposal guidelines for asbestos-containing materials.

Stockpile goals for asbestos were unchanged from those of 1985.

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

(Metric tons)

	Stockpile goals	Total inventories 1984	1985	1986
Amosite	15,422	30,855	30,855	30,853
Chrysotile	2,722	9,754	9,772	9,711
Crocidolite	--	33	33	33
Total	18,144	40,642	40,660	40,597

Source: General Services Administration, Federal Property Service.

Environmental Impact.—The International Labor Organization at its 1986 conference voted to support the controlled use of asbestos.[9] Its recommendations would require ratifying countries to enact legislation that would protect the worker from asbestos exposure; provide for safe, proven asbestos substitutes if the use of asbestos would represent an unacceptable hazard to the worker; ban the use of crocidolite and the use of sprayed asbestos except under special conditions; and establish worker exposure limits.

EPA announced the availability of a regulatory determination for solid waste from the extraction and beneficiation of ores and minerals as required by the Resource Conservation and Recovery Act (RCRA).[10] The report discussed wastes from asbestos, phosphate, uranium, and several metal mining operations. Approximately 5 million metric tons of waste containing greater than 5% chrysotile were generated from asbestos production according to the EPA report. EPA concluded that current RCRA criteria could not be used to evaluate asbestos waste sites and that different criteria would have to be developed.

DOMESTIC PRODUCTION

Mine shipments decreased 11% in quantity and 15% in value from those of 1985. The decreased activity was due primarily to adverse publicity on asbestos-related health risks.

Three mines in California and Vermont marketed asbestos. Calaveras Asbestos Ltd. in California led in asbestos sales in the United States, followed by KCAC Inc. and Vermont Asbestos Group Inc.

Table 3.—Asbestos producers in the United States in 1986

State and company	County	Mine	Type of asbestos
California:			
Calaveras Asbestos Ltd	Calaveras	Copperopolis	Chrysotile.
KCAC Inc	San Benito	Santa Rita	Do.
Vermont: Vermont Asbestos Group Inc	Orleans	Lowell	Do.

CONSUMPTION AND USES

Total U.S. asbestos consumption decreased 26%. Approximately 98% of the asbestos consumed was chrysotile and 2% was crocidolite. 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.

The packing and flange manufacturers increased their use of asbestos substitutes because of stricter asbestos regulations and increased concern over asbestos-related health risks.[11] Traditionally 80% to 90% of their products contained asbestos. In 1986, slightly over 50% of the products contained asbestos.

Table 4.—U.S. asbestos consumption by end use, grade, and type

(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				
1985 total	0.1	1.7	18.8	12.1	13.7	104.0	150.4	0.3	4.8	7.3	155.5
1986:											
Asbestos-cement pipe	--	--	12.7	1.5	3.4	--	17.6	--	2.0	--	19.6
Asbestos-cement sheet	--	--	--	([4])	2.9	2.0	5.0	--	--	--	5.0
Coatings and compounds	--	--	--	--	--	17.4	17.4	--	--	--	17.4
Flooring products	--	--	--	--	--	5.3	5.3	--	--	--	5.3
Friction products	--	.1	.4	5.0	3.0	17.1	25.6	--	--	--	25.6
Insulation:											
Electrical	--	--	([4])	--	--	.2	.3	--	--	--	.3
Thermal	--	--	([4])	([4])	--	--	([4])	--	--	--	([4])
Packing and gaskets	--	.1	.5	2.5	.2	1.5	4.8	--	--	--	4.8
Paper	--	--	--	--	.4	12.3	12.7	--	--	--	12.7
Plastics	--	--	--	([4])	--	.5	.6	--	--	--	.6
Roofing products	--	--	--	([4])	.4	19.4	19.8	--	--	--	19.8
Textiles	--	.8	([4])	--	--	--	.9	--	--	--	.9
Other	--	([4])	.6	.2	([4])	2.8	3.6	--	--	--	3.6
Total[5]	--	1.1	14.2	9.3	10.3	78.6	113.7	--	2.0	3.9	115.7

[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 1986 was $338 per metric ton. The average unit value of exported asbestos was $307 per ton.

Table 5.—Customs unit values of imported asbestos

(Dollars per metric ton)

	1982	1983	1984	1985	1986
Canada:					
Chrysotile:					
Cement	234	257	284	--	--
Crude	380	199	1,084	576	547
Spinning	917	932	699	731	507
Other	334	384	431	283	229
South Africa, Republic of:					
Amosite	771	840	869	830	--
Crocidolite	646	629	705	569	582

Source: Bureau of the Census.

FOREIGN TRADE

There was a 16% decrease 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 of brake linings and disc pads accounted for 76% of the value of all asbestos products exported. Canada remained the largest importer of U.S. asbestos fibers and products, followed by Japan, Mexico, the Federal Republic of Germany, Brazil, and Venezuela.

Canada provided 96% of the asbestos imported into the United States, and the Republic of South Africa provided 4%. Several other countries provided minor amounts. Approximately 95% of asbestos fiber imports was chrysotile. The value of imported asbestos fiber decreased 40%.

Table 6.—Countries importing U.S. asbestos fibers and products

(Thousand dollars)

Country	1985 Unmanufactured fibers	1985 Manufactured products	1985 Total	1986 Unmanufactured fibers	1986 Manufactured products	1986 Total[1]
Australia	1	1,379	1,380	17	1,341	1,358
Brazil	251	3,592	3,843	467	2,555	3,022
Canada	714	148,663	149,377	605	123,819	124,424
Germany, Federal Republic of	75	1,948	2,023	300	2,746	3,047
Japan	3,294	10,140	13,434	2,981	7,867	10,848
Korea, Republic of	190	1,814	2,004	624	825	1,449
Kuwait	31	437	468	--	221	221
Mexico	6,261	6,483	12,744	2,667	5,593	8,260
Saudi Arabia	2	1,409	1,411	--	1,062	1,062
Thailand	2,330	332	2,662	2,490	354	2,844
Turkey	--	544	544	--	361	361
United Kingdom	50	926	976	166	1,313	1,479
Venezuela	267	3,487	3,754	218	2,688	2,906
Other	2,900	12,325	15,225	3,864	12,108	15,972
Total[1]	16,366	193,479	209,845	14,401	162,851	177,252

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

Source: Bureau of the Census.

Table 7.—U.S. exports and reexports of asbestos and asbestos products

Products	1984 Quantity	1984 Value (thousands)	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
EXPORTS						
Unmanufactured:						
Crudes, fibers, stucco ... metric tons	26,381	$14,106	29,382	$12,705	30,252	$9,728
Sand and refuse ... do	13,398	4,115	15,693	3,661	16,645	4,673
Total ... do	39,779	18,221	45,075	16,366	46,897	14,401

Table 7.—U.S. exports and reexports of asbestos and asbestos products —Continued

Products	1984 Quantity	1984 Value (thousands)	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
EXPORTS —Continued						
Manufactured:						
Asbestos fibers ___ metric tons	958	$5,067	607	$3,793	723	$3,902
Brake linings and disk brake pads ___ do	NA	103,303	NA	144,262	NA	123,515
Clutch facings and linings ___ number	NA	23,206	NA	20,718	NA	16,187
Gaskets ___ metric tons	275	1,815	78	900	266	1,285
Insulation ___ do	NA	5,720	NA	4,566	NA	1,889
Packing and seals ___ do	1,150	9,063	1,192	6,716	820	6,373
Shingles and clapboard ___ do	2,098	1,615	984	893	880	805
Other articles of asbestos ___ do	1,759	2,595	1,521	2,437	1,614	1,553
Other articles, n.s.p.f ___ do	NA	10,306	NA	9,191	NA	7,342
Total	XX	162,690	XX	193,476	XX	162,851
REEXPORTS						
Unmanufactured:						
Crudes and fibers ___ metric tons	140	125	369	71	329	98
Sand and refuse ___ do	--	--	212	52	54	20
Total[1] ___ do	140	125	581	123	384	119
Manufactured:						
Asbestos fibers ___ do	1	5	(2)	3	--	--
Brake linings and disk brake pads ___ do	NA	47	NA	103	NA	222
Clutch facings and linings ___ number	NA	194	NA	73	NA	604
Gaskets ___ metric tons	46	136	1	18	6	65
Insulation ___ do	(2)	10	NA	r2	NA	23
Packing and seals ___ do	(2)	1	4	63	(2)	50
Other articles of asbestos ___ do	NA	264	NA	20	NA	3
Other articles, n.s.p.f ___ do	--	--	NA	1	NA	78
Total	XX	657	XX	r283	XX	1,045

rRevised. 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 8.—U.S. imports for consumption of asbestos fibers, by type, origin, and value

Type	Canada Quantity (metric tons)	Canada Value (thousands)	South Africa, Republic of Quantity (metric tons)	South Africa, Republic of Value (thousands)	Other Quantity (metric tons)	Other Value (thousands)	Total[1] Quantity (metric tons)	Total[1] Value (thousands)
1984	195,651	$56,267	13,912	$8,033	400	$449	209,963	$64,749
1985:								
Amosite	--	--	121	100	--	--	121	100
Chrysotile:								
Crude	94	86	174	100	--	--	268	187
Spinning fibers	1,990	1,454	--	--	90	110	2,080	1,564
All other	127,307	36,045	522	301	37	16	127,866	36,362
Crocidolite (blue)	--	--	4,794	2,726	--	--	4,794	2,726
Other (unspecified asbestos type)	1,728	962	5,374	1,997	200	196	7,302	3,155
Total[1]	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

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

Source: Bureau of the Census.

WORLD REVIEW

World production of asbestos decreased slightly from that of 1985. The major production change occurred in Canada, where shipments were down 110,000 tons. The U.S.S.R. remained the largest producer of asbestos, followed by Canada, Brazil, Zimbabwe, China, the Republic of South Africa, and Italy.

Canada.—Three Canadian asbestos producers, Asbestos Corp. Ltd., Bell Asbestos Mines Ltd., and Lac d'Amiante du Quebec, formed a partnership, effective July 1, 1986, that strengthened their resources and improved their position in domestic and export markets.[12] The new partnership was governed by a board of directors, although each facility operated under local management. The partnership controlled approximately 50% of the asbestos production in the Province of Quebec.

Carey Canada Inc., a subsidiary of the Jim Walter Corp., permanently closed its chrysotile mine in the Beauce Mountains, near East Broughton, Quebec.[13] Economic conditions made the mine unprofitable. Carey Canada produced chrysotile grades 4D to 7W for asphalt compounds, friction materials, asbestos paper, vinyl asbestos tile, gaskets, phenolic compounds, and caulking compounds. The company marketed asbestos primarily in North America and Asia.

China.—Approximately 100 asbestos-cement (A-C) manufacturing plants operated with 200 production lines.[14] Production of shingle and board were operating below capacity because of shortages of asbestos and cement. Expansion was anticipated to meet increasing demands for new markets such as in power station cooling towers, ventilation and roofing needs in textile mills, guard structures in fertilizer plants, and replacements for traditional clay brick structures. Plans were made to increase asbestos production and upgrade existing mill and plant equipment.

Italy.—Asbestos was produced by only one company, Amiantifera di Balangero S.p.A., from a surface mine at San Vittore.[15] The crushed rock was processed in an automated plant where the fibers were removed from the host rock, dried in static vertical and revolving horizontal driers, and graded. Automated sampling was performed every 6 minutes to determine fiber quality. Approximately 70% of the asbestos was used by the A-C industry. Other uses included gaskets, brake linings, paint filler, and insulation material. Over 50% of manufactured products was exported.

Morocco.—Although chrysotile deposits occur near Bou Azzer and Inguiem, no domestic production was undertaken.[16] Demand for asbestos was met by imports, primarily from Canada and Botswana. Asbestos was consumed primarily by the domestic A-C industry for building and irrigation projects. Despite domestic demand, 30% to 50% of A-C products was exported to neighboring countries.

South Africa, Republic of.—Griqualand Exploration and Finance Co. Ltd. implemented an environmental program to revegetate old mine dumps.[17] The mine dumps, which had been previously covered by soil and grass, were exposed owing to the grazing of livestock. The companies began planting vegetation that provides a dense soil cover and is impenetrable by animals.

Table 9.—Asbestos: World production, by country[1]

(Metric tons)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Argentina	1,218	1,240	1,093	[e]1,200	1,100
Australia	18,587	[r]3,909	--	--	--
Brazil (fiber)	145,998	158,885	134,788	172,027	175,000
Bulgaria	600	700	500	400	500
Canada (shipments)	834,000	858,000	837,000	750,000	[3]640,000
China[e]	110,000	160,000	135,000	[r]150,000	150,000
Colombia	[e]5,400	[e]5,400	9,982	12,435	13,000
Cyprus	18,952	17,288	7,429	16,360	16,000
Egypt	424	245	[e]325	[e]325	300
Greece	17,016	31,811	45,376	46,811	48,000
India	26,761	24,873	25,450	30,183	30,000
Indonesia[e]	25,000	25,000	25,000	25,000	25,000
Italy	116,410	139,054	147,272	136,006	[3]115,208
Japan[e]	[3]4,135	4,000	4,000	4,000	4,000
Korea, Republic of	15,933	12,506	8,062	4,703	5,000
Mozambique	852	[r e]600	[r e]400	55	--
South Africa, Republic of	211,860	221,111	167,389	163,574	140,000
Swaziland	30,145	26,287	25,832	25,130	25,000

See footnotes at end of table.

Table 9.—Asbestos: World production, by country[1] —Continued

(Metric tons)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Taiwan	2,392	2,819	1,355	625	--
Turkey	958	1,510	1,499	[e]1,500	1,500
U.S.S.R.[e]	[r]2,700,000	[r]2,800,000	[r]2,850,000	[r]2,900,000	2,900,000
United States (sold or used by producers)	63,515	69,906	57,422	57,457	[3]51,437
Yugoslavia	11,657	10,502	8,556	6,916	7,000
Zimbabwe	[r]197,682	[r]153,221	165,385	173,580	174,000
Total	[r]4,559,495	[r]4,728,867	4,659,115	4,678,287	4,522,045

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

[1]Table includes data available through Apr. 28, 1987.

[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

A semiquantitative method for distinguishing between asbestiform and nonasbestiform crystals was developed.[18] The flexibilities of several asbestiform and nonasbestiform tremolite crystals were measured and their bending strengths were calculated. The asbestiform and nonasbestiform varieties of tremolite could be differentiated using this technique.

A process was developed to synthesize zeolites using chrysotile as a starting material.[19] The magnesium was stripped from the chrysotile structure. The remaining siliceous material was mixed with alumina and heated under pressure to synthesize zeolite crystals. Production of 1 ton of zeolite consumes 2 tons of chrysotile. If economically feasible, this synthesis process will create a new market for chrysotile.

Asbestos is used in pressure pipe to provide reinforcement strength, improve the drainage characteristics, and provide dimensional stability to uncured pipe. With concerns over asbestos-related environmental issues, asbestos used in A-C pipe and sheet was facing competition from a variety of artificial and natural fibers. In general, these substitute fibers did not have the same reinforcing properties, did not bind as well with the cement and silica particles, and did not disperse in the cement matrix as well as asbestos.[20]

A study of A-C pipe, polyvinyl chloride (PVC) pipe, and ductile iron (DI) pipe indicated that A-C pipe was more cost effective over a wide range of diameters, strength classes, and applications than either PVC or DI pipe.[21] A-C pipe is more versatile because interior and exterior coatings are not required for corrosion resistance; for a given diameter, A-C pipe has higher crush and burst strengths; use of rubber sealing rings provides joint flexibility, shock resistance, pipe-expansion and pipe deflection; A-C pipe has a smooth bore, which results in a low coefficient of friction; and a single manufacturing facility can make all forms of A-C pipe.

The packing and flange manufacturers investigated the use of asbestos substitutes in packings and gaskets.[22] The major replacements were flexible graphite, carbon and graphite yarn, glass fibers, aramid, polybenzimidazale, polytetrafluoroethylene, ceramics, mica, and metals. Although none of these substitutes possessed all of the desirable properties of asbestos, packings and gaskets of equal or superior quality were produced using a combination of asbestos substitutes. Asbestos substitutes, however, were still not adaptable to many severe use applications and were more costly than asbestos.

The Chlorine Institute estimated that replacing asbestos diaphragm cells with nonasbestos membrane cells would cost the U.S. chlor-alkali industry $2 million.[23] Approximately 97% of the chlorine produced in the United States was generated using diaphragm cells. No substitute had the strength, physical structure, and chemical resistance to acids and alkalies of asbestos. An alternative to replacing asbestos with asbestos substitutes was converting diaphragm cells to membrane cells. Membranes consisting of carboxylic-sulfonic compounds were developed to fit around the anodes of the diaphragm cell. Use of these membranes was reported to reduce electricity costs by 20% and produce high-purity caustic soda of 30% to 35% concentration.

Techniques for evaluating and controlling asbestos exposures were developed.[24] All of these techniques focus on evaluating the health risk posed by asbestos materials in the workplace. Detailed information on the type of asbestos, condition of the asbestos material, and activity levels are a few of the considerations of these risk management programs.

A technique for encapsulating asbestos in buildings using a low-density cellular polymer insulation was developed.[25] The polymer insulation formed a durable coating over the asbestos that was more abrasion and impact resistant than resin coatings. The durable coating reduced the risk of asbestos release through abrasion. Encapsulation using the cellular polymer insulation costs from 50% to 75% less than asbestos removal and eliminates the potential for fiber release that may occur during removal operations.

E. I. du Pont de Nemours & Co. Inc., Standard Oil Co., Rhodes-American, Ashland Oil Inc., and Union Carbide Corp. formed a coalition to promote the use of asbestos substitutes.[26] The coalition, called Alternative Materials Institute (AMI), reported that substitutes such as aramid fibers, carbon fibers, graphite, and other mineral and artificial fibers are available and that the transition to asbestos alternatives has already begun for some products. AMI will focus on providing up-to-date information on the availability and use of safe and effective alternatives to asbestos.

Several products that could replace asbestos in hot glass handling processes were developed.[27] Using glass fiber fabrics impregnated with fluorocarbon resins, materials with high temperature capabilities, and a dry lubricated wear surface were produced. Several of these materials could be molded to shape and had applications up to 1,000° F.

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Barite

By Sarkis G. Ampian[1]

Domestic production of barite decreased 60% to 297,000 short tons valued at $12 million, continuing the downward trend that started in 1982 and has persisted ever since, except in 1984. Production from Nevada, the leading producer, decreased about 70%. Production from Georgia and Missouri, the second and third leading States, increased and decreased respectively. Imports for consumption of crude barite decreased 64% to 745,000 tons, and ground barite imports decreased nearly 70% from 71,024 tons to 21,845 tons valued at $2.5 million. Although imports of barite exceeded domestic production for the fifth straight year, the import figure of 745,000 tons for 1986 was nearly 1.6 million tons below the record high 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, after increasing in 1984, returned to the downward trend that began in 1982 owing to a decrease in drilling activity, prompted by oil oversupplies and declining oil prices. The trend has been further exacerbated by the return to drilling shallower wells that consume less barite. 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 87 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)

	1982	1983	1984	1985	1986
United States:					
Barite, primary:					
Sold or used by producers	1,845	754	775	739	297
Value	$69,522	$29,203	$25,445	$21,501	$12,326
Exports	49	23	1	6	7
Value	$6,510	$3,514	$574	$692	$1,021
Imports for consumption (crude)	2,320	1,396	1,731	2,056	745
Consumption (apparent)[1]	4,116	2,127	2,505	2,789	1,035
Crushed and ground (sold or used by processors)[2]	4,088	2,745	2,883	2,184	1,216
Value	$322,700	$194,380	$220,806	$154,463	$75,965
Barium chemicals (sold or used by processors)	25	22	26	24	25
Value	$18,720	$16,860	$17,105	$16,036	$16,871
World: Production	8,002	r5,924	6,399	p6,597	e5,404

eEstimated. pPreliminary. rRevised.
[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 beneficiation processes such as washing, jigging, or magnetic separation. Run-of-mine barite, the lowest cost primary barite sold or used by producers, represented 36% of total production compared with 59% in 1985; the other 64% 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 filler and chemical applications.

Reported primary production decreased 60%. Nevada and Georgia remained the two leading barite producing States. Other producing States, in descending order, were Missouri and Tennessee. All domestic barite output is a primary product. Barite was formerly produced as a coproduct of fluorspar mining and milling in Illinois.

The leading domestic barite producers were Dresser Minerals Div. of Dresser Industries Inc., FMC Corp., and IMCO Services Div. of Halliburton Co., with mines in Nevada; and NL Baroid/NL Industries Inc., with mines in Missouri and Nevada. Another producer in Nevada was Circle A Construction Co. Inc., and in Missouri, De Soto Mining Co. Inc. A. J. Smith Co. Inc. also produced significant quantities in Tennessee. The Georgia producers were Cyprus Industrial Minerals Co. and New Riverside Ochre Co.

The domestic barite industry experienced a severe downturn during the year, primarily owing to a decrease in oil- and gas-well-drilling activity. This downturn, except for a slight upturn in 1984, continues the trend of declining barite production rates that have been prevalent since 1981, the record-high production year (2.8 million tons). Production data also revealed that, despite a downturn in drilling activity, competitive rail rates to the gulf coast and midcontinent areas based on unit trains and guaranteed tonnage contracts continued to enable modest domestic mining campaigns. Nevertheless, the persistent oil glut and lower energy consumption rates, exacerbated by Mideast overproduction, continued to thwart an upturn in oil- and gas-well-drilling activity. Other factors depressing the domestic marketplace were sliding and inconsistent oil prices, which in turn created a substantial overcapacity in the drilling fluids business. In addition, lower ocean freight rates, in part due to lower bunker fuel costs and

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)
1985:									
Georgia	2	--	--	W	W	W	W	W	W
Illinois	1	--	--	W	W	--	--	W	W
Missouri	3	26	$896	--	--	21	$1,895	47	$2,791
Montana	1	W	W	--	--	--	--	W	W
Nevada	9	389	7,485	--	--	201	3,419	590	10,904
Tennessee	1	W	W	--	--	--	--	W	W
Washington	1	--	--	W	W	--	--	W	W
Total	18	[3]436	[3]9,441	[3]58	[3]$4,099	[3]246	[3]7,961	[3]739	[3]21,501
1986:									
Georgia	2	--	--	W	W	W	W	W	W
Missouri	3	--	--	W	W	W	W	W	W
Nevada	7	[4]107	[4]1,865	--	--	82	1,522	[4]189	[4]3,386
Tennessee	1	[5]W	[5]W	--	--	--	--	[5]W	[5]W
Total	13	107	1,865	W	W	[3]190	[3]10,462	[3]297	[3]12,326

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

excess bottoms, helped make foreign ores more competitive than domestic barite. The shrinking domestic market, still the world's largest, has turned a soft market into a buyer's market. The viability of the domestic industry, for producers and grinders alike, continued to be threatened by imports of barite into an already depressed marketplace, which could further soften foreign barite prices.

Most mining and grinding operations continued to be either suspended or on minimal production schedules. Many of the additions to mining, milling, and/or grinding capacity were largely to reduce operating costs to remain competitive in a soft market situation. Many ongoing and planned projects, including most exploration programs, have been indefinitely deferred.

Dresser's Magcobar Minerals Div. (with the exception of a lead-zinc operation) and Halliburton's IMCO Services Div. have agreed to combine their worldwide drilling fluid operation in a joint venture company, M-I Drilling Fluids Co. Dresser will have a 60% interest in the venture and Halliburton, 40%. In another merger, Hughes Tool Co. and Baker International Corp. have agreed to merge their oil-fluid services and drill-bit operations under a holding company to be called Baker Hughes Inc.

Table 3.—Producers of barium materials in 1986

Company	Plant location	Material
BARITE MATERIALS		
American Minerals Inc	Camden, NJ	Filler and well drilling.
Do	Rosiclare, IL	Do.
Circle A Construction Co. Inc	Wells, NV	Primary and filler.
Clark Minerals Inc	South Plainfield, NJ	Filler.
Coastal & Western Minerals Co	Knippa, TX	Do.
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.
Extender Products Ltd	Mineral Point, MO	Filler.
General Barite Co	Washington, MO	Primary.
GEO International Inc	Florin, CA	Well drilling.
Hughes Drilling Fluids, Drilling Mud Inc	Houma, LA	Do.
Do	Houston, TX	Do.
IMCO Services Div., Halliburton Co	Battle Mountain, NV	Do.
Do	Brownsville, TX	Do.
Do	Crescent Valley, NV	Primary and ground.
Do	Houma, LA	Well drilling.
Do	Houston, TX	Do.
Industrial Chemicals Div., FMC Corp	Battle Mountain, NV	Primary.
Magcobar Minerals Div., Dresser Industries Inc	do	Well drilling.
Do	Brownsville, TX	Well drilling and filler.
Do	Galveston, TX	Well drilling.
Do	Lander, NV	Primary and ground.
Do	New Orleans, LA	Well drilling.
Do	West Lake Charles, LA	Well drilling and filler.
Milpark Inc	Argenta, NV	Well drilling.
Do	Clinton, OK (2 plants)	Do.
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	Chatsworth, GA	Filler.
Do	Houston, TX	Well drilling.
Do	Morgan City, LA	Do.
Minerals, Pigments & Metals Div., Pfizer Inc	St. Louis, MO	Filler.
New Riverside Ochre Co	Bartow, CA	Primary.
NL Baroid/NL Industries Inc	Potosi, MO	Well drilling and filler.
Do	Corpus Christi, TX	Well drilling.
Do	Dunphy, NV	Do.
Do	Elko, NV	Primary and ground.
Do	Fountain Farm, MO	Well drilling.
Do	Lake Charles, LA	Do.
Do	New Orleans, LA	Do.
Do	Washington, MO	Primary and ground.
Old Soldiers Minerals Ltd	Abbeville, LA	Well drilling.
Do	Elk County, OK	Do.
Oster Rocky Mountain Refractories Inc	Salt Lake City, UT	Do.
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.
Sierra Chemicals	Reno, NV	Do.

The Environmental Protection Agency (EPA) issued a final National Pollutant Discharge Elimination System general permit for oil and gas operation wells on the Alaskan Outer Continental Shelf and in offshore and coastal waters of the Cook Inlet and Gulf of Alaska.[2] In another final action, EPA exempted inert barium sulfate, barite, and carnauba wax from the requirements of a tolerance when used as a carrier, density control agent (barium sulfate), and/or binder (carnauba wax) in pesticide formulations for application to animals.[3]

CONSUMPTION AND USES

Consumption of crushed and ground barite decreased about 45% from 2.2 million tons in 1985 to 1.2 million tons in 1986. This downturn, except for an increase in 1984, continued the decline in barite consumption that has occurred since 1981, when the record high of 4.7 million tons of crushed and ground barite was established. This decrease indicated a downturn in barite required for oil well drilling, which still accounted for about 90% of total sales. The oil- and gas-well-drilling industry completed over 31,000 wells and drilled nearly 147 million feet of hole;[4] both figures were 40% lower than in 1985.

Total well footage drilled exceeded 8 million feet in four States: Texas, 56.1; Oklahoma, 19.4; Louisiana, 14.5; and Kansas, 8.5. Generally, the deeper a hole is drilled, the more barite is used per foot of drilling. Among the four leading States, Louisiana had the highest average well depth, over 6,000 feet, and Kansas, the lowest, about 3,200 feet. Wyoming, absent from the top States this year in well footage drilled, again had the highest average well depth, over 7,500 feet. The U.S. average remained unchanged at about 4,700 feet. The main reason that barite consumption decreased was the 40% reduction in the number of wells drilled. This decrease was accompanied by a decline in the amount of barite used per foot of drilling, to 15.0 pounds from 16.8 pounds in 1985.

The latter decrease was due to shallower drilling that required less barite. Another benchmark of drilling activity, Hughes' rig count, showed the average number of operating domestic rigs decreased by over 50% to 964 rigs.[5] The 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 to 2,231 rigs in 1983. The 1986 average rig count of 964 is the first time since 1971 (964 rigs) that the count was under 1,000. The estimated rig count during the year ranged from 663 to 1,915. The low rig count of 663, recorded the week of July 4, 1986, is the lowest since World War II. The high, 1,915 rigs, was registered the week of January 6, 1986.

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

State	1985			1986		
	Number of plants	Quantity (thousand short tons)	Value (thousands)	Number of plants	Quantity (thousand short tons)	Value (thousands)
Louisiana	10	937	$60,702	9	585	$38,215
Missouri	3	15	1,529	3	18	752
Nevada	4	274	13,426	4	101	2,523
Oklahoma	4	79	6,206	3	38	2,140
Texas	13	700	49,163	11	361	19,703
Utah	4	35	2,493	2	W	W
Other[2]	9	144	20,944	10	111	12,632
Total	47	2,184	154,463	42	[3]1,216	75,965

W Withheld to avoid disclosing company proprietary data.
[1]Includes imports.
[2]Includes Arkansas, California, Georgia, Illinois, Montana (1985), New Jersey (1986), New York, and Tennessee (1986).
[3]Data do not add to total 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	1985 Quantity	1985 Value	1986 Quantity	1986 Value
Barium chemicals, filler and/or extender, glass	142	21,504	119	13,707
Well drilling	2,042	132,959	1,097	62,258
Total	2,184	154,463	1,216	75,965

[1]Includes imports.

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

Barium chemical	1985 Plants[2]	1985 Production (short tons)	1985 Sold or used by processors: Quantity (short tons)	1985 Sold or used by processors: Value (thousands)	1986 Plants[2]	1986 Production (short tons)	1986 Sold or used by processors: Quantity (short tons)	1986 Sold or used by processors: Value (thousands)
Barium carbonate	2	W	W	W	2	W	W	W
Barium chloride	2	W	W	W	2	W	W	W
Black ash	1	W	W	W	1	W	W	W
Blanc fixe	1	W	W	W	1	W	W	W
Other	2	24,057	23,811	$16,036	2	26,075	25,446	$16,871
Total	3	24,057	23,811	16,036	3	26,075	25,446	16,871

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Only data reported by barium chemical plants that consume barite are included. Partially estimated.
[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]: Oil	Gas	Dry holes	Total	Successful wells (percent)	Average depth per well (feet)	Average barite per well (short tons)
1966	1,022	16.78	4.38	15.23	36.39	58.1	4,478	28.08
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

[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 actual sales, increased nearly 43%, f.o.b. plant, from $29.09 per ton in 1985 to $41.50. This rise in value for domestic material is attributed to a greater percentage of higher valued filler- and chemical-grade material in the total. The average reported value per ton of ground drilling-mud-grade barite from Louisiana and Texas was $61.19; the average value of that from California, Nevada, and Utah was $65.66. The value of the Louisiana and Texas ground material, in direct response to both foreign competition and soft market conditions, declined 47%. Material from the other major grinding States remained relatively unchanged. The average customs value of barite exported to Canada was about $325 per ton; the customs value of material exported to Mexico and Latin America was about $110 per ton.

Table 8.—Barite price quotations

Item	Price per short ton[1]	
	1985	1986
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	106.00
Water-ground, 95% $BaSO_4$, 325 mesh, 50-pound bags	$80.00-165.00	$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	80.00-115.00	60.00- 90.00
Crude, imported, specific gravity 4.20 to 4.30, f.o.b. shipping point	55.00- 75.00	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	450.00	470.00
Anhydrous, bags, carlots, same basis	565.00	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. 186, No. 12, Dec. 1985, p. 11; and v. 187, No. 12, Dec. 1986, p. 19.
[3]Chemical Marketing Reporter. V. 228, No. 25, Dec. 16, 1985, p. 41; and v. 230, No. 26, Dec. 29, 1986, pp. 24-25.

FOREIGN TRADE

Exports of natural barium sulfate or barite increased about 20% from about 6,000 tons to nearly 7,000 tons. This represented a second year of increases in exports after 5 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 do not indicate the grades of barite traded; however, based on the value of individual shipments, an estimated 82% was ground drilling-mud grade, and an estimated 18% was chemical-, filler-, or glass-grade. Crude barite was not exported in 1986. Canada and Mexico, traditionally either first or second among export recipients, were replaced by Venezuela and Chile, in decreasing order, as the leading buyers of U.S. ground barite and accounted for about 80% of the total exports. Canada and Mexico received about 13% of the total. Exports to Mexico, a major oil producing country, declined to only 53 tons from a high of 18,000 tons in 1983. Both Canada and Mexico continued to rely more on domestic production. The strong U.S. dollar, which weakened at midyear, and low oil exploration levels continued to have an adverse effect on barite exports.

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

Country	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)
Argentina	59	$43	80	$42
Barbados	1,266	149	--	--
Canada	897	244	878	284
Chile	--	--	1,950	178
Japan	21	8	--	--
Liberia	1,485	16	--	--
Mexico	5	1	53	27
Mozambique	1,018	82	--	--
Paraguay	762	81	--	--
Philippines	14	3	23	12
Venezuela	50	24	3,787	192
Other	301	42	199	285
Total[1]	5,876	692	6,969	1,021

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

Source: Bureau of the Census.

Imports for consumption of crude barite decreased 64% from 2.06 million tons in 1985 to under 750,000 tons. The 1986 barite import figure was 68% below the record high of 2.32 million tons in 1982. The average unit c.i.f.[6] value of this material dropped 7% to $35.40 per ton, indicating that prices of foreign ores continued to decline in response to oversupply and lower ocean shipping rates. Domestic producers and consumers, faced with high rail rates 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. Average value per ton of material shipped from the principal source countries, in descending order, was Mexico, $38.60; India, $38.53; Thailand, $35.79; China, $34.99; Morocco, $34.91; Chile, $29.99; and Ireland, $17.60. 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. Imports of ground barite decreased about 70% to nearly 22,000 tons from about 71,000 tons in 1985; of this, Morocco supplied 57%. Prior to 1983, ground barite imports had been limited to premium-quality pharmaceutical grade, which was unavailable domestically. Sources were Belgium-Luxembourg, Canada, France, the Federal Republic of Germany, and the Netherlands, and prices averaged $300 to $600 per ton. The average c.i.f. value of Moroccan imports, $76.04, suggests that this barite is probably drilling-mud-grade material. The increase in imports of mud-grade barite noted during the last 5 years appears to be ending because of increasing competition from domestic grinders. Nevertheless, continued imports of ground drilling-mud-grade barite, in an already soft market situation, will probably result in the closure of additional grinding plants and adversely affect the few domestic mines that still supply ore for blending. The value of imports from China and Thailand, about $115 per ton, indicates that this ground material was probably destined for domestic filler and/or extender markets that are usually supplied by U.S. producers.

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 1986 (1985) was New Orleans, LA, 58% (58%); Houston, TX, 34% (38%); and Laredo, TX (Port of Brownsville, TX), 8% (4%). Small amounts were also received, in decreasing amounts, in the upper New York State, Georgia, Michigan, California, and New York City districts.

Imports of barium chemicals, excluding unwrought and/or waste and scrap barium metal, decreased 3% to about 32,000 tons valued at nearly $22 million. Barium carbonate, the predominant chemical imported, declined 9% to nearly 11,500 tons. The Federal Republic of Germany, China, Italy, Japan, Canada, and Brazil, in descending order, were the major suppliers. Barium metal imports were nearly 2 tons, valued at over $48,000.

The U.S. Department of Commerce and

the U.S. International Trade Commission (ITC) on November 13, 1986, in response to a request by a petitioner, Chemical Products Corp., Cartersville, GA, conducted an administrative review of the antidumping duty order on barium chloride from China. The review covered one exporter of this salt to the United States for the period October 1, 1984, through September 30, 1985. The review indicated the existence of dumping margins during the period. As a result of the review, Commerce has made a preliminary determination to assess autidumping duties equal to the calculated differences between U.S. price and foreign market value.[7]

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

Country	1985 Quantity (short tons)	1985 Value[1] (thousands)	1986 Quantity (short tons)	1986 Value[1] (thousands)
Crude barite:				
Chile	72,219	$2,008	29,248	$877
China	890,659	34,265	429,196	15,019
India	443,406	17,142	114,685	4,419
Indonesia	33,013	1,217	--	--
Ireland	19,499	519	12,731	224
Mexico	35,533	1,522	34,045	1,314
Morocco	319,207	11,897	81,963	2,862
Peru	28,991	1,058	--	--
Switzerland	80,919	3,410	--	--
Thailand	115,316	4,374	39,956	1,430
Other	17,162	803	3,163	225
Total[2]	2,055,924	78,216	744,986	26,369
Ground barite:				
Belgium-Luxembourg	20	6	--	--
Canada	3,539	499	5,019	860
China	47,779	2,543	273	32
France	20	5	102	30
Germany, Federal Republic of	353	106	436	186
Mexico	--	--	237	4
Morocco	17,107	1,254	12,457	947
Netherlands	146	46	194	70
Thailand	2,050	234	3,126	358
Other	10	4	1	2
Total	71,024	4,697	21,845	2,489

[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 Value (thousands)	Barium chloride Quantity (short tons)	Barium chloride Value (thousands)	Barium hydroxide Quantity (short tons)	Barium hydroxide Value (thousands)
1982	NA	NA	8,135	$5,580	2,930	$878	3,570	$2,758
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

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)
1982	682	$263	7,787	$3,055	753	$629
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

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)
1982	292	$482	41	$44
1983	1	4	49	12
1984	41	24	185	129
1985	1	6	141	68
1986	2	8	145	70

[1]Barium carbonate.

Source: Bureau of the Census.

WORLD REVIEW

Estimated world production of barite decreased 18% to 5.4 million tons. The United States produced 5% of the world total and imported 14% of the world output.

Austria.—Mining and processing test work was under way to rehabilitate the old Brixlegg copper and barite property in the State of Tyrol, which was operated until the late fifties.[8] The new approach will selectively mine both the copper-barite and pure barite mineralizations and treat the latter with a dry separation process. Plans call for about 10,000 tons per year of barite concentrates destined for local and neighboring markets.

Cameroon.—The mining and grinding complex, a joint venture of Milchem Inc., Houston, TX, and the state-owned Société Anonyme de Broyage de Minerai, was operated at an annual rate of 50,000 tons, largely for export to Nigeria and the nearby offshore drilling industry.[9]

India.—The Commerce Ministry, concerned about declining barite exports, in part brought about by lower cost competitive Chinese material, revised its minimum bulk export prices (MEP's) for shipments from Madras Port.[10] The MEP's for the different grades now range between $22 and $110 per metric ton, f.o.b. Barite lumps were fixed at $22 per metric ton, white barite at $88, snow-white barite (93% to 95%) at $100, and super snow-white barite (above 95%) at $110. In addition, the order stipulated a surcharge of $8 above the floor price when the material is exported in pellet form.

Ireland.—Magcobar, a division of Dresser, Houston, TX, produced about 240,000 tons of barite from its Silvermines deposit, but production was halted at the Clonakilty, County Cork, vein deposit, which was for sale.[11] Smaller Irish-based companies were also actively exploring for new commercial sources of barite throughout the country.

Italy.—The world's largest barium carbonate producer, Kali-Chemie AG, Hanover, Federal Republic of Germany, expanded the production facilities of its subsidiary, Società Bario e Derivati S.p.A. (Sabed) of Massa, for the production of high-purity barium carbonate.[12] The high-purity carbonate is targeted largely for optional and special glasses and for the synthesis of barium titanates for electroceramics magnetoceramics.

Morocco.—Compagnie Marocaine des Barytes (Comabar), the country's major barite producer, was determining the feasibility of constructing a drilling-mud-grade barite grinding plant on the Atlantic coast at Safi. The proposed 28,000-ton-per-year grinding plant for 4.2-specific-gravity material was due to start production at midyear 1987. The entire production was scheduled for the state-owned oil company Office Nationale de Recherches et de l'Exploitation des Pétroles' (ONAREP) modest offshore and onshore drilling programs and for customers in West Africa. Grinding plants in Morocco are rare since most customers prefer to grind ore to their own standards. In addition, S.A. Cherifienne d'Études Minières (SACEM) was developing a barite-galena-copper oxides property at its Taza Mine in the north of the country. Studies were under way into the separation and classification of the ore from both open pit and underground mining systems. A 55,000-ton-per-year barite plant was set to come on-stream late in 1986 or early in 1987. Plans call for an initial life of 10 to 20 years' production of drilling-grade material with the possibility of extra sales from byproduct galena and copper oxides.[13]

Pakistan.—Bolan Mining Enterprises

Ltd., a joint venture of the Baluchistan Government and Pakistan Petroleum Ltd., was proceeding with plans for a new barite grinding mill.[14] The joint venture invited tenders from mill manufacturers for a roller grinding mill with a 10- to 15-ton-per-hour capacity.

Thailand.—Barite deposits with nearly 20 million tons of reserves of 4.25-specific-gravity material are reportedly found in three main regions: north, northeast, and south.[15] Chiang Mai and Phrae are the major producing Provinces in the north; Loei dominates production in the northeast, with exceptionally high-grade (90%) materials in some places. Nakhon Si Thammarat, Trang, and Surat Thani are the main areas for barite in the south.

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

(Thousand short tons)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Afghanistan[e] [3]	[4]2	2	2	2	2
Algeria	112	[e]120	97	66	66
Argentina	40	67	49	[e]55	55
Australia	31	13	22	[e]22	23
Belgium[e]	44	44	43	44	44
Bolivia	1	1	1	1	([5])
Brazil	155	140	158	124	132
Burma[6]	18	11	11	9	9
Canada	31	50	52	78	41
Chile	322	126	24	60	[4]59
China[e]	990	1,100	1,100	1,100	1,100
Colombia	4	4	4	6	6
Czechoslovakia[e]	67	67	66	66	66
Egypt	3	4	6	5	5
Finland	--	4	10	[e]10	10
France	158	168	163	[e]165	160
German Democratic Republic[e]	39	39	39	37	37
Germany, Federal Republic of	183	181	184	189	220
Greece[7]	43	33	3	4	4
Guatemala[e]	[4]2	([5])	([5])	[r]1	1
India	359	356	492	639	386
Iran[e]	88	94	100	100	100
Ireland	293	220	243	236	231
Italy	198	153	118	141	[4]126
Japan	66	77	73	85	[4]59
Kenya	--	([5])	([5])	[e]([5])	([5])
Korea, Republic of	--	1	3	3	3
Malaysia	28	24	26	26	25
Mexico	401	394	470	516	413
Morocco	565	318	619	551	[4]209
Pakistan	24	29	30	33	50
Peru	413	122	51	24	33
Philippines	10	1	1	--	--
Poland	100	89	89	[e]88	88
Portugal[e]	1	[4]1	([5])	([5])	([5])
Romania[e]	86	86	80	80	80
South Africa, Republic of	4	7	5	5	[4]10
Spain	55	58	76	74	74
Thailand	365	207	193	255	220
Tunisia	34	22	13	[e]22	22
Turkey	127	87	218	183	193
U.S.S.R.[e]	570	570	580	595	595
United Kingdom	89	40	69	118	110
United States[8]	1,845	754	775	739	[4]297
Yugoslavia	35	39	[e]40	[e]40	40
Zimbabwe	1	1	1	([5])	([5])
Total	8,002	[r]5,924	6,399	6,597	5,404

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through June 16, 1987.
[2]In addition to the countries listed, Bulgaria also produces barite, but available information was inadequate to make reliable estimates of output levels.
[3]Year beginning Mar. 21 of that stated.
[4]Reported figure.
[5]Less than 1/2 unit.
[6]Data are for fiscal years beginning Apr. 1 of that stated.
[7]Barite concentrates.
[8]Sold or used by producers.

Tunisia.—The Government was planning a major lithopone venture to revitalize its depressed barite industry, hard hit by the downturn in the oil-well-drilling markets.[16] Plans call for redirecting barite production to this market via the Sfax-based Société Métallurgique de Tunisienne (SMT). The proposed 25,000-ton-per-year lithopone plant, its output targeted almost exclusively for domestic paint consumption, was to come on-stream in 1988 and be operated under the auspices of Société Tuniso-Algerienne de Lithopone (Sotali). Both Société Minière de Spath Fluor et Barytine (Fluobar) and Société Tunisienne d'Expansion Minière (SOTEMI) were expected to provide the barite for the lithopone venture.

Turkey.—A new shaft was being sunk closer to the ore by Brait Maden Turk AS (BMT) at its Sikeroba high-quality white barite mine, used chiefly for filler and chemical production. BMT was also relocating the milling equipment from the recently purchased Matosan's Osmanli plant, about 60 miles southeast of Istanbul, to its grinding operation at Bahçe about 75 miles from Adana in the south of the country. The new equipment will add 175,000 tons per year of capacity to the Bahçe operation. Relocation was scheduled for completion by yearend 1986. The new capacity is not required immediately but is aimed more at future development.[17]

United Kingdom.—Strontian Minerals Ltd. diversified its barite product line into the filler-grade area.[18] The company's existing plant is now capable of producing a range of white filler-grade barite products down to minus 10 micrometers. Ashover Consolidated Mining Ltd. began shipping oil-well-drilling-grade barite on a daily basis from its Eaglesham operation in Renfrewshire, Scotland.[19] Forward commitments covering the next 2 years were cited for the over-60-ton-per-day underground and jigging operation. Recent exploration discovered an area of white barite that reportedly can either be micronized for filler use or marketed to the barium chemical producers.

Yugoslavia.—The Government's proposed new 150,000-ton-per-year barite mine and plant complex at Krupanjn was awaiting financial arrangements.[20] The development program includes a credit for lead, zinc, and silver values.

TECHNOLOGY

The Bureau of Mines investigated the availability of barite from 35 U.S. and 41 non-U.S. mines and deposits in 17 market economy countries.[21] The technical appraisal assessed the availability of mud-grade barite and concentrates consumed by the chemical and filler industries. The demonstrated reserves defined in this work totaled 130 million tons of barite (contained $BaSO_4$) yielding a potential of 115 million tons of recoverable concentrates. The publication contains operation summaries for the domestic and foreign mines surveyed, along with a detailed engineering and economic analysis.

The geology, mining methods, and production flowsheet for three barite-fluorspar mines in the Federal Republic of Germany were detailed.[22] The operations' main features were highlighted, along with the newly installed modern trackless mining and hauling schemes.

Indepth reviews were published on the industrial minerals of Italy,[23] Morocco,[24] Thailand,[25] Tunisia,[26] and Turkey[27] that included detailed sections on barite, local geology, mineralogy, mining and milling flowsheets, and indigenous mining methods. The Italian and Thai reports stressed the individual mining and grinding operations, while the Moroccan and Tunisian studies concentrated on the countries' overall, present and future, mining plans for barite. The Turkish work included a unique, detailed, and candid profile of a major domestic barite producer. The profile discussed the company's mining, grinding, and quality control problems along with future plans and market strategies.

Another similar study reviewed the uses of barite by the well-drilling industry and outlined the history of barite mining in Nova Scotia, progressing to present-day exploration, development, and production activities.[28] The work included a section technically evaluating the market potential for the Province's barites by comparing items with drilling-mud-, chemical-, filler-, and pharmaceutical-grade specifications.

The quality of mineral additives in drilling fluids, such as barite, was laboriously correlated with catastrophic and expensive down-hole drilling problems and failures.[29] The investigation revealed that the presence of certain caustic soluble carbonate minerals associated with barite can cause serious rheological and filtration (filter cake) problems in freshwater and seawater bentonitic muds. Another study on standardization of minerals for drilling fluids carefully formulated special muds to perform the following essential functions: (1) lift the cuttings to the surface, (2) control well pressure, (3) seal the formation with a filter cake to isolate formation fluids from well bore fluids, and (4) protect and not react with the formation to excessively change the mechanical properties of the rocks being drilled.[30] The state-of-the-art in oil well drilling was technically explored in another related effort.[31] The work, stressing the Continental Shelf and onshore wells, contains a glossary of technical drilling terms, specifications, and flowsheets for typical oil- and water-based mud systems. Tables depicting the principal functions of selected minerals and chemicals were also featured.

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[24]Work cited in footnote 13.

[25]Work cited in footnote 15.

[26]Work cited in footnote 16.

[27]Work cited in footnote 17.

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Bauxite and Alumina

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

Domestic bauxite mines operated at reduced rates during the year with output falling 24% from 1985 levels. Demand for calcined, refractory, and abrasive grades remained depressed. Because of the availability of foreign oil at relatively low cost, the petroleum industry also reduced the use of proppants used to enhance domestic oil and gas recovery. Although the U.S. rated capacity for alumina production increased slightly, actual output declined for the second year. World production of bauxite and alumina increased slightly over the 1985 levels. The U.S. Geological Survey published a new comprehensive reference on world bauxite deposits, updating its 1967 report.[3]

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)

	1982	1983	1984	1985	1986
United States:					
Production: Crude ore (dry equivalent)	732	679	856	674	510
Value	$12,334	$11,309	$15,643	$12,855	$10,366
Exports (as shipped)	49	74	82	56	69
Imports for consumption[1]	10,122	7,601	r9,435	r7,158	6,456
Consumption (dry equivalent)	9,217	9,100	10,519	8,206	6,901
World: Production	r79,335	r78,634	87,771	p85,310	e85,938

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

Legislation and Government Programs.—The National Defense Stockpile goals for all forms of bauxite were unchanged. The calcined refractory grade bauxite from China, purchased by the General Services Administration in two 1984 contracts, added 75,496 metric tons[4] to the stockpile inventory in March 1986, raising the total to 278,630 tons, or about 20% of the goal.

DOMESTIC PRODUCTION

Bauxite production continued a decline that began in 1985. Central Arkansas was the predominant source of bauxite during the year. The Aluminum Co. of America (Alcoa) at Bauxite, AR, mined ore for processing at its local Bayer alumina plant and also calcined bauxite for shipment to the abrasive and proppant industries. The American Cyanamid Co. mined and calcined bauxite near Bryant, AR, for the production of aluminum sulfate at the company's plants in Illinois and Michigan. Porocel Corp. at Berger, AR, purchased bauxite from a local supplier to produce activated bauxite for use by the petroleum industry. Bauxite mining in the southeastern States was discontinuous as the operators satisfied much of the demand by calcining stocks accumulated at their plants. Harbison-Walker Refractories Div. of Dresser Industries Inc. operated mines west of Eufaula, AL, to supply bauxite to its local calcining plant and bauxitic clay to the Standard Oil Proppants Co. plant at Eufaula. In Sumter County, GA, Mullite Co. of America calcined bauxite stocks at the Andersonville plant to produce various grades of refractory bauxite for the industry.

Improved plant efficiencies resulting from changes in bauxite feed and adjustments to the Bayer circuit led to increases in the rated annual plant capacities at Alcoa's Point Comfort, TX, and Kaiser Aluminum & Chemical Corp.'s Gramercy, LA, refineries, raising the total U.S. alumina capacity to 4.57 million tons per year. Despite this 3.6% increase over 1985 capacity, U.S. production was down 10%. Apparent capacity utilization in 1986 was about 68%. Smelter closures, tolling of foreign alumina, availability of lower cost alumina imports, and metal recycling were all contributing factors in the reduced demand for domestic alumina. Reynolds Metals Co. reported that its aluminum recycling efforts since the late 1960's saved nearly 5 million tons of bauxite.

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]
1984	1,054	856	15,643	1,332	1,227	35,719
1985	787	674	12,855	993	989	34,506
1986	617	510	10,366	771	733	33,078

[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
1985	[r]330	166	284
1986	250	128	196

[r]Revised.
[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)	1982	1983	1984	1985	1986
Less than 8	--	--	11	74	77
From 8 to 15	63	75	55	14	--
More than 15	37	25	34	12	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]				
1982	3,810	465	4,280	4,130
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
Shipments:[e]				
1982	3,730	420	4,150	4,020
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

[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	1984	1985	1986
Aluminum Co. of America:			
Bauxite, AR	340	340	340
Point Comfort, TX	1,400	1,600	1,735
Total	1,740	1,940	2,075
Kaiser Aluminum & Chemical Corp.:			
Baton Rouge, LA	955	--	--
Gramercy, LA	770	770	795
Total	1,725	770	795
Martin Marietta Aluminum Inc.: St. Croix, VI	635	--	--
Ormet Corp.: Burnside, LA	545	--	--
Reynolds Metals Co.: Corpus Christi, TX	1,700	1,700	1,700
Grand total	6,345	4,410	4,570

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

CONSUMPTION AND USES

Weak demand for alumina held consumption of crude and dried metallurgical grade bauxite to a level well below that of 1985. Consumption of calcined and activated bauxite also declined, and only the chemical industry reported increased consumption in 1986. Nonalumina uses accounted for about 13% of the bauxite consumed during the year. Low world oil prices drastically curtailed domestic oil and gas drilling and sharply reduced the market for proppants used to increase production from deep wells. Nearly 85% of the alumina produced in the United States was consumed by U.S. primary aluminum smelters. Industrial mineral uses such as abrasives, ceramics, chemicals, and refractories accounted for the remaining 500,000 tons (calcined equivalent). Despite recent news reports about alumina usage in advanced ceramics, extended-duty refractories, and ultrahard abrasives, this work is largely in the research and development stage and does not yet offer a significant market. The bulk of the specialty alumina was consumed as fillers, flame retardants, and in general chemical uses.

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

(Thousand metric tons, dry equivalent)

Industry	Domestic	Foreign	Total
1985:			
Alumina	664	6,555	7,219
Abrasive[1]	W	W	305
Chemical	[2]30	[2]244	219
Refractory	111	297	408
Other	W	W	55
Total[2 3]	868	7,338	8,206
1986:			
Alumina	[3]460	[3]5,779	5,980
Abrasive[1]	W	W	259
Chemical	[2]37	[2]253	231
Refractory	80	292	372
Other	W	W	59
Total[2 3]	577	6,324	6,901

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

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

(Thousand metric tons, dry equivalent)

Type	Domestic origin	Foreign origin	Total[1]
1985:			
Crude and dried	729	6,797	7,526
Calcined and activated	140	541	680
Total[1]	868	7,338	8,206
1986:			
Crude and dried	W	W	6,305
Calcined and activated	W	W	597
Total	577	6,324	6,901

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

Table 9.—Production and shipments of selected aluminum salts in the United States in 1985

Item	Number of producing plants	Production (thousand metric tons)	Total shipments including interplant transfers	
			Quantity (thousand metric tons)	Value (thousands)
Aluminum sulfate:				
Commercial and municipal (17% Al_2O_3)	81	1,150	1,014	$131,653
Iron-free (17% Al_2O_3)	20	93	91	12,229
Aluminum chloride:				
Liquid and crystal (32° Be)	3	6	W	W
Anhydrous (100% $AlCl_3$)	4	W	W	W
Aluminum fluoride, technical	4	W	W	W
Aluminum hydroxide, trihydrate (100% $Al_2O_3 \cdot 3H_2O$)	7	530	530	147,171
Other inorganic aluminum compounds[1]	NA	NA	NA	69,943

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 report Form MA-28A, "Annual Report on Shipments and Production of Inorganic Chemicals."

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

(Thousand metric tons, dry equivalent)

Sector	1985[r]	1986
Producers and processors	220	152
Consumers	3,423	3,147
Government	18,357	18,472
Total	22,000	21,771

[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	1985	1986
Producers[e]	194	151
Primary aluminum plants	1,438	1,888
Total[e]	1,632	2,039

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

PRICES

Metal grade bauxite is rarely traded on world commodity markets, and sales of metal grade calcined alumina are equally limited. Neither the inter- and intra-company long-term sales contracts nor the government-to-company contracts are normally made public. A few trade journals quote spot sales and prices of specialty forms of bauxite and alumina.

The average value in 1986 of domestic crude bauxite shipments, f.o.b. mine or plant, was estimated by the Bureau of Mines to be $16.76 per ton. The average value of calcined domestic bauxite was estimated to be $156 per ton. Base prices quoted by principal sales agents for imported calcined refractory grade bauxite during 1986 ranged from $110 to $130 per ton, f.o.b. barge, Burnside, LA, for Chinese material with a typical content of 85% Al_2O_3. Guyanese refractory bauxite, minimum 86% Al_2O_3, ranged in price from $164 per ton, January to March; $168, April to June; and $165, July to December, f.o.b. railcar, Baltimore, MD, or f.o.b. barge, Burnside, LA, or Mobile, AL. Adjustments were applied to the base prices of calcined bauxite imports for various grain-size specifications, size of order, and fuel cost factors.

The estimated average value of shipments of domestic calcined alumina was $165 per ton. Trade data of the Bureau of the Census indicated an average value of $159 per ton, f.a.s. port of shipment, and $172 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	1985		1986	
	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	$14.72	$23.35	$15.43	$23.43
Brazil	30.27	39.53	24.58	27.53
Guinea	29.76	36.26	25.98	32.73
Guyana	42.40	54.31	34.02	45.45
Jamaica	30.81	35.09	30.93	34.99
Suriname	37.09	48.26	37.36	47.35
Weighted average	28.95	35.72	27.54	33.66

[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. 31, 1985	Dec. 30, 1986
Alumina, calcined	$418.88	$418.88
Alumina, hydrated, heavy	209.44	209.44
Alumina, activated, granular, works	905.00	905.00
Aluminum sulfate, commercial, ground (17% Al_2O_3)	259.04	225.97
Aluminum sulfate, iron-free, dry (17% Al_2O_3)	439.82	330.69

Source: Chemical Marketing Reporter.

FOREIGN TRADE

Dried bauxite exports totaled 40,608 tons and were shipped to Canada, 36,465 tons; Yugoslavia, 2,206 tons; Mexico, 1,534 tons; and other countries, 403 tons. Of the total 28,496 tons of calcined bauxite exports, Mexico received 23,649 tons; Canada, 4,638 tons; and other countries, 209 tons. Alumina exports increased 54% over 1985 shipments but were still 25% below 1984 shipments. Canada received 54%; Mexico, 19%; Ghana, 16%; and other countries, 11%.

Imports for consumption of crude and dried bauxite declined from those of 1985. Approximately 94% of the ore was supplied by Guinea, 52%; Jamaica, 33%; and Australia, 9%. With the exception of Jamaica, imports from all other sources were lower than those of 1985. Even at full capacity operation, the three remaining U.S. refineries that use imported bauxite could only consume an estimated 9.6 million tons of ore, or approximately 3 million tons more than was imported.

China and Guyana supplied nearly equal quantities of calcined refractory grade bauxite to the United States during the year. Increased deliveries of other grades (predominantly abrasive grade) of calcined bauxite from China, Guyana, and Suriname were responsible for an overall gain of 20% compared with those of 1985. Brown fused crude aluminum oxide was produced in Canada from imported calcined abrasive grade bauxite and was subsequently shipped to U.S. plants for the manufacture of abrasive and refractory end products.

Alumina imports for consumption were supplied by Australia, 85%; Suriname, 6%; Jamaica, 4%; and other countries, 5%. The imported tonnage was lower than that of 1985, and the unit value at port of shipment dropped from $192 to $159 per ton, reflecting the effects of world refinery overcapacity. Material classified as "aluminum oxide abrasives," "crude aluminum oxide," and "refined and ground aluminum oxide" have been excluded from tables 14 and 17 because these classifications include fused bauxite as well as Bayer process alumina.

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

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

Country	1984[r]		1985[r]		1986	
	Quantity	Value	Quantity	Value	Quantity	Value
Argentina	1	452	(²)	178	1	624
Belgium-Luxembourg	2	2,459	2	2,209	2	3,485
Brazil	(²)	186	1	770	--	593
Canada	73	30,037	126	30,561	263	47,491
France	1	1,418	(²)	747	--	1,259
Germany, Federal Republic of	3	5,351	3	4,958	3	4,379
Ghana	--	--	--	--	77	12,540
Japan	3	7,845	1	2,443	21	6,426
Mexico	111	32,423	104	28,451	91	23,627
Netherlands	11	3,457	1	2,478	1	2,365
Norway	369	81,181	45	7,417	11	645
Sweden	60	9,288	22	2,546	--	456
United Kingdom	3	3,599	3	4,803	2	2,441
Venezuela	4	2,712	1	1,138	1	1,573
Other	8	13,372	6	11,133	14	17,416
Total[3]	648	193,781	316	99,829	487	125,322

[r]Revised.
[1]Includes exports of aluminum hydroxide (calcined equivalent) as follows: 1984—13,100 tons; 1985—16,700 tons; and 1986—12,199 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	1984	1985	1986
Australia	560	829	579
Brazil	786	560	100
Guinea	3,718	3,752	3,356
Guyana	264	225	169
Jamaica[2]	[r]3,766	[r]1,540	2,119
Sierra Leone	--	56	--
Suriname	325	176	112
Other	15	20	22
Total[3]	[r]9,435	[r]7,158	6,456

[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]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: 1984—10,436,135 tons; 1985—7,257,840 tons; and 1986—6,854,083 tons.

Source: Bureau of the Census.

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

(Thousand metric tons and thousand dollars)

Country	1985				1986			
	Refractory grade		Other grade		Refractory grade		Other grade	
	Quantity	Value[1]	Quantity	Value[1]	Quantity	Value[1]	Quantity	Value[1]
Australia	--	--	23	3,705	--	--	14	1,110
China	169	13,131	41	2,077	112	8,958	48	3,881
Guyana	102	12,402	4	538	109	14,232	9	935
Suriname	([2])	8	([2])	11	--	--	11	558
Other	([2])	4	([2])	92	--	--	([2])	41
Total[3]	272	25,546	69	6,424	221	23,190	83	6,526

[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	1984[r]		1985[r]		1986	
	Quantity	Value[2]	Quantity	Value[2]	Quantity	Value[2]
Australia	3,055	593,688	3,014	564,212	3,051	458,965
Brazil	38	6,661	48	9,280	20	4,720
Canada	47	17,232	42	16,958	42	16,109
France	7	13,025	5	11,046	5	12,019
Germany, Federal Republic of	15	19,295	11	13,896	13	14,924
Jamaica	572	125,974	372	66,171	140	20,370
Japan	3	2,761	4	4,112	3	3,371
Suriname	392	73,371	326	42,949	216	24,780
Venezuela	116	15,158	--	--	55	9,712
Other	43	16,306	5	6,614	58	9,240
Total	4,288	[3]883,470	3,827	735,238	3,603	574,210

[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

Twenty-five countries mined bauxite in 1986. Production in Australia, Brazil, Guinea, and Jamaica accounted for most of the total. Australia, Jamaica, Suriname, and the United States produced about one-half of the world's alumina, while Hungary, Romania, and the U.S.S.R. produced about one-sixth of the world total. It was a relatively quiet year for the bauxite and alumina business with few significant openings or closings of mines or refineries. Some of the major aluminum companies were successful in negotiations with the Governments of Brazil, Guinea, Jamaica, and Suriname to lower levies on bauxite exports in an effort to offset the very low prices for alumina.

Australia.—Bauxite production of 32.4 million tons and alumina production of 9.4 million tons placed Australia as the number one producer and set new record-high levels for both commodities. Bauxite exports of about 5 million tons were little changed from those of 1985, but alumina exports rose to nearly 7.69 million tons, a record-high level. Comalco Ltd. added a new product to its Weipa, Queensland, operations by making the first shipment of paper-coating-grade kaolin to Japan in November. The kaolin was mined from deposits underlying the vast Weipa bauxite reserves and was processed in a newly constructed 100,000-ton-per-year plant at Weipa. Pricing of exports of bauxite and alumina by Swiss Aluminium Australia Ltd. (Austraswiss) from its Gove, Northern Territory, operation was questioned by the Government of Australia. The Government initiated a special investigation to determine whether Austraswiss had been making sales to its parent Swiss Aluminium Ltd. at preferentially low prices. Although the matter had not been resolved by yearend, a special study commissioned by Austraswiss found no irregularities in the company's pricing methods. In Western Australia, it was reported that The Broken Hill Pty. Co. Ltd. (BHP) was looking for a buyer for its 20% share of Worsley Alumina Pty. Ltd., owned jointly with Reynolds Alumina Australia Ltd. (40%), Shell Co. of Australia Ltd. (30%), and Kobe Alumina Associates (Australia) Pty. Ltd. (10%). Unlike the other partners in Worsley, BHP does not own a primary aluminum smelter, but it does have an alumina tolling contract with the Columbia Falls Aluminum Co. smelter in Kalispell, MT, in the United States, to process 140,000 tons per year of alumina into aluminum metal for a 3-year term.

Brazil.—Bauxite production in 1986 was little changed from that of 1985, placing Brazil as the world's fourth largest producer. Alumina output was estimated at the same level as that of 1985. The year began with a postponed decision by Nippon Amazon Aluminium Co. (NAAC) as to whether or not it would provide funds to continue construction of the 800,000-ton-per-year Alumina do Norte do Brasil S.A. (ALUNORTE) alumina plant adjacent to the operating Alumínio Brasileiro S.A. (ALBRÁS) primary aluminum smelter on the Amazon River near Belém. The $600 million ALUNORTE project, which was to have been financed 70% by Cia. Vale do Rio Doce and 30% by the NAAC Japanese consortium, was planned to provide alumina to the ALBRÁS smelter. At yearend, with 30% of the refinery completed, further construction was stalled by NAAC's indecision on additional funding. The base export price for bauxite mined at Trombetas by Mineração Rio do Norte S.A. was provisionally reduced to $25.68 per ton from $28.50 during the first quarter of 1986. The foreign North American and Western European partner-customers argued to the Government of Brazil that a price cut was essential to keep Trombetas ore competitive in the world market and placed the matter before the International Chamber of Commerce in Paris. Although the Government extended the term of lower price until November 17, the chamber had not made a decision by that date, and the price was returned to $28.50 per ton through yearend.

Greece.—The much-publicized agreement between the U.S.S.R. and Greece to build a 600,000-ton-per-year alumina plant near Delphi was once again confirmed as "final" in September 1986. It was reported by the Greek Ministry of National Economy that in this version of the contract, the U.S.S.R. would now take 580,000 tons of alumina annually, rather than share 200,000 tons of the annual output with Bulgaria. The $500 million project was to use Soviet design, technology, and equipment and was scheduled for completion in 1990. Greek and international environmentalists were protesting that the proposed plant, to be sited 7 miles from the ruins of the Temple of Apollo, would destroy this ancient limestone archaeological monument with acid rain created by the powerplant.

Guinea.—The world's second largest bauxite producer supplied about 52% of the metal grade ore imported by the United States. Production declined more than 7% from the 1985 level. Halco (Mining) Inc., a consortium of eight aluminum companies that controls 51% of Compagnie des Bauxites de Guinée (CBG), was reported to have concluded an agreement with the Government of Guinea (in control of 49% of CBG) to reduce the $13.13-per-ton levy on bauxite exports beginning in 1988.

Guyana.—Total bauxite production in 1986 was about 1.5 million tons. Although this was less than 2% of world production, approximately one-third of the output was calcined bauxite for abrasive and refractory markets. Alumina has not been produced in Guyana since 1982 when the refinery at Linden was closed owing to equipment breakdown and the need for replacement parts. Negotiations with Brazilian and East German firms for assistance in rehabilitating the plant had not been concluded by yearend. A barter agreement was announced in which the U.S.S.R. would receive 50,000 tons of bauxite per year in exchange for investments in Guyana's gold and diamond industries and for other considerations that were not described. In another countertrade deal, Guyana was to supply the Interamericana de Alúmina C.A. (Interalumina) refinery in Venezuela with 250,000 tons of metal grade bauxite per year for 2 years in exchange for petroleum products.

India.—Bauxite and alumina production each increased about 7% over 1985 output, ranking India among the top 10 world bauxite producers. The National Aluminium Co. Ltd. commissioned its 2.4-million-ton-per-year Panchpatmali bauxite mine in the Koraput District of Orissa State. The mine was part of the $1.85 billion integrated project that was to include an 800,000-ton-per-year alumina plant at Damanjodi, a 218,000-ton-per-year primary aluminum smelter, and a 600-megawatt power facility. Pechiney of France was providing technical assistance for the complex. India signed a contract with the U.S.S.R. for the development of a new bauxite mine in Andhra Pradesh. Annual production was to be 2.3 million tons when the mine opened in 1990. The Bharat Aluminium Co. Ltd. planned to produce gallium as a byproduct at its new alumina refinery, and the Madras Aluminium Co. reportedly set up a pilot operation at its Mettur alumina plant for the recovery of 25 to 30 kilograms of gallium per year using an amalgam metallurgy process.

Jamaica.—The world's third largest bauxite producer mined 6.96 million tons of ore in 1986 and exported 2.1 million tons to the United States and 821,000 tons to the U.S.S.R. The balance of the bauxite mined was consumed by the three operating refineries to produce about 1.59 million tons of alumina. Exports of alumina went to Canada, 41%; the Netherlands, 19%; the United Kingdom, 13%; the United States, 11%; Norway, 8%; and the balance to Asia, Ghana, and the U.S.S.R. Alcoa continued to operate its Clarendon refinery under contract to the Government while international alumina sales were reportedly handled by Switzerland-based Clarendon Ltd. In November, the Government reported discussions with Kaiser regarding the possible reopening of the Alumina Partners of Jamaica refinery, owned jointly by Kaiser and Reynolds Metals, which was closed in August 1985. At yearend, neither these discussions nor similar requests by the Government to Alcan Jamaica Co. to increase alumina production led to definite commitments.

Suriname.—Substantial losses in recent years by Billiton International Metals BV (a Royal Dutch/Shell Group subsidiary) and Alcoa's subsidiary, Suriname Aluminum Co. (Suralco), forced the two companies to seek relief from the Government's bauxite levy. In October, following lengthy negotiations, the Government of Suriname agreed to temporarily abolish the levy in exchange for a $150 million investment in the country's aluminum industry by Billiton and Suralco. Ironically, the agreement had just been signed when Suralco's mine at Moengo was shut down by antigovernment rebels in November. The alumina plant at Paranam, owned jointly by Suralco, 55%, and Billiton, 45%, was reported to require a blend of Moengo and local Onverdacht bauxites for efficient operation. Alcoa made immediate arrangements to purchase and ship substitute bauxite supplies from stockpiles in the Dominican Republic accumulated from Alcoa mining operations in earlier years.

Venezuela.—Development work continued on the state-owned 3-million-ton-per-year Los Pijiguaos bauxite mining project near the Orinoco River in Bolívar State. Revised estimates by C.V.G. Bauxita Venezolana C.A. (Bauxiven) placed the total cost of the project, including infrastructure, at about $462 million. Financing was to be provided by Government funds and a loan from the Inter-American Development Bank. Ore shipments were expected to begin moving down the Orinoco to the Interalumina refinery by the end of 1988. The proposed ore transport system was complex and costly. Bauxite was to move by truck from the mine to a 7.5-kilometer belt conveyor, to a 52-kilometer railroad, to a 6-kilometer belt conveyor, to a 650-kilometer barge line, and finally to a conveyer to the stockpile at the alumina plant in Ciudad Guayana. The Government announced plans to raise the annual alumina capacity of Interalumina from 1 million tons to 2 million tons by 1990 to supply the planned expansion of primary aluminum smelter capacity to 750,000 tons per year.

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

(Thousand metric tons)

Country	1982	1983	1984	1985[p]	1986[e]
Australia	23,625	24,372	31,537	31,839	[2]32,431
Brazil	6,289	7,199	6,433	6,251	6,224
China[e]	1,500	1,600	1,600	1,650	1,650
Dominican Republic[3]	141	--	--	--	--
France	1,662	1,663	1,607	1,530	[2]1,379
Germany, Federal Republic of	(4)	(4)	(4)	(4)	(4)
Ghana	64	70	115	[e]124	226
Greece	2,853	2,455	2,296	2,453	2,500
Guinea[5]	11,827	12,421	13,160	13,100	[2]12,130
Guyana[3]	1,783	1,087	1,333	[e]1,675	[2]1,466
Haiti[3 6]	377	--	--	--	--
Hungary	2,627	2,917	2,994	2,815	3,022
India	1,854	1,923	1,994	2,121	2,270
Indonesia	700	778	1,003	830	750
Italy	23	[r]13	--	--	--
Jamaica[3 7]	[r]8,378	7,683	8,937	5,975	[2]6,964
Malaysia	589	502	680	492	[2]566
Mozambique	--	--	--	5	10
Pakistan	4	3	3	2	3
Romania[e]	680	650	620	600	600
Sierra Leone	631	785	1,040	1,087	[2]1,242
Spain	7	5	7	2	7
Suriname	4,205	3,400	3,454	[e]3,000	[2]3,847
Turkey	508	306	132	214	220
U.S.S.R.[e 8]	4,600	4,600	4,600	4,600	4,600
United States[3]	732	679	856	674	[2]510
Yugoslavia	3,668	3,500	3,347	3,250	3,300
Zimbabwe	8	23	23	21	21
Total	[r]79,335	[r]78,634	87,771	84,310	85,938

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through July 7, 1987.
[2]Reported figure.
[3]Dry bauxite equivalent of crude ore.
[4]Less than 1/2 unit.
[5]Dry bauxite equivalent of ore processed by drying plant.
[6]Shipments.
[7]Bauxite processed for conversion to alumina in Jamaica plus kiln-dried ore prepared for export.
[8]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 production was as follows, in thousand metric tons: 1982—2,500; 1983—2,500; 1984—2,500; 1985—2,500; and 1986—2,500. Estimated alunite ore production was as follows, in thousand metric tons; 1982—610; 1983—615; 1984—615; 1985—615; and 1986—620. 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.

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

(Thousand metric tons)

Country	1982	1983	1984	1985[p]	1986[e]
Australia	6,631	7,231	8,781	8,792	[3]9,423
Brazil	606	787	891	[e]1,000	1,000
Canada	[e]1,127	1,116	1,126	[e]1,020	1,100
China[e]	800	800	800	825	825
Czechoslovakia	80	80	85	[e]85	85
France	960	853	898	734	[3]740
German Democratic Republic	46	42	43	47	45
Germany, Federal Republic of	1,510	1,580	1,701	1,657	1,300
Greece	404	410	482	380	400
Guinea	549	583	508	572	[3]556
Guyana	73	--	--	--	--
Hungary	710	836	811	798	[3]856
India[e]	500	450	560	560	600
Ireland	--	66	653	555	[3]686
Italy	698	466	607	555	[3]618
Jamaica	1,758	1,851	1,749	1,513	1,586
Japan	959	1,065	1,172	978	[3]607
Romania	514	512	552	548	550
Spain	673	737	742	725	725
Suriname	1,055	1,129	1,208	[e]1,000	[3]1,471
Turkey	84	57	75	113	120
U.S.S.R.[e]	3,000	3,200	3,300	3,500	3,700
United Kingdom	88	93	105	110	110
United States[e]	4,130	4,000	4,545	3,465	3,106
Venezuela	--	560	1,139	[e]1,085	1,100
Yugoslavia	1,017	1,010	[e]1,000	[e]1,000	1,000
Total	27,972	29,514	33,533	31,617	32,309

[e]Estimated. [p]Preliminary.
[1]Figures presented generally represent calcined alumina; exceptions are noted individually.
[2]Table includes data available through July 7, 1987.
[3]Reported figure.

Table 20.—Alumina: World annual capacity, by country

(Thousand metric tons, yearend)

Country	1984	1985	1986
Australia	9,750	9,750	9,750
Brazil	1,150	1,150	1,150
Canada	1,225	1,225	1,225
China	850	850	850
Czechoslovakia	100	100	100
France	[r]1,270	[r]1,040	1,040
German Democratic Republic	65	65	65
Germany, Federal Republic of	1,745	1,745	1,745
Greece	500	500	500
Guinea	700	700	700
Guyana	355	355	355
Hungary	895	895	920
India	675	675	675
Ireland	800	800	800
Italy	920	920	920
Jamaica	2,825	2,825	2,825
Japan	[r]2,380	[r]1,060	975
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	4,500	4,600
United Kingdom	140	140	120
United States	6,345	4,410	4,570
Venezuela	1,000	1,000	1,000
Yugoslavia	1,635	1,635	1,635
Total	[r]42,715	[r]39,230	39,410

[r]Revised.

TECHNOLOGY

A three-volume report by the Electric Power Research Institute (EPRI)[5] reviewed a hydrochloric (HCl) direct acid leaching process to recover alumina and other metal oxides from coal fly ash. The process was developed for EPRI by the Oak Ridge National Laboratory. Aluminum and iron oxides were considered to be readily recoverable and salable products. A 50-pound-per-hour pilot scale test of the process was proposed.

The Bureau of Mines reported research on modifications and refinements to improve the economics of the clay-HCl leaching process for production of alumina from domestic kaolinitic clay.[6] Specific areas addressed included reduction of acid concentration, shortened leaching time, elimination of the solvent extraction step for iron removal, and direct formation of basic aluminum chloride instead of the intermediate aluminum chloride hexahydrate. Although recovery of alumina was less than when longer leach times were used, kaolinitic clay is a relatively low-cost raw material, and acceptance of aluminum extractions of less than 90% may prove to be the most economically attractive approach.

Manganese dioxide (MnO_2) ore was reported by the BHP Central Research Laboratories, New South Wales, Australia, to be an effective oxidant for the removal of organics in a simulated Bayer liquor.[7] Humic acids and lignins in the bauxite tend to build up to equilibrium concentrations in the recycled Bayer liquor of an alumina plant, causing undesired alumina precipitation as fine particles, reduced mud settling rate, foaming, loss of caustic, and a colored alumina trihydrate product. Suggested process options included treating a Bayer liquor sidestream with the manganese ore, in which case the MnO_2 could be recovered, or mixing the manganese ore with the bauxite at the digestion stage to be discharged with the red mud waste.

A description of the dry mud stacking procedure employed at the Burntisland, Scotland, alumina plant was published.[8] The Burntisland refinery was built in 1917, and the annual capacity has been gradually expanded from 5,000 tons to 120,000 tons. The dry mud stacking procedure was adopted in 1941, and use of synthetic flocculants in the primary decanters was introduced in 1983. The operation was unique in that the mud waste was transported by truck 2 kilometers from the plant to the impoundment site, an abandoned oil shale mine pit. Mud transported from the plant contained about 60% solids. It was dumped from the trucks at controlled discharge points to promote optimum drying and, after a few years, reached an apparent stable equilibrium at about 70% solids.

A new company, D'Marge, was formed in July 1986 to process and market the dicalcium silicate waste accumulated during years of operating a "lime-soda sinter" or combination Bayer process alumina plant near Benton, AR.[9] The company plans to package and sell the highly absorbent "brown mud" waste as litter material for cat boxes or other absorbent uses. Aluminum companies and the Bureau of Mines have examined numerous plans to recycle the Bayer alumina plant red mud and brown mud wastes, 1 ton of which is produced for each ton of alumina. Although the mud has been used as a cement additive, a soil conditioner, a raw material for mineral fiber production, and as a clay substitute in brick and ceramic tile, none of these have developed into economically viable business operations. D'Marge estimates that 14 to 18 million tons of brown mud is available at the Hurricane Creek plant in Arkansas shut down by Reynolds Metals in 1983.

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[1]Physical scientist, Division of Nonferrous Metals.

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

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Beryllium

By Deborah A. Kramer[1]

Domestic production of beryllium raw materials increased in 1986, reversing a 2-year decline in production. The United States continued to be the leading world producer of beryllium ores and the leading producer and consumer of beryllium metal, alloys, and oxide. The second largest domestic beryllium-copper alloy producer reportedly sold the majority of its alloy business to a Japanese firm. However, interest in beryllium continued as resource exploration and development activities continued in Canada, Texas, and Utah.

Developments in beryllia ceramic technology for ion lasers and new methods of beryllium metal forming may increase the use of beryllium components in advanced technology applications. At the same time, components fabricated from other advanced materials, such as metal-matrix composites, have replaced beryllium in some aerospace applications.

Exports of beryllium declined significantly from the exceptionally high level of 1985. Beryl imports, primarily from Brazil, decreased slightly in quantity in 1986 from those of the previous year.

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)

	1982	1983	1984	1985	1986
United States:					
Beryllium-containing ores:					
Mine shipments	218	267	241	230	261
Imports for consumption, beryl[1]	106	88	53	66	60
Consumption, reported	215	280	360	316	318
Price, approximate, per short ton unit BeO, imported cobbed beryl at port of exportation	$121	$126	$88	$87	$88
Yearend stocks	214	281	226	199	195
World: Production[1]	360	398	394	[p]359	[e]395

[e]Estimated. [p]Preliminary.
[1]Based on a beryllium metal equivalent of 4% in beryl.

Legislation and Government Programs.—At yearend, Government stocks of beryllium materials in the National Defense Stockpile were the same as those of 1985: beryl, 17,987 short tons; beryllium-copper master alloy, 7,387 tons; and beryllium metal, 290 tons. On November 14, 1986, the President signed the Department of Defense Authorization Act, 1987 (Public Law 99-661), which stated that no action may be taken before October 1, 1987, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984. Therefore, stockpile goals for beryllium materials remained as follows: beryl, 18,000 tons; beryllium-copper master alloy, 7,900 tons; and beryllium metal, 400 tons.

DOMESTIC PRODUCTION

Shipments of beryllium ores increased moderately from those of 1985. Production of metallic beryllium and beryllium oxide ceramics was slightly higher, but output of beryllium-copper master alloy declined for the second year in a row.

Brush Wellman Inc. remained the only major domestic producer of beryllium ores, mining bertrandite from its Spor Mountain, UT, deposit. Small quantities of beryl were recovered by other firms in the United States, mainly as a byproduct of pegmatite minerals mining. Brush Wellman processed bertrandite and imported and domestic beryl into beryllium hydroxide at its Delta, UT, mill.

The Cabot Wrought Products Div. of Cabot Corp. produced beryllium-copper and other beryllium alloys at its Reading, PA, plant. In September, Cabot announced the sale of most of its beryllium-copper production and fabrication facilities to NGK Insulators Ltd. of Japan, who renamed the company NGK Metals Corp. The purchase reportedly included Cabot's Reading production plant; Athens, TN, foundry; service centers at Elkhart, IN, and Elmsford, NY; a rerolling plant in Couceron, France; and a sales and warehousing operation in Oberursel, Federal Republic of Germany. Cabot also reportedly sold its beryllium-copper alloy cold strip mill in Elkhart, IN, which was completed in 1984, to Inco Alloys International Ltd., a unit of Inco Ltd. In November 1986, NGK announced that it would spend $20 million to modernize the equipment and facilities it purchased from Cabot. These improvements reportedly were expected to double NGK's annual beryllium-copper alloy capacity.

In October, Cyprus Minerals Co. reportedly formed a joint venture with Cabot to develop Cabot's beryllium deposit, Sierra Blanca, near El Paso, TX. Under the joint venture, Cyprus would be the operator of Sierra Blanca and would have the option to purchase the deposit, as well as a beryllium property in Brazil. Initial core drilling indicated the Sierra Blanca deposit contained more than 25 million pounds of beryllium oxide in ore, at a grade greater than 2.0% beryllium oxide. In this deposit, the beryllium oxide is contained in the minerals bertrandite and behoite (beryllium hydroxide). Cyprus planned to complete feasibility studies and mine development within 2 years.

In August, Emery Energy Inc. announced the formation of a joint venture with Cominco American Inc., a wholly owned subsidiary of Cominco Ltd. of Canada, to mine and mill bertrandite on Emery's property in Juab County, UT. The joint venture would complete feasibility and permitting studies including drilling, metallurgical testing, and a market survey. Cominco would be the mine operator and hold a 51% stake in the venture. Drilling at the prospect reportedly began late in July to verify and expand reserves and provide material for metallurgical testing. A mill for producing high-purity beryllium oxide was planned. At the company's annual meeting in December, Emery officially changed its name to Beryllium International Corp.

CONSUMPTION AND USES

Consumption of beryllium in 1986 was slightly higher than that of 1985, partially because of a rebound in demand in the electrical industry.

Copper-based alloys, referred to as beryllium-copper, containing 0.5% to 2% beryllium, continued to be the most widely used beryllium products in commercial applications, because of their high resistance to wear, corrosion, and fatigue and high electrical and thermal conductivities. Beryllium-copper strip was used primarily to produce small parts for electronic and electrical applications by high-speed stamping techniques. These parts were used in the automotive, aerospace, radar, and telecommunications industries. Large-diameter beryllium-copper alloy rod and tube were used in equipment for oil and gas exploration, marine, and industrial applications. Beryllium-copper alloy wire was used in electronic and electrical applications, and beryllium-copper alloy bar and plate were used in systems such as robotic welding machines and materials handling devices. In addition, small quantities of beryllium were consumed in the manufacture of nickel- and aluminum-based alloys.

Beryllium metal was used principally in aerospace and defense applications, where its light weight, high thermal conductivity, and high stiffness-to-weight ratio were important. Beryllium oxide ceramic materials were used in the electronic, automotive, and defense industries because of their excellent electrical insulating properties and high mechanical strength and hardness.

PRICES AND SPECIFICATIONS

At the beginning of the year, the price range for beryl ore quoted in Metals Week was $85 to $100 per short ton unit (20 pounds) of contained beryllium oxide. The range was reduced to $78 to $85 at the beginning of May, and it remained in this range through yearend.

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	152
Beryllium-copper casting alloy	$5.40- 6.00
Beryllium-copper in rod, bar, wire	8.50
Beryllium-copper in strip	7.65
Beryllium-aluminum alloy, in 100,000-pound lots	248
Beryllium oxide powder	55.70

FOREIGN TRADE

Exports of beryllium alloys decreased in quantity to two-thirds of the level of 1985, although the average value increased. Canada, France, the Federal Republic of Germany, Spain, and the United Kingdom were the principal destinations, accounting for most of U.S. exports.

Beryl imports dropped slightly in quantity from those of 1985, but the average value increased from $867 per ton in 1985 to $877 per ton in 1986. In addition to ore imports, 42,954 pounds of wrought, unwrought, and waste and scrap beryllium, valued at $105,578, was imported into the United States, of which 60% was imported from the United Kingdom, and 23% came from the Dominican Republic. Imports of beryllium oxide or carbonate and other compounds, totaling 2,258 pounds and valued at $44,303, were received from Brazil, the Federal Republic of Germany, Hong Kong, and the United Kingdom. Beryllium-copper master alloy imports of 24,160 pounds, valued at $114,174, were received from Canada, Hong Kong, and the United Kingdom.

Table 2.—U.S. exports of beryllium alloys, wrought or unwrought, and waste and scrap,[1] by country

Country	1985		1986	
	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)
Belgium-Luxembourg	1,256	$126	560	$56
Canada	2,233	336	6,471	224
Finland	35	5	53	5
France	4,632	802	7,817	1,264
Germany, Federal Republic of	17,685	1,674	8,527	2,066
Hong Kong	3,067	24	--	--
India	440	37	--	--
Ireland	--	--	113	3
Israel	3	1	53	28
Italy	382	12	24	3
Jamaica	--	--	164	2
Japan	2,279	489	3,530	477
Korea, Republic of	3	1	2,253	22
Malaysia	2,000	12	--	--
Mexico	643	11	126	4
Netherlands	271	65	2,540	320
Pakistan	--	--	182	2
South Africa, Republic of	200	4	--	--
Spain	49,010	280	30,038	90
Sweden	17,450	73	--	--
Switzerland	1,642	209	753	105

See footnote at end of table.

Table 2.—U.S. exports of beryllium alloys, wrought or unwrought, and waste and scrap,[1] by country —Continued

Country	1985 Quantity (pounds)	1985 Value (thousands)	1986 Quantity (pounds)	1986 Value (thousands)
Taiwan	4,405	$51	4,400	$21
United Kingdom	11,785	2,158	11,363	2,697
Venezuela	--	--	587	4
Other	7	5	2	1
Total	119,428	6,375	79,556	7,394

[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. import duties for beryllium

Item	TSUS No.	Most favored nation (MFN) Jan. 1, 1986	Most favored nation (MFN) Jan. 1, 1987	Non-MFN Jan. 1, 1986
Ore and concentrate	601.09	Free	Free	Free.
Unwrought beryllium waste and scrap.	628.05	8.5% ad valorem	8.5% ad valorem	25% ad valorem.
Beryllium, wrought	628.10	9% ad valorem	9% ad valorem	45% ad valorem.
Beryllium-copper master alloy	612.20	6.6% ad valorem	6% ad valorem	28% ad valorem.
Beryllium oxide or carbonate	417.90	3.7% ad valorem	3.7% ad valorem	25% ad valorem.
Other beryllium compounds	417.92	3.9% ad valorem	do	Do.

Table 4.—U.S. imports for consumption of beryl, by country

Country	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)
Argentina	113	$107	20	$18
Brazil	1,262	1,077	759	646
China	102	96	502	497
France	--	--	153	112
Macao	--	--	6	4
Madagascar	11	13	13	8
Mozambique	--	--	18	12
Rwanda	33	23	--	--
South Africa, Republic of	39	38	39	27
Switzerland	66	59	--	--
Zimbabwe	20	14	--	--
Total	1,646	1,427	1,510	1,324

Source: Bureau of the Census.

WORLD REVIEW

The United States continued to be the world's largest mine producer of beryllium minerals, primarily in the form of bertrandite. World beryl production, principally from Brazil and the U.S.S.R., was slightly higher than that of 1985. China was thought to be a substantial beryl producer, but production data were not available.

Hecla Mining of Canada Ltd., a subsidiary of Hecla Mining Co., reportedly signed a joint venture agreement with Highwood Resources Ltd. to develop Highwood's Thor Lake, Northwest Territories, beryllium-rare earths property. Within 18 months, Hecla was expected to complete technical and marketing feasibility studies, and at that point, the company would acquire 50% interest in the property by repaying Highwood's prior expenditures and financing construction of a mine and downstream facilities. If feasibility studies prove positive, production of beryllium oxide was expected to begin in 1988.

Table 5.—Beryl: World production, by country[1]

(Short tons)

Country	1982	1983	1984	1985[p]	1986[e]
Argentina	7	26	28	[e]17	35
Brazil	1,251	1,039	1,551	967	1,050
Madagascar[2]	75	([3])	51	[e]55	55
Mozambique	9	7	8	[e]7	7
Portugal	13	3	11	[e]11	13
Rwanda	76	35	49	30	30
South Africa, Republic of	64	23	1	6	6
U.S.S.R.[e]	2,000	2,100	2,100	2,100	2,100
United States[4] (mine shipments)	5,451	6,665	6,030	5,738	[5]6,533
Zimbabwe	57	52	21	42	45
Total	9,003	9,950	9,850	8,973	9,874

[e]Estimated. [p]Preliminary.
[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. 14, 1987.
[2]Includes ornamental and industrial products.
[3]Less than 1/2 unit.
[4]Includes bertrandite ore, calculated as equivalent to beryl containing 11% BeO.
[5]Reported figure.

TECHNOLOGY

Nuclear Metals Inc. reportedly developed methods for producing beryllium tubing, which was expected to compete with graphite composite parts in aerospace applications. The new seamless beryllium extrusions reportedly can be used for structural components in communications and military satellites.

Brush Wellman announced the investment of $4.9 million to expand its facility in Elmore, OH, for near-net-shape forming from beryllium powders. The expansion reportedly includes equipment for cold die isostatic pressing and vacuum sintering, which will complement the hot isostatic pressing (HIP) system that was installed late in 1985. The expanded processing facility is scheduled to become operational early in 1989. Conventional beryllium parts production requires that the part be machined to net shape from blocks cut from billets made by vacuum hot pressing of powders. Beryllium parts formed to near net shape reportedly will require minimal machining, thus making the beryllium parts more cost competitive with other materials. The use of HIP also may result in increased part strength compared with beryllium parts produced by conventional processes.

Advances in commercial ion-laser technology included developments in tube designs to improve properties. A beryllia core encapsulated in a glass tube was developed to compete with metal-ceramic tubes in these lasers. Advantages of the beryllia-glass tube system include higher efficiency and lower tube current. Ion lasers are used in a wide variety of applications, such as light shows, videodisk mastering, and medical diagnostics.[2]

Research personnel at Corning Glass Works reportedly produced clear bulk beryllium fluoride glass samples by a direct vapor deposition process that could be suitable for telecommunications systems. An aluminum-doped beryllium fluoride glass would be used to produce the fiber core, and beryllium fluoride glass would be used to fabricate the cladding. These halide glasses have the potential to offer optical performance superior to that of doped silica, the traditional optical fiber material, and were developed with support from the U.S. Navy as a part of its ultra-low-loss fiber program.[3]

As a part of its assessment of worldwide availability of selected minerals, the Bureau of Mines published an investigation of worldwide beryllium resources, production methods, and costs. Total domestic beryllium-bearing resources in market economy countries were estimated to be 130 million tons of ore, containing over 36,000 tons of beryllium metal. These resources are expected to be sufficient to meet domestic needs and those of other market economy countries well into the 21st century.[4]

The U.S. Air Force reportedly will substitute carbon brakes for beryllium brakes on the C-5B aircraft. Carbon brakes would save 400 pounds in each aircraft, reduce braking time by 7 seconds and braking distance by 885 feet, and require 37% less overhaul time than beryllium brakes. Additionally, carbon and beryllium brakes can be used on the same aircraft.

ARCO Chemical Co. announced that it will supply a missile guidance system instrument cover of silicon carbide-reinforced aluminum metal-matrix-composite material to a U.S. defense contractor. This represents the first commercial application of such a material in a precision system and reportedly will replace beryllium in this application. The metal-matrix-composite covers reportedly cost significantly less and have better dimensional stability than beryllium covers.[5]

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[1]Physical scientist, Division of Nonferrous Metals.

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Bismuth

By James F. Carlin, Jr., and Robert D. Brown, 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 domestic primary production. Consumption continued to be mostly in the Northern and Eastern United States. The aluminum, chemical, cosmetic, pharmaceutical, and steel industries were major users. Domestic production declined as feedstocks rich in bismuth became harder to obtain for the single domestic refinery. Domestic consumption rose to the highest level in recent years, reflecting the general economic improvement, especially in capital goods markets. Prices declined throughout the year because of a continuation of the world excess supply that has existed for several years.

The potential for the use of bismuth in advanced materials applications was increased through research on electronic devices, free-machining alloys, and pigments.

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. Production data are not published to avoid disclosing company proprietary data.

Legislation and Government Programs.—Government stocks remained at 2,081,298 pounds. The National Defense Stockpile goal remained at 2,200,000 pounds.

On November 14, 1986, the President signed the Department of Defense Authorization Act, 1987 (Public Law 99-661), which stated that no action could be taken before October 1, 1987, to make any change in a stockpile goal in effect on October 1, 1984, that results in a reduction in the quantity or quality of any strategic and critical material to be acquired for the National Defense Stockpile.

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)

	1982	1983	1984	1985	1986
United States:					
Consumption	1,876	2,285	2,648	r2,644	2,919
Exports[1]	53	306	312	269	93
Imports, general	2,026	1,972	1,948	1,999	2,490
Price, average, domestic dealer, per pound	$1.61	$1.72	$4.27	$5.18	$3.25
Stocks, Dec. 31: Consumer	542	577	480	507	763
World: Mine production[2]	r9,058	r8,777	8,256	p10,498	e8,965

[e]Estimated. [p]Preliminary. [r]Revised.
[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 1986. Small quantities of secondary bismuth were produced by several firms from bismuth scrap materials.

CONSUMPTION AND USES

Domestic consumption rose more than 10% to 2.9 million pounds, the largest quantity since 1973, reflecting a continuation of the general economic improvement and certain favorable demands in specific end-use markets. All major consumption categories contributed to the increase.

Table 2.—Bismuth metal consumed in the United States, by use

(Thousand pounds)

Use	1985	1986
Chemicals[1]	1,325	1,462
Fusible alloys	610	639
Metallurgical additives	668	772
Other alloys	21	28
Other[2]	[r]20	18
Total	[r]2,644	2,919

[r]Revised.
[1]Includes industrial and laboratory chemicals, cosmetics, and pharmaceuticals.
[2]Includes experimental.

PRICES

The range of prices for bismuth quoted by Metals Week at the beginning of the year was from $3.50 to $3.75 per pound and was reduced to $2.90 to $3.05 per pound by the end of June. By yearend, the price quotes decreased to a range of $2.65 to $2.80 per pound.

FOREIGN TRADE

Exports of bismuth declined substantially to the lower levels that prevailed in the early 1980's. Imports rose substantially and continued to be the major source of supply for domestic consumption.

Starting January 1, 1986, 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), 5.9% ad valorem for MFN and 45% ad valorem for non-MFN; and compounds (TSUS 418.00 and 423.80), 7.9% 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	1985 Quantity (pounds)	1985 Value (thousands)	1986 Quantity (pounds)	1986 Value (thousands)
Belgium-Luxembourg	41,850	$160	216	$1
Brazil	377	3	3,613	26
Canada	17,235	147	33,719	252
Chile	780	8	--	--
China	7,202	64	--	--
Egypt	--	--	2,211	15
Germany, Federal Republic of	--	--	730	7
Hong Kong	380	2	37	3
India	1,226	8	--	--
Ireland	32	16	98	1
Israel	957	6	--	--
Italy	245	3	--	--
Japan	7,532	51	4,804	29
Mexico	--	--	100	7
Netherlands	--	--	1,602	15
Peru	--	--	104	1
Singapore	1,385	5	2,600	11
South Africa, Republic of	247	10	--	--
Spain	88	1	--	--
Taiwan	529	12	3,206	16
Thailand	--	--	509	3
United Kingdom	187,433	100	39,357	28
Venezuela	1,171	7	--	--
Total	268,669	603	92,906	415

Source: Bureau of the Census.

Table 4.—U.S. general imports[1] of metallic bismuth, by country

Country	1985 Quantity (pounds)	1985 Value (thousands)	1986 Quantity (pounds)	1986 Value (thousands)
Belgium-Luxembourg	460,842	$2,388	847,465	$2,526
Canada	127,868	897	73,138	381
China	44,888	181	54,249	150
France	--	--	4,409	31
Germany, Federal Republic of	96,060	585	4,739	29
Hong Kong	7,725	38	11,229	34
Japan	99,430	496	219,634	581
Korea, Republic of	29,761	119	48,490	141
Mexico	678,155	2,928	800,049	1,955
Netherlands	--	--	12,126	39
Peru	173,306	910	235,849	387
United Kingdom	280,830	1,630	178,257	641
Total	1,998,865	10,172	2,489,634	6,895

[1]General imports and imports for consumption were the same in 1985 and 1986.

Source: Bureau of the Census.

WORLD REVIEW

World mine production of bismuth declined slightly. Australia remained the major producer of bismuth, although, reportedly, bismuth-rich residues in Australia have been stockpiled in recent years. In 1985, Bolivia restarted bismuth production at the Tasna Mine in the Quechisla District, but also has been reportedly stockpiling bismuth-rich residues because of weak prices. The worldwide excess supply of bismuth prevalent for several years continued to exist.

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 Perú 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]	1982	1983	1984	1985[p]	1986[e]
Australia (in concentrates)[e 3 4]	3,310	3,110	2,980	3,090	2,200
Bolivia (in concentrates)	11	13	7	351	180
Canada[5]	417	445	366	489	440
China (in ore)[e]	570	570	570	570	570
Japan (metal)	1,071	1,263	1,241	1,415	1,400
Korea, Republic of (metal)	209	220	278	298	220
Mexico[6]	1,336	1,202	955	2,039	1,980
Peru[6]	[r]1,676	[r]1,495	1,433	1,731	1,500
Romania (in ore)[e]	180	180	180	180	180
U.S.S.R. (metal)[e]	170	180	180	185	185
United States (metal)	W	W	W	W	W
Yugoslavia (metal)	108	99	66	150	110
Total	[r]9,058	[r]8,777	8,256	10,498	8,965

[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. 7, 1987.

[2]In addition to the countries listed, Brazil, Bulgaria, France, the German Democratic Republic, the Federal Republic of Germany, 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, bismuth-rich residues have reportedly been stockpiled owing to weak demand and low prices.

[4]Data are for fiscal years ending June 30 of that stated.

[5]Refined metal and bullion plus recoverable bismuth content of exported concentrate.

[6]Bismuth content of refined metal, bullion, and alloys produced indigenously plus recoverable bismuth content of ores and concentrates exported for processing.

TECHNOLOGY

Researchers at Japan's Research and Development Corp. formed a ferromagnetic glass by rapidly solidifying a mixture of zinc, bismuth, and iron compounds. The glass was expected to result in the development of new electronic applications because it allows passage of infrared rays while traditional magnetic materials are opaque at all wavelengths. The research emphasis was on developing thin films of the new glass, a necessary step for the production of optoelectronic devices such as optical switches.[2]

Industrial testing showed favorable productivity improvements for free-machining steel products that use bismuth additives rather than lead, sulfur, selenium, or tellurium additives.[3] Bismuth has several additional advantages over the other additives. It has been shown to be nontoxic by its broad usage for many years in the pharmaceutical and cosmetic industries. Adding bismuth provides the same or improved free-machining performance as the addition of lead, and its density is closer to that of iron than lead, making it easier to obtain a more uniform dispersion in the steel matrix during the alloying process. The addition of bismuth does not lower corrosion resistance of stainless steels as does sulfur.

Research in the Federal Republic of Germany demonstrated that bismuth vanadate-molybdate pigments have excellent fastness properties and produce a new class of inorganic paints.[4] One particular pigment is nontoxic and shows promise for use in the automobile paint industry.

[1]Physical scientists, Division of Nonferrous Metals.

[2]The Bulletin of the Bismuth Institute. No. 49, 1986, pp. 9-12.

[3]American Machinist. Steel Improves Screw Machining. Feb. 1986, p. 101.

[4]Weinand, H., and W. Ostertag. Bismutvanadat/Molybdat—ein neuartiges Gelbpigment (Bismuth Vanadate-Molybdate—A New Yellow Pigment). Farbe + Lack (Color and Varnish), v. 92, Sept. 1986, pp. 818-821.

Boron

By Phyllis A. Lyday[1]

U.S. production and sales of boron minerals and chemicals decreased during the year. Glass fiber insulation continued to be the largest use for borates, followed by textile-grade glass fibers, borosilicate glasses, and miscellaneous uses.

California was the only domestic source of boron minerals, mostly as sodium borate, but also as calcium borate and calcium-sodium borates. The United States continued to provide essentially all of its own supply while maintaining a strong position as a source 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. producers also collected data on domestic consumption 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)

	1982	1983	1984	1985	1986
United States:					
Sold or used by producers:					
Quantity:					
Gross weight[1]	1,234	1,303	1,367	1,269	1,251
Boron oxide (B_2O_3) content	607	637	667	636	629
Value	$384,597	$439,181	$456,687	$404,775	$426,086
Exports:					
Boric acid:					
Quantity[2]	35	38	45	49	42
Value	$19,082	$20,688	$24,402	$21,598	$23,562
Sodium borates:					
Quantity[3]	[4]227	[4]225	576	623	624
Value[e]	$59,000	$51,000	$134,000	$151,000	$161,000
Imports for consumption:[5]					
Boric acid:					
Quantity	2	4	4	10	6
Value	$1,903	$3,456	$3,449	$5,121	$3,824
Colemanite:					
Quantity	2	16	20	33	16
Value	$6,386	$8,309	$12,123	$24,620	$8,770
Ulexite:					
Quantity	14	11	47	31	42
Value	[e]$2,800	$3,116	$10,202	$11,120	$17,766
Consumption: Boron oxide (B_2O_3) content	266	341	375	360	338
World: Production	2,503	2,464	2,776	[p]3,383	[e]3,534

[e]Estimated. [p]Preliminary.
[1]Minerals and compounds sold or used by producers, including both actual mine production and marketable products.
[2]Includes domestic and imported orthoboric and anhydrous boric acid.
[3]1982-83, U.S. Exporters; 1984-86, The Journal of Commerce Port Import/Export Reporting Service.
[4]Refined.
[5]Boron oxide (B_2O_3) content. Data indicate conversion to B_2O_3 content.

Legislation and Government Programs.—The Environmental Protection Agency approved (EPA Reg. No. 44757-6-48740 and EPA Est. No. 48740-AZ-1) a sodium borate cellulosic insecticide that can be installed into new or existing homes. The product was effective in killing cockroaches, termites, ants, and other household pests that would come in contact with the material. When blown into walls, attics, and crawl spaces, the insecticide provided pest control properties that continued to work throughout the life of the structure.[2]

DOMESTIC PRODUCTION

Boron minerals, sold or used, decreased in quantity but increased in value during the year. The majority of the output continued to be from Kern County, CA, with the balance from San Bernardino and Inyo Counties, CA.

American Borate Co., a wholly owned subsidiary of Owens-Corning Fiberglas Corp., mined colemanite (a calcium borate) and probertite-ulexite (two similar calcium-sodium borates mined and sold as one) at its Billie Mine in Death Valley National Monument. Colemanite was ground and processed at the Amargosa, NV, plant. The processed colemanite was trucked to Dunn, CA, for blending, storing, and shipping by rail primarily to manufacturers of textile-grade glass fibers. On April 19, the mine ceased production. Concentration of stocks continued at the washing, flotation, and calcining plant. Production at the plant ceased on June 1. Probertite-ulexite ore was ground, screened, and blended to specification; stored; and shipped by rail from the Dunn facility. American Borate planned to continue to operate the Dunn facility as a custom grinding facility that will grind a variety of products to customer specifications. The reasons cited for the mine and plant closure were the strength of the U.S. dollar in world markets, which had the effect of increasing worldwide prices of boron minerals, and the increase in world supply. The length of the closure would depend upon future market conditions.

Kerr-McGee Chemical Corp. operated the Trona and Westend plants at Searles Lake, in San Bernardino County, to produce refined sodium borate compounds and boric acid from the mineral-rich brines. At the Trona plant, boric acid, pentahydrate borax, and anhydrous borax were produced. Byproducts included potassium compounds. The Westend plant continued production of boric acid and produced sodium borates by a carbonation process that also produced lime, soda ash, and sodium sulfate. Production capacity was 210 short tons per day of the combined borate products. Screening and grinding facilities were at both plants. A coal-fired electrical generating plant produced process steam and electricity. Surplus electricity was sold to the Southern California Edison Co. Shipments were by rail via a company-owned spur to the Southern Pacific Railroad at Searles Junction, CA. Borates were marketed by Kerr-McGee under the brand name Three Elephant and trade names Dehydrated Borax, Pyrobor, Refined Pentahydrate, and V-Bor. In addition, Kerr-McGee produced boron specialty chemicals 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 member of the RTZ Group of London, United Kingdom, continued to be the primary world supplier of sodium borates. U.S. Borax mined and processed crude and refined hydrated sodium borates, their 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 boric acid from U.S. Borax's extensive kernite ore reserves. The boric acid was produced to compete with imported colemanite used in glass manufacture. The company produced electricity from a gas-fired cogeneration plant that supplied 50% of the process steam requirements. Surplus electricity was sold to Southern California Edison.

Shipments from Boron were via the Santa Fe Railroad. The majority of material was shipped to U.S. Borax's storage, loading, and shipping facilities at Wilmington, CA. The Wilmington facility also produced some boron specialty chemicals and borated soap products. U.S. Borax marketed domestic borates under the Twenty Mule Team trade name.

U.S. Borax expanded from a supplier of boron compounds to a supplier of other raw materials to the glass and vitreous industries with purchases of Ottawa Silica Co. in 1986 and Pennsylvania Glass Sand Corp. in 1985.

Mountain States Mineral Enterprises Inc. completed solar ponds and began solution mining tests at its Fort Cady site in the Mojave Desert near Barstow, CA. Initial tests involved pumping a solution into the deposit and reversing the pump action to recover a product. The results of the tests were used to determine what future pumping rates would be achieved during actual mining. The tests were performed on one of two wells that were drilled as part of the studies conducted by Duval Corp., the initial developer of the deposit. The deposit contained 147 million tons of ore that average 12% colemanite, or approximately 8 million tons of boron oxide. The reserves were delineated by 33 core holes based on 800-foot centers; 27 of the cores contained borate minerals, and 22 cores contained ore-grade mineralization. The colemanite generally occurs as fine-grained crystals in beds, bands, and disseminations within the anhydrite-rich part of the section. Celestite occurred in the ore zones in concentrations of approximately 10%.

Because of the geology and low grade of the ore, solution mining would be the most economical method for recovering the deposit. Although solution mining of borates had prior patents, this would be the first recovery of borates on a large scale. The processing of the solution that would be recovered would use solar ponds to utilize the abundant energy of the Mojave Desert. A process for the cyclic solution mining of borate ores was patented.[3] The process used hydrochloric acid to leach boric acid and calcium chloride. Using solar energy to concentrate the leach solution would precipitate boric acid. The hydrochloric acid could be regenerated with sulfuric acid to produce calcium sulfate as a coproduct of the recycling process. The calcium sulfate coproduct could be used in the construction industry in the manufacture of wallboard, in cement to retard the setting of the concrete, and in agriculture to neutralize alkaline and saline soil, to improve the permeability of argillaceous materials, to provide sulfur, and in catalytic support for maximum fertilizer utilization.

CONSUMPTION AND USES

U.S. consumption of borates decreased. Glass fiber insulation and glass fiber primarily used as reinforcement for plastics continued to be the largest consuming industries.

The largest area of demand for borates, in glass fiber thermal insulation for new construction, increased. Cellulosic insulation, the seventh largest area of demand, decreased in demand, primarily because of the end of government programs for energy tax credits at yearend 1985. A study completed in 1985 by No-Tox Products Inc. reported 160 manufacturers of cellulosic insulation in the United States. In an update to the report, No-Tox expected the cellulose industry to experience a 25% decrease in the number of manufacturers and a 30% decrease in value and quantity sold during 1986. No-Tox changed from the marketing of chemically treated cellulose as a traditional insulator to its use because of pest control qualities.

The second major market for borates, manufacturing high-tensile-strength glass fiber materials for use in a range of products, showed a decrease in demand. The makers of the glass reinforcing agents were CertainTeed Corp., Owens-Corning, and PPG Industries Inc. Thermoset unsaturated polyester and epoxy resins that were reinforced with glass in the form of filament, chopped, or flake glass were used as high-performance composite materials. High-volume composites were replacing traditional metals in automobiles. Sheet molded polyesters were the primary material in flat panels, but polyureas were replacing polyurethanes in side panels. New fabricating processes made expensive reinforced resin systems competitive.

Thermoplastic composites were used in automobile roof side panels and springs typically manufactured from nylon or polyethylene resins reinforced with glass filaments. The reinforced plastics content of the Pontiac Fiero averaged 200 pounds per car. Ford Motor Co. predicted that the exterior of every U.S.-built car will contain about 300 pounds of composites by the year 2000. General Motors Corp. has been producing between 130,000 and 160,000 plastic body cars per year of Chevrolet Corvette and Pontiac Fiero models.[4]

General Motors planned all-plastic bodies for Camaro-Firebird F cars using a fiberglass reinforced compression molding process. Budd Corp., Goodyear Corp., and Premix Corp. received the major portion of the General Motors plan to produce 600,000 vehicles in the 1990 model year. Chrysler Corp.'s Liberty program planned exterior panel production to coordinate with the automobile production rate to lessen costly inventories and operating expenses.[5]

In addition, the U.S. Department of Defense planned to construct about $80 billion worth of helicopters and advanced fighter aircraft that included boron reinforcement composites and boron carbide sintered parts.[6]

Estimates in aerospace usage by the Advanced Systems Div. of Northrop Corp. for 1985, in thousand pounds, were as follows: Aircraft engines, 60 ($3.6 million); business aircraft, 120 ($0.7 million); commercial aircraft, 4,410 ($23.7 million); helicopters, 2,430 ($12.7 million); military aircraft, 650 ($4.5 million); and missiles and space, 130 ($0.8 million).[7]

Military uses of glass fiber included Owens-Corning's S-2 used in a turret demonstrator for the Bradley Fighting Vehicle and a prototype High-Mobility Multipurpose Wheeled Vehicle. M. C. Gill Corp. used fiberglass in flexible-laminated and rigid-laminated armor for lightweight civilian use. Reinforced fiberglass was also used by Executive Armoring Corp. to modify armored cars.[8]

Owens-Corning, a major producer of glass fiber, insulation, and other construction products, announced plans to sell the Aerospace and Strategic Materials Group purchased from Armco Inc. in 1985. The offering was part of a major restructuring to generate cash to be used to block a hostile takeover attempt by Wickes Companies.[9]

PPG Industries was a major supplier of continuous fiberglass yarn for fiberglass screening and fiberglass asphalt shingles. The fiberglass-reinforced shingles were first used in areas where brushfires are common because of their fire resistance. Because the shingles are attractive, economical, and easy to apply and maintain, they were used on 80% of all new roofs.[10]

Glass fiber containing boron was used as a facing on 20-gauge steel to deaden noise levels by 60 decibels.[11] Fiber-reinforced plastic linings on steel were easy to apply and inexpensive, and they provide excellent corrosion resistance. The linings had provided excellent corrosion protection in many applications where thermal cycling was significant. The lining also prevents corrosion in storage tanks for aliphatic organics, such as gasoline, where water accumulates on the bottom of the tank.[12]

Consumption of borates in borosilicate glasses remained the fourth major end use, although demand decreased. Boron was added to the glass batch to reduce the viscosity of the melt and prevent thermal stress in the product.

Boron compounds in cleaning and bleaching were also an important consumption sector. Boron compounds continued to find application in algicides, fertilizers, herbicides, insecticides, and the manufacture of biological growth control chemicals for use in water treatment. By 1970, boron deficiency had been identified as the most common micronutrient deficiency among crop plants in the United States. Boron compounds can be applied as a spray and incorporated in herbicides, other fertilizers, and irrigation water.[13]

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.

Allied-Signal Inc. planned to build the world's first commercial plant to make its rapid solidification amorphous metal ribbon Metglas, which is composed of boron, iron, and rare earths. Metglas is used in aerospace, electronic, and soldering applications, and utility transformers. The company planned a domestic site for the 600,000-ton-per-year plant. Investments in the product totaled almost $100 million during the past 15 years.[14]

Boron can be used to improve efficiency, reduce corrosion, and improve wear resistance through techniques such as rapid solidification and surface modification techniques. In the United States, 40 million distribution transformers lose 35 billion kilowatt hours annually. Replacement with amorphous core transformers that are magnetized easier would mean a savings of 23 billion kilowatt hours, or $1.2 billion annually. Approximately 1 million pole transformers are replaced every year, which translates into a demand of 100,000 tons per year of amorphous metal.[15]

Other uses included two boron alloys, rapid-solidified NI-44MO-1.7B, Alloy 3065, and NI-36-MO-9Fe-1.9B, Alloy 7025, that demonstrated corrosion rates comparable to Hastelloy Alloy B-2 when tested in hydrochloric acid. The plasma spray coatings have applications where corrosion is a problem, such as demonstrated during power generation. This new technology minimizes cost to end users.[16]

Boron implanted into steel improves resistance to corrosion by changes in the surface. Under proper conditions, an amorphous structure that is free of grain boundaries is impervious to pitting corrosion that initiates at grain-boundary sites. Ion implantation of boron has improved the wear resistance of certain types of steel, notably 316 stainless and high-speed steels.[17]

Demand increased for many important but small-percentage end uses of borates and boron containing chemical derivatives that comprised a diverse miscellaneous category. For example, Morton-Thiokol Inc. announced the expansion of its sodium borohydride production in Western Europe. Morton had doubled the capacity of the Elma, WA, plant in 1985. Sodium borohydride is a reducing agent in chemical production and purification. Sodium borohydride is also the beginning compound for making diborane, the intermediate chemical for producing pentaborane, decaborane, and other alkyl boranes. Diborane is used to produce high-energy fuels.

Chemists have developed a new way to control precisely the shape of molecules during their construction, a method particularly promising for the synthesis of insect attractants and antibiotics. The boron atom derived from borax was used as a connection point for molecular assembly. The orientation of the connection was guided by a molecular fragment derived from turpentine. The new method gives 99% control of the right versus left connection that was to be applied to the synthesis of high-purity sugars.[18]

Table 2.—U.S. consumption of boron minerals and compounds, by end use

(Short tons of boron oxide content)[1]

End use	1985	1986
Agriculture	15,003	14,821
Borosilicate glasses	34,629	30,761
Enamels, frits, glazes	12,295	11,755
Fire retardants:		
Cellulosic insulation	26,522	18,917
Other	298	417
Glass fiber insulation	103,490	118,162
Metallurgy	3,307	3,089
Miscellaneous uses	22,521	27,601
Nuclear applications	1,088	1,079
Soaps and detergents	24,548	24,498
Sold to distributors, end use unknown	44,147	37,268
Textile-grade glass fibers	71,785	49,632
Total	359,633	338,000

[1]Includes imports of 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	1985	1986
Agriculture	194	251
Borosilicate glasses	11,015	8,564
Enamels, frits, glazes	1,335	1,199
Fire retardants:		
Cellulosic insulation	4,770	3,882
Other	274	402
Insulation-grade glass fibers	144	134
Metallurgy	382	138
Miscellaneous uses	11,284	10,405
Nuclear applications	932	897
Soaps and detergents	424	539
Sold to distributors, end use unknown	16,181	16,358
Textile-grade glass fibers	18,360	25,242
Total	65,295	68,011

[1]Includes imports.

PRICES

Prices for anhydrous borax, boric acid, and colemanite remained at 1985 levels. Decahydrate and pentahydrate borax prices increased because of increased demand, primarily for exports to China.

Table 4.—Borate prices per short ton[1]

Product	Price, Dec. 31, 1986 (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]	247
Borax, technical, granular, decahydrate, 99.5%, bulk, carlots, works[2]	192
Borax, technical, granular, pentahydrate, 99.5%, bags, carlots, works[2]	265
Borax, technical, granular, pentahydrate, 99.5%, bulk, carlots, works[2]	220
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	400

[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. 230, No. 26, Dec. 29, 1986, p. 25.

FOREIGN TRADE

The International Trade Administration of the U.S. Department of Commerce published the Commodity Series of Market Share Reports for Boric Oxide and Boric Acid, No. 85-790104; Fluoride, Fluorosilicates, Fluoroborates, and Other Complex Fluorine Salts, No. 85-790128; and Borates and Perborates, No. 85-790145. Each report shows the dollar values for exports to the world, the United States, and 97 foreign country markets from 14 principal exporting countries of a single commodity category for the years 1980-83. The reports also show exports separately for the United States and eight other major suppliers of the commodity category, in descending order. The country of destination is shown, but in some instances, the values of exports from the United States and other suppliers to important entrepot countries, such as the Netherlands, were known to be overstated.

A large part of output from U.S. Borax was exported to Western Europe from company-owned storage and loading facilities at Wilmington, Los Angeles County, CA. Bulk shipments for both U.S. Borax and Kerr-McGee went to a terminal at Botlek, near Rotterdam, Netherlands, and were then shipped by rail to many European countries.[19]

Table 5.—U.S. exports of boric acid and sodium borate compounds, by country

Country	1985			1986		
	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	1,428	$826	8,326	1,230	$575	7,406
Belgium-Luxembourg	--	--	74	--	--	148
Brazil	8	5	3,387	12	10	2,545
Canada	4,826	2,560	[3]51,392	5,426	2,892	[3]55,205
Chile	--	--	138	--	--	111
China	20	12	11,353	--	--	--
Colombia	239	147	5,024	118	59	4,121
Costa Rica	--	--	438	1	3	375
Denmark	64	37	--	--	--	3
Dominican Republic	--	--	44	--	--	109
Ecuador	4	3	845	--	--	719
El Salvador	10	6	40	--	--	460
France	3	1	--	2,794	1,767	--

See footnotes at end of table.

Table 5.—U.S. exports of boric acid and sodium borate compounds, by country —Continued

Country	1985 Boric acid[1] Quantity (short tons)	1985 Boric acid[1] Value (thousands)	1985 Sodium borates[2] (short tons)	1986 Boric acid[1] Quantity (short tons)	1986 Boric acid[1] Value (thousands)	1986 Sodium borates[2] (short tons)
Germany, Federal Republic of	6	$13	--	--	--	661
Guatemala	--	--	62	--	--	65
Haiti	--	--	77	13	$5	133
Honduras	--	--	62	--	--	140
Hong Kong	209	122	2,323	277	161	2,974
India	--	--	11,590	--	--	17,423
Indonesia	144	73	5,126	179	97	4,051
Iran	21	12	--	--	--	--
Israel	25	15	309	60	34	413
Jamaica	25	3	--	--	--	--
Japan	21,701	12,796	61,073	22,266	12,611	55,242
Korea, Republic of	1,186	731	18,209	2,294	1,326	18,662
Madagascar	--	--	78	--	--	--
Malaysia	18	16	3,866	29	18	5,004
Mexico	3,815	1,868	[3]21,678	2,968	1,322	[3]17,076
Netherlands	--	--	360,264	494	287	355,003
New Zealand	2,113	972	3,250	797	403	2,132
Nicaragua	--	--	66	--	--	--
Pakistan	--	--	233	--	--	471
Panama	20	6	9	3	5	54
Papua New Guinea	84	42	193	131	60	253
Peru	6	4	34	11	10	61
Philippines	63	46	1,065	92	80	1,310
Saudi Arabia	--	--	465	8	5	268
Singapore	7	5	2,947	24	12	1,607
South Africa, Republic of	11	26	3,866	111	98	4,389
Spain	--	--	42,323	--	--	46,190
Sri Lanka	12	7	8	11	6	20
Sweden	--	--	--	21	12	--
Taiwan	1,664	936	--	2,195	1,241	14,977
Thailand	167	110	1,454	198	129	1,137
Trinidad and Tobago	11,200	5	78	--	--	3
United Kingdom	--	--	123	69	124	1,731
Uruguay	4	4	36	4	4	39
Venezuela	354	189	1,107	312	185	1,283
Zimbabwe	--	--	339	4	3	33
Other	--	--	--	25	16	30
Total[4]	49,457	21,598	623,375	42,178	23,562	624,057

[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	1985 Quantity (short tons)	1985 Value[1] (thousands)	1986 Quantity (short tons)	1986 Value[1] (thousands)
Brazil	--	--	16	$13
Canada	73	$56	25	29
China	--	--	1	1
France	219	196	218	261
Germany, Federal Republic of	51	63	68	109
Italy	1,873	1,039	2,342	1,371
Japan	--	--	([2])	2
New Zealand	44	25	--	--
Turkey	8,058	3,665	3,461	1,480
U.S.S.R	105	76	--	--
United Kingdom	([2])	([2])	9	558
Total[3]	10,423	5,121	6,141	3,824

[1]U.S. Customs declared values.
[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

Argentina.—Party Sasimagi planned the development of a chemical plant to process salts of the Salar del Rincón, Puna. Borates in the form of borax and ulexite occur in the salar-type deposits of Argentina. Production was planned for 1987.[20]

Chile.—A second major brine project in the Salar de Atacama in northern Chile was announced by Sociedad Minera Salar de Atacama Ltda. (Minsal Ltda.). It will be the first plant to produce boric acid from the salar. Production of 30,000 tons per year of boric acid, 500,000 tons per year of potassium chloride, and 250,000 tons per year of potassium sulfate was planned.[21] The Comisíon Chilena de Energía Nuclear was to allow the coproduction of 2,800 tons per year of lithium metal. The new company announced its ownership by AMAX Inc.'s subsidiary, AMAX Exploration Inc., 63.75%; Molíbdenos y Metales S.A., 11.25%; and the Chilean state development agency, Corporación de Fomento de la Producción, 25%. The first lithium plant, which began production in 1984 at the southern portion of the salar, did not plan to produce boric acid.[22]

China.—Three new salt processing plants, each with a crude salt capacity of 400,000 tons per year, were commissioned in the Province of Quinghai. Boron compounds were not being produced, although the Playa lake contains borates.[23]

Netherlands.—Morton-Thiokol announced a $15 million expansion of sodium borohydride production to go on-stream by 1988 at Delfzijl. Sterns Catalytic was the contractor for the project.

Turkey.—Etibank, the Turkish state mining organization, continued to mine and concentrate colemanite ores. Proven reserves and production capacity of ore were as follows, in tons: Bigadic, 935 million and 300,000; Emet, 544 million and 800,000; and Kestelek, 7 million and 450,000.[24]

Three grades of colemanite concentrates were produced. The highest grade had a low iron content and was used in the worldwide manufacture of textile-grade glass fiber, an intermediate grade was used for glass manufacture, and the lowest refining grade had a high arsenic content and was used in the manufacture of boric acid.

Ulexite concentrates, produced at Bigadic, were exported to several European countries, Japan, and the United States for manufacture of insulation-grade fiberglass.

Tincal concentrates produced at Kirka were exported to Western European countries for the manufacture of sodium perborate. Etibank produced pentahydrate borax from tincal at a plant at Kirka. Plant modifications were expected to increase production, which was approximately 25,000 tons, produced since the plant opened in 1984. An adjacent plant was to produce anhydrous borax from the pentahydrate borax. The completion of the boric acid plant at Bandirman was planned for 1988.[25]

U.S.S.R.—On April 25, the world's worst nuclear power accident occurred during a routine maintenance procedure. How to block the release of radiation into the atmosphere and cool down the red-hot graphite reactor were two problems with conflicting solutions. The sole method to block radiation releases was to put a layer of material on top of the graphite, which would cause the graphite to become hotter and cause a possible reactor core meltdown. A meltdown would collapse the foundation and allow radiation to leak into the water table 50 feet below. On April 27, a decision was made to proceed with a cement and steel support to strengthen the foundation and then cover the reactor with boron, dolomite, clay, sand, and lead dropped from helicopters. Boron was chosen to absorb neutrons; dolomite to produce carbon dioxide to smother the fire; clay and sand to act as a filter to trap radioactive particles; and lead because it would melt into a smooth cover to absorb radiation and transfer heat. As material was dropped, the level of radiation leaking from the reactor fell, but the temperature of the graphite rose. One final emission occurred on May 5, and then the graphite fire was brought under control.[26]

Table 7.—Boron minerals: World production, by country[1]

(Thousand short tons)

Country	1982	1983	1984	1985[p]	1986[e]
Argentina	136	125	157	154	145
Chile	(2)	1	4	5	7
China[e]	30	30	30	30	30
Peru[e]	15	11	11	11	11
Turkey	868	774	987	1,694	1,870
U.S.S.R.[e]	220	220	220	220	220
United States[3]	1,234	1,303	1,367	1,269	[4]1,251
Total	2,503	2,464	2,776	3,383	3,534

[e]Estimated. [p]Preliminary.
[1]Table includes data available through May 26, 1987.
[2]Less than 1/2 unit.
[3]Minerals and compounds sold or used by producers, including both actual mine production and marketable products.
[4]Reported figure.

TECHNOLOGY

Borosilicate glass in the form of optical fibers consists of a core within cladding that has a lower index of refraction. Bell Telephone Laboratories uses a chemical vapor deposition process to speed up fabrication of glass preforms from which glass fibers are made. Various doping agents control the refractive index of each layer; for example, boron lowers the index, but compounds of aluminum, germanium, phosphorus, or titanium raise the index. Use of optical fibers has a strategic benefit in that they would not be disabled from the electromagnetic pulse of a nuclear blast. The material's lightweight and small size make it ideal for spacecraft, aircraft, and naval use. Other advantages are the lack of shock and fire hazard. General Motors demonstrated transmission of control signals over fibers within a car, and Japanese companies have built some fiber-equipped vehicles.[27]

Computers are approaching the limits of integrated-circuit technology, but research continued on the use of beams of light through optical fibers instead of electrical current. Because light beams do not interfere with one another, optical computers would be able to perform far more transactions simultaneously than electronic computers. Applications of the technology had depended upon the invention of an optical transistor device that can control electrical energy. American Telephone & Telegraph Co.'s Bell Laboratories had an experimental material under research that may have the necessary properties. Bell projected the development of an experimental optical computer. The use of fiber optics instead of electrical current has the potential for replacing existing electrical systems that use aluminum and copper.[28]

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Bromine

By Phyllis A. Lyday[1]

Of the 817 million pounds of bromine produced worldwide in 1986, the United States produced 38%, followed by Israel, 28%; the U.S.S.R., 18%; the United Kingdom, 8%; and six other countries accounted for the remainder of world output. 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 and the emergence of Israel as a major producer. In 1986, five companies operated nine bromine producing plants in Arkansas and Michigan. The quantity of bromine sold or used in the United States was about 310 million pounds

Table 1.—Salient bromine and bromine compound statistics

(Thousand pounds and thousand dollars)

	1982	1983	1984	1985	1986
United States:					
Bromine sold or used:[1]					
Quantity	401,100	370,000	385,000	320,000	310,000
Value	$103,000	$91,000	$95,000	$80,000	$93,000
Exports:					
Elemental bromine:					
Quantity	NA	[2]4,500	[3]68,200	[3]6,252	[2]17,900
Value	NA	[2]$1,000	[e]$15,200	[e]$1,400	[2]$8,170
Bromine compounds:[4]					
Gross weight	55,600	61,300	53,200	61,000	28,000
Contained bromine	47,200	52,000	45,100	51,900	23,000
Value	$21,100	$21,600	$16,200	$23,400	$23,900
Imports:					
Ammonium bromide:					
Gross weight	1,599	1,634	1,450	2,786	5,721
Contained bromine	1,304	1,333	1,183	2,729	4,667
Value	$989	$962	$854	$1,593	$2,994
Calcium bromide:					
Gross weight	82	1,722	1,598	5,093	6,218
Contained bromine	65	1,377	1,278	4,072	4,972
Value	$40	$900	$203	$917	$741
Potassium bromate:					
Gross weight	390	679	661	1,069	641
Contained bromine	187	325	350	512	340
Value	$336	$572	$610	$899	$669
Potassium bromide:					
Gross weight	281	436	367	968	697
Contained bromine	189	293	246	650	468
Value	$204	$303	$268	$685	$486
Sodium bromide:					
Gross weight	645	2,534	1,916	2,901	467
Contained bromine	501	1,927	1,488	2,253	364
Value	$423	$971	$851	$1,108	$217
Other:					
Gross weight	6,191	12,070	15,150	10,087	10,112
Contained bromine	4,060	10,241	11,535	6,863	8,004
Value	$3,953	$8,105	$8,210	$5,863	$4,627
World: Production	843,963	801,863	875,150	[p]839,982	[e]817,080

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

valued at $93 million. Exports of bromine compounds amounted to 23 million pounds. Prices of elemental bromine in bulk were listed between 33.0 and 34.5 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 nine 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) released at yearend 1985 a list of 405 acutely toxic chemicals for local governments to become aware of potential hazards and prepare emergency plans. Included in the list were bromadiolone, bromine, and methyl bromide. A number of programs to help communities collect data were in place during 1986. The Chemical Manufacturers Association (CMA) began a comprehensive effort for plant managers to develop community outreach programs and provide the public with information about chemicals used inside local plants. Other programs in operation were the National Response Center, operated by the Coast Guard, and the Chemical Transportation Emergency Center, an emergency response network of CMA. A recommended source of information was the SRI International Directory of Chemical Producers. EPA provided chemical profiles containing technical information on any of the compounds on the list from data derived from the National Institute for Occupational Safety & Health Administration's data base, the Registry of Toxic Effects of Chemical Substances. These profiles included synonyms and Chemical Abstracts numbers for each chemical.

Chemicals included on EPA's acutely toxic list had to satisfy certain criteria as follows: For dermal exposure, the median lethal dose must be less than or equal to 50 milligrams per kilogram of body weight; for oral exposure, the dose must be less than or equal to 25 milligrams per kilogram of body weight; for inhalation, the median lethal concentration must be less than or equal to 0.5 milligram per liter of air. Using these criteria EPA added 379 chemicals from its inventory under the Toxic Substances Control Act to the list of toxic chemicals. The agency listed additional compounds that did not meet these strict criteria but were produced in such large quantities that EPA believed them to constitute a potential hazard. Radioactive chemicals and chemicals used in food, drugs, or cosmetics were not included. Compounds that are explosive, flammable, reactive, and corrosive are not included if one of those properties is their primary hazard. About 140 chemicals on the list are no longer manufactured or imported into the United States.[2]

Effective January 1, 1986, EPA reduced the allowable amount of lead added to some gasolines to raise octane levels to 0.1 gram per gallon from 0.5 gram per gallon.[3] Regulated lead reductions posed a concern to the bromine industry because of the effect of decreased demand for ethylene dibromide (EDB) used as a lead scavenger in automotive engines.

EPA will regulate three wastes generated during the production of EDB under the Resource Conservation and Recovery Act (RCRA), according to a final rule published in the Federal Register on February 13.[4]

A proposal to amend regulations under RCRA listed as hazardous five wastes generated during the production of tetraethyl and tetramethyl lead and from the formulation of mixed lead compounds. EDB was present in one waste. The effect of the proposed rule, if promulgated, was to regulate these wastes as hazardous.[5]

A section 18 exemption was granted by EPA to the Mississippi Agriculture and Commerce Department and the Arkansas State Plant Board for the use of bromoxynil for control of weeds in rice. The Mississippi Department's exemption provided for use of the pesticide on 25,000 acres to control hemp sesbania, morning glory, and cocklebur.[6]

EPA announced the receipt of a pesticide petition 5F3198 from the Methyl Bromide Industry Panel relating to the establishment of tolerances for residues of inorganic bromide in or on certain commodities from soil fumigation with the insecticide methyl bromide.[7]

EPA announced the regulatory status of chemical substitutes for EDB for insect control in stored grains, including alternative grain fumigants and grain protectants. After December 31, 1985, methyl bromide for use as a grain fumigant would continue to be available.[8]

Final RCRA authorization for the State of Michigan was delayed by EPA in a May 22, 1986, notice in the Federal Register. EPA was to continue administering and enforcing the prohibition requirements of the Hazardous and Solid Waste amendments until the State receives authorization. Earlier in the year, EPA granted tentative approval, pending clarification in five areas of Michigan's request.

Registration was granted by EPA for both the technical and formulated grades of dibromonitrilopropionamide to AmeriBrom Inc., the U.S. marketing agent for the Dead Sea Bromine Co. Ltd. (DSB), a part of Israel Chemicals Ltd. (ICL). EPA approval for bromochlorodimethylhydantoin, a pool sanitizer, was pending.[9]

EPA issued an extension of the tolerance for residues of the pesticide EDB in the edible pulp of mangoes that have been fumigated after harvest with EDB in accordance with the Mediterranean Fruit Fly Control Program or the Quarantine Program of the U.S. Department of Agriculture (USDA). The tolerance expiration date of September 30, 1986, was extended for an additional year to September 30, 1987. In response to comments that opposed the extension, EPA said alternative treatment will not be in place by the EDB expiration date, but there is a possibility that a hot water treatment may receive USDA approval by that date.[10] The USDA affirmed in the Federal Register on October 7, 1986, an interim rule pertaining to residues of EDB on mangoes.

EPA approved a label with detailed procedures for handling EDB in the fumigation of citrus fruit for export. An amended registration held by Great Lakes Chemical Corp. provided increasing controls through the 1989 shipping season when the current registration was to expire.[11]

The Food and Drug Administration denied a request to allow marketing of Indian black pepper contaminated with illegal residues of EDB.[12]

Officials in Kansas City, KS, sued EPA after the agency brought 30,000 gallons of EDB into an EPA laboratory without notifying local officials. The suit was dropped and EPA will be allowed to bring in another 30,000 gallons of EDB as part of an agreement.[13]

Great Lakes' third-party complaint against EPA was dismissed by the U.S. District Court for the Western District of Washington at Seattle. The dismissal, requested by EPA, also remanded the remaining case to State court.[14]

DOMESTIC PRODUCTION

Three companies representing the U.S. Bromine Alliance accounted for over 99% of U.S. elemental bromine capacity. Great Lakes had become the largest producer in 1981 with its acquisition of the bromine assets of Velsicol Chemical Corp., giving Great Lakes a 39% control of total domestic plant capacity, which included a 50% interest and management of Arkansas Chemicals Inc. The Dow Chemical Co. and Ethyl Corp. accounted for 32% and 24% of capacity, respectively. 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. The only other domestic elemental bromine producer was Morton Thiokol Inc., which was the only domestic producer of some inorganic bromides.

Dow operated one plant in Arkansas and two in Michigan. Plans had been announced in 1984 to phase out brine production at the Midland, MI, plant in 1986 and to increase brine operations at Ludington, MI, and Magnolia, AR. On April 28, Dow announced the closure of the bromine plant at Midland.

On September 12, Ethyl announced that an agreement had been reached with Dow to acquire Dow's bromine and bromine derivative chemicals business worldwide. Included in the agreement was Dow's bromine chemicals plant in Magnolia, AR, as well as its brine field leases located in Arkansas along with distribution equipment, and certain patents pertaining to Dow's bromine chemicals. The cost of the transaction was not disclosed. At yearend, the acquisition had not been completed.

Ethyl announced plans to build a new plant to produce brominated flame retardant products at its chemicals complex in Magnolia, AR. Cost of the plant was expected to be approximately $10 million, with startup scheduled for the second quarter of 1987. Production will be transferred from Sayreville, NJ, to the new facility on a selected basis depending on market and economic considerations. Flame retardant research, certain domestic U.S. sales functions, and warehousing facilities would be maintained at Sayreville.[15]

The State of Florida, working closely with the State's Department of Environmental Regulation (DER), filed suit against Great Lakes on April 29. In the complaint, DER claims that approximately 1,200 wells throughout the State have been polluted by EDB since 1983. DER analysts estimated that EDB has a hydrolysis life of 14 years. Although Florida approved the label and acknowledged that application directions may not have been followed, the State's position was that the EDB producer still must assume product liability for the contamination.[16]

Table 2.—Bromine producing plants in the United States in 1986

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
Do	Midland	Midland	do	85
Morton Thiokol Inc	Manistee	Manistee	do	5
Total				665

[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 (ITC) publication "Synthetic Organic Chemicals, 1985" 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.

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 1986 prices for elemental bromine and selected compounds

Product	Value per pound (cents)
Ammonium bromide, National Formulary (N.F.), granular, drums, carlots, truckloads, freight equalized	131
Bromine, purified:	
Carlots, truckloads, delivered	75
Drums, carlots, truckloads, delivered east of the Rocky Mountains[1]	87
Bulk tank car, tank trucks (45,000-pound minimum), delivered east of the Rocky Mountains[1]	33- 34.5
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. works	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. 230, No. 26, Dec. 29, 1986, pp. 24-31.

FOREIGN TRADE

The United States-Israel Free Trade Agreement had been in effect 1 year on August 19, 1986. The United States was Israel's best customer and was the major supplier of its imports. Bilateral trade reached almost $5 billion in 1985. The agreement will eliminate customs duties on all trade between the two countries during a 10-year reduction in duties beginning on September 1, 1985 and ending on January 1, 1995. The phaseout covered most of the significant products manufactured by the domestic bromine industry.

The ITC agreed on March 7 to consider a request by the U.S. Bromine Alliance that sodium bromide be removed from the Generalized System of Preferences (GSP). Sodium bromide is a dry crystalline "photographic grade" material used to make photographic chemicals, medicines, oil and gas well-drilling compounds, and in the preparation of other bromine compounds. The GSP is a list of imports from developing nations to which the United States gives duty-free treatment. Domestic bromine producers have complained that heavily subsidized Israeli bromine has threatened to put them out of business. A hearing was held at the Office of the U.S. Trade Representative on March 14.

On June 28, the President denied the request of the U.S. Bromine Alliance to graduate Israel from eligibility for the GSP. However, the President did not waive the 50% competitive need limit and under that provision Israeli sodium bromide was denied GSP duty-free treatment effective July 1, subject to review in 1987.[17] Sodium bromide had entered the United States duty free since 1976. Duty in 1986 for most-favored-nation countries, including Israel, was 3.6 cents per pound and for non-most-favored-nation countries was 10 cents per pound.

WORLD REVIEW

France.—Entreprise Minière & Chimique decreased losses from its potash division, Mines de Potasse d'Alsace S.A. The improvement was attributed to higher productivity and increased bromine sales.

German Democratic Republic.—Production in a new low potash carnallite deposit at Bleicherode in the south Harz Mountains began in 1985. After potash was processed, the remaining brine was rich in magnesium chloride and bromine. Bromine was produced from the potash bitterns. In 1983, bromine production had begun at the Gluckauf Mine, Sondershausen, by Lurgi Gesellschaft für Wärme-und Chemotechnik mbH, with equipment from a closed bromine plant at the Hattorf Mine in the Federal Republic of Germany.

Germany, Federal Republic of.—Kali und Salz AG, a 72% subsidiary of the BASF Group via Wintershall AG, produced bromine in conjunction with operation of the potash mines. The Friedrichshall Mine, operated as part of the Bergmannssegen-Hugo Mine, and the Salzdetfurth Mine produced bromine from the bitterns of mined potash production. Bromine production was from the Zechstein Upper Permian geological period. The deposit is situated between the Werra and Fulda Rivers south of Kassel where the Thuringen and Hesses potash beds average 3 to 12 feet thick.

Israel.—The Government began efforts to privatize some of Israel's 189 State-owned companies. In August, a Government economics committee approved the $14 million sale of the State's 29% interest in Haifa Chemicals Ltd. to a group of New York investors including Rapid-American Corp. A syndicate led by Bear, Stearns & Co. and Shearson Lehman Bros. expected to offer between 20% and 25% share of DSB.

Much of Israel's organic and inorganic chemical activity takes place within the framework of the massive ICL, composed of 28 companies with a work force of 7,000 and consolidated sales of approximately $800 million. DSB operated as an independent industrial and commercial entity that exports 95% of its production to supply over 20% of world bromine consumption and 60% of total world trade in the product.[18]

ICL announced plans in 1986 for a $500 million investment program over the succeeding 5 years, based mainly on its bromine and potash operations. ICL announced record-high earnings for the 1984-85 fiscal year, up nearly 50%. Much of this increase was attributed to a move into downstream products, which included the bromine and bromine compounds of DSB. About $150 million will be spent on bromine operations. Money was to come from group profits, internal funds, and from the sale of equity in group subsidiaries, including DSB. About 26% of ICL will be privatized. The most attractive sector in 1986 was DSB, valued at $200 million. Plans called for about 30% to be sold to raise $40 million.[19]

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:			
Bergmannssegen-Hugo Mines	Lehrte	8 (combined)	Do.
Salzdetfurth Mine	Bad Salzdetfurth.		
India:			
Hindustan Salts Ltd	Jaipur	1.6 (combined)	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	Nanyo	26	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]	1982	1983	1984	1985[p]	1986[e]
France[e]	37,000	35,000	[r]38,600	44,000	42,000
Germany, Federal Republic of	6,775	6,914	7,288	6,784	5,500
India[e]	770	770	770	770	770
Israel[e]	154,000	154,000	198,400	220,000	231,500
Italy[e]	1,320	1,100	1,100	1,320	990
Japan[e]	26,500	26,500	26,500	26,500	16,700
Spain[e]	800	700	660	800	620
U.S.S.R.[e]	150,000	150,000	154,000	154,000	143,000
United Kingdom	65,698	56,879	62,832	65,808	66,000
United States[3]	401,100	370,000	385,000	320,000	310,000
Total	843,963	801,863	875,150	839,982	817,080

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through May 8, 1987.
[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.

Japan.—Toyo Soda Manufacturing Co. Ltd. accounted for about 80% of total domestic bromine production. In 1980, Toyo Soda built a multipurpose organic synthesis plant at the bromine production site to produce bromine compounds. By 1986, about 150 bromine compounds had been developed, of which one-half had been marketed as raw materials for pharmaceuticals and agrochemicals. Another plant to produce a variety of products in small quantities had an output of approximately 3,000 pounds per year.

[1]Physical scientist, Division of Industrial Minerals.

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Cadmium

By Patricia A. Plunkert[1]

Domestic production of cadmium metal decreased slightly in 1986 with four companies operating four plants accounting for all of the domestic metal production. Imports for consumption increased dramatically, and the principal supplying country continued to be Canada. The tightness of supply during the early months of 1986 contributed to a rapid rise in metal prices during that period. As the supply of cadmium increased, prices began to decrease and closed the year slightly above the 1985 yearend price levels.

The development of advanced technology applications for cadmium continued in 1986. A commercial application for cadmium telluride solar cells was announced, and an advanced cadmium alloy was investigated for use in the manufacture of magnetic semiconductors.

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 5. 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 tables 3 and 4.

Table 1.—Salient cadmium statistics

	1982	1983	1984	1985	1986
United States:					
Production[1] metric tons	1,007	1,052	1,686	1,603	1,486
Shipments by producers[2] do.	1,832	1,495	1,811	1,791	2,030
Value thousands	$2,628	$1,786	$2,581	$2,436	$1,883
Exports metric tons	11	170	106	86	38
Imports for consumption, metal do.	2,305	2,196	1,889	1,988	3,174
Apparent consumption do.	3,728	3,763	3,300	3,720	4,385
Price: Average per pound[3]	$1.11	$1.13	$1.69	$1.21	$1.25
World: Refinery production metric tons	[r]16,387	[r]17,444	19,114	[p]18,634	[e]18,257

[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 Safe Drinking Water Act Amendments of 1986 (Public Law 99-339) was signed by the President on June 19, 1986. Cadmium was 1 of 83 contaminants for which the Environmental Protection Agency (EPA) was required to set maximum permissible levels in drinking water within 3 years. On November 13, 1985, the EPA proposed lowering the permissible cadmium level to 0.005 milligram per liter.[2] However, no final action had been taken on this proposal by yearend 1986; therefore, the permissible level remained at 0.010 milligram of cadmium per liter of drinking water.

On October 10, the EPA announced a preliminary determination to cancel registrations and to deny applications for all pesticide products that contained cadmium compounds as active ingredients and that were for use on turf sites, predominantly golf courses. The proposed action was based on EPA's determination that the use of cadmium fungicides would result in unreasonable adverse effects to applicators of the products for these uses. The notice also informed the public of the availability of a draft Notice of Intent to Cancel and documents in support of the action.[3]

On October 17, 1986, the President signed the Superfund Amendments and Reauthorization Act of 1986 (Public Law 99-499) that extended and amended the Comprehensive Environmental Response, Compensation, and Liability Act of 1980. Cadmium will continue to be taxed under the new law. The tax, which is to be collected from producers and importers beginning January 1, 1987, was set at the old rate of $4.45 per short ton of cadmium. The tax terminates on December 31, 1991.

The Department of Defense Authorization Act, 1987 (Public Law 99-661), signed by the President on November 14, 1986, stated that no action may be taken before October 1, 1987, to implement or administer any change in a stockpile goal in effect on October 1, 1984, that results in a reduction in the quality or quantity of any strategic and critical material to be acquired for the National Defense Stockpile (NDS). Therefore, as of December 31, 1986, the NDS goal for cadmium metal remained at 5,307 metric tons, and the stockpile inventory was 2,871 tons of cadmium metal.

DOMESTIC PRODUCTION

Domestic production of cadmium metal decreased slightly in 1986 compared with that of 1985; however, the production of cadmium compounds, both oxides and sulfides, increased. A labor dispute resulted in a 1-month work stoppage at AMAX Inc.'s zinc refinery and cadmium plant in Sauget, IL.

Table 2.—Primary cadmium producers in the United States in 1986

Company	Plant location
AMAX Inc	Sauget, IL.
ASARCO Incorporated	Denver, CO.
Jersey Minière Zinc Co	Clarksville, TN.
St. Joe Resources Co	Bartlesville, OK.

Table 3.—U.S. production of cadmium compounds other than cadmium sulfide[1]

(Metric tons)

Year	Quantity (cadmium content)
1982	971
1983	1,024
1984	1,510
1985	1,021
1986	1,459

[1]Includes plating salts and oxide.

Table 4.—U.S. production of cadmium sulfide[1]

(Metric tons)

Year	Quantity (cadmium content)
1982	374
1983	670
1984	771
1985	477
1986	645

[1]Includes cadmium lithopone and cadmium sulfoselenide.

CONSUMPTION AND USES

Apparent consumption of cadmium increased compared with that of 1985 and reached its highest level since that of 1979. Although the Bureau of Mines does not collect actual consumption data, apparent consumption by use categories in 1986 was estimated as follows: coating and plating, 32%; batteries, 29%; pigments, 16%; plastic stabilizers, 15%; and alloys and other uses, 8%.

Battery Systems Inc. announced the introduction of an advanced fiber electrode nickel-cadmium storage battery to the U.S. market. The company claimed that this battery design, which has been successfully marketed in Europe for the past 3 years, provided increased cycle life, power-to-weight and power-to-space ratios, and improved power-versus-temperature performance.[4]

SAFT America Inc. announced that it had expanded its line of nickel-cadmium batteries with the introduction of three cylindrical batteries suitable for use in cordless electrical appliances. Also introduced was a rechargeable nickel-cadmium battery in a rectangular configuration that reportedly featured ultrathin plates and improved capacity efficiency. The company claimed that this compact design would make the batteries ideal for use in small cordless portable devices.[5]

Matsushita Battery Industrial Co. Ltd. announced the signing of a contract with Texas Instruments Inc. to supply cadmium telluride solar cells for calculators at a rate of 1 million units per month. This reportedly would be the first commercial application of cadmium telluride solar cells.

Table 5.—Supply and apparent consumption of cadmium

(Metric tons)

	1984	1985	1986
Stocks, Jan. 1	732	901	686
Production	1,686	1,603	1,486
Imports for consumption, metal	1,889	1,988	3,174
Total supply	4,307	4,492	5,346
Exports	106	86	38
Stocks, Dec. 31	901	686	923
Apparent consumption[1]	3,300	3,720	4,385

[1]Total supply minus exports and yearend stocks.

STOCKS

Total inventories of cadmium in all forms increased 35% compared with those of 1985 but remained well below the average stock level for the previous 5-year period. Cadmium inventories rose in all categories with the exceptions of cadmium metal stocks held by compound manufacturers and cadmium compound stocks held by distributors.

Table 6.—Industry stocks, December 31

(Metric tons)

	1985		1986	
	Cadmium metal	Cadmium in compounds	Cadmium metal	Cadmium in compounds
Metal producers	136	W	303	W
Compound manufacturers	111	377	73	481
Distributors	59	3	65	1
Total	306	380	441	482

W Withheld to avoid disclosing company proprietary data; included with "Compound manufacturers."

PRICES

At the beginning of 1986, the domestic producer price for cadmium metal published by Metals Week was $1.00 per pound. On April 4, St. Joe Resources Co.'s National Zinc Div. increased its price quotation for cadmium metal to $1.20 per pound and on April 10 announced a further price increase to $1.50 per pound. On April 7, AMAX increased its published price for cadmium metal from $1.00 to $1.20 per pound. Both published domestic producer prices remained at these levels through yearend.

In January, the range of New York dealer prices for cadmium metal was listed by Metals Week at $0.77 to $0.83 per pound. The quoted price range increased steadily throughout the early months of 1986 and reached a high of $1.30 to $1.40 per pound at the end of April. The range of dealer prices for cadmium metal fluctuated during the remainder of 1986 but trended downward to close the year at $0.97 to $1.05 per pound.

FOREIGN TRADE

Exports of cadmium metal and cadmium in alloys, dross, flue dust, residues, and scrap declined in 1986, continuing a downward trend that began in 1983. Sweden received approximately one-half of U.S. cadmium exports in 1986.

Cadmium metal imports for consumption increased dramatically in 1986 compared with those of 1985 and reached their highest level in over 30 years. The principal supplying country continued to be Canada.

The Bureau of the Census reported that in 1986 the United States exported over 10 million nickel-cadmium batteries. The two major recipients, Hong Kong and the United Kingdom, received approximately 70% of these battery exports. Imports of nickel-cadmium batteries, including those incorporated into other products, totaled 62.2 million batteries. Japan and Mexico supplied 47% and 36%, respectively, of the total battery imports.

Imports of metal and flue dust from most favored nations (MFN) continued to be duty free. A statutory duty of $0.15 per pound continued to be imposed on cadmium metal imported from non-MFN.

Table 7.—U.S. exports of cadmium metal and cadmium in alloys, dross, flue dust, residues, and scrap

Year	Quantity (metric tons)	Value (thousands)
1984	106	$208
1985	86	342
1986	38	188

Source: Bureau of the Census.

Table 8.—U.S. imports for consumption[1] of cadmium metal, by country

Country	1985		1986	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Australia	458	$1,043	[2]589	$1,143
Belgium-Luxembourg	12	96	29	84
Canada	1,044	2,159	[2]1,221	2,571
China	--	--	[2]76	143
Finland	30	61	46	83
France	20	55	[2]21	43
Germany, Federal Republic of	203	356	227	390
Hong Kong	--	--	[2]22	34
Korea, Republic of	--	--	59	121
Mexico	162	238	441	782
Netherlands	--	--	54	106
Norway	--	--	40	79
Peru	27	48	[2]141	255
Spain	--	--	40	69
Sweden	6	15	15	30
United Kingdom	--	--	[2]144	257
Yugoslavia	24	49	10	17
Total[3]	1,988	4,122	3,174	6,208

[1]General imports and imports for consumption were the same in 1985 and 1986.
[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

Bolivia.—Corporación Minera de Bolivia reported the closure of its largest zinc mine, the Matilde Mine. In 1985, this mine reportedly produced 6,500 metric tons of zinc, along with 100 tons of lead and 16 to 20 tons of cadmium.[6]

Japan.—Société d'Accumulateurs Fixés et de Traction (SAFT) of France and Japan Storage Battery Co. announced the signing of a joint venture agreement to build a nickel-cadmium battery manufacturing and marketing company in Uji, Kyoto Prefecture. The plant reportedly would produce cylindrical-, button-, and coin-type batteries.[7]

Table 9.—Cadmium: World refinery production,[1] by country

(Metric tons)

Country	1982	1983	1984	1985[p]	1986[e]
Algeria[e]	[r]30	[r]30	[r]24	[r]24	24
Argentina[e]	[2]21	19	20	20	20
Australia	1,010	[r]1,106	1,082	[e]1,000	1,000
Austria	48	46	49	53	50
Belgium	996	1,260	1,472	1,252	1,300
Brazil	73	189	225	[e]225	230
Bulgaria[e]	200	200	200	200	200
Canada	854	1,456	1,605	1,717	[2]1,421
China[e]	300	300	300	300	300
Finland	566	616	614	[e]610	620
France	[3]793	513	568	337	400
German Democratic Republic[e]	16	15	15	15	15
Germany, Federal Republic of	1,030	1,094	1,111	1,095	1,185
India	131	131	148	194	170
Italy	[3]475	[r]385	452	526	[2]411
Japan	2,034	2,214	2,423	2,535	2,400
Korea, North[e]	100	100	100	100	100
Korea, Republic of	320	320	320	([4])	100
Mexico	607	642	571	734	700
Namibia	110	51	40	58	50
Netherlands	497	513	636	598	570
Norway	104	117	150	159	155
Peru	421	451	390	[e]420	500
Poland[e]	[2]570	570	570	600	600
Romania[e]	80	80	75	75	75
Spain	286	278	290	268	275
U.S.S.R.[e]	2,900	3,000	3,000	3,000	3,000
United Kingdom	354	340	390	370	350
United States[3]	1,007	1,052	1,686	1,603	[2]1,486
Yugoslavia	174	48	270	[e]250	250
Zaire	280	308	318	296	300
Total	[r]16,387	[r]17,444	19,114	18,634	18,257

[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. 7, 1987.

[2]Reported figure.

[3]Includes secondary.

[4]Revised to zero.

TECHNOLOGY

The Bureau of Mines investigated a process that utilized the electrokinetic properties of magnesium oxide (MgO) to simultaneously filter suspended solids and to remove trace amounts of dissolved heavy metals from synthetic mine water. Greater than 95% removal of metals from influent at neutral pH containing 1 to 6 milligrams per liter of heavy metals, such as cadmium, copper, manganese, nickel, and zinc, could be achieved by filtering through a granular bed of MgO. The conventional practice of treating mine drainage and other water sources contaminated with heavy metals by lime precipitation and settling of the hydrous oxides produced a voluminous toxic sludge that could result in another type of disposal problem. The resulting sludge from the Bureau's MgO process was up to four times more compact than that produced by liming. Because many of the metals removed by this process are considered critical and strategic, the technique can be adapted to reclaim their metal values. Recoveries of 10 elements from the MgO column using a water plus ethylenediaminetetraacetic acid (EDTA) backwash ranged from 93.6% to 97.7%.[8]

Researchers at Kidd Creek Mines Ltd. of Canada and KHD Humboldt Wedag AG of the Federal Republic of Germany described the results of pilot-plant test work on a new single-stage zinc-solution purification process using a vibratory reactor. The technique was modified for continuous cadmium cementation. The combination of an intensely agitated reactor with a high mass of precipitant in the form of granular zinc instead of zinc dust reportedly produced a significant reduction in cementation agent consumption and a substantial upgrading of the cadmium cement. The companies claimed that this technique had the potential to minimize equipment, reduce plant size, and diminish operating costs.[9]

Sandia National Laboratories reported that it was studying an advanced alloy of cadmium and tellurium in which magnetic atoms of manganese were substituted for some of the cadmium atoms for use in the manufacture of magnetic semiconductors. These semiconductors could then be combined with optical fiber technology to produce a magnetic field sensor capable of making measurements of changes in magnetic fields with nanosecond response times. Because optical fibers do not conduct electricity, they reportedly would allow measurements to be taken in electrically noisy environments where interference would hamper conventional methods.[10]

BASF AG and Varta Batterie AG of the Federal Republic of Germany announced the development of a dry-cell battery system based on a polymer of pyrrole. The companies claimed that the battery, which was still in the experimental stage, retained its charge well and could be recharged 500 times. Because the unit burns, it reportedly was easier to dispose of than lead or nickel-cadmium cells.[11]

Developments in cadmium technology during the year were abstracted in Cadmium Abstracts, a quarterly publication available through the Cadmium Association, 34 Berkeley Square, London, W1X 6AJ, England.

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[1]Physical scientist, Division of Nonferrous Metals.

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[5]———. V. 22, No. 8, Aug. 1986, p. 5.

[6]Metal Bulletin (London). Comibol Closures. No. 7097, June 27, 1986, p. 11.

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[10]Photonics Spectra. FO Sensors Check Magnetic Fields. V. 20, No. 6, June 1986, pp. 38, 41.

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Calcium and Calcium Compounds

By Lawrence Pelham[1]

Calcium, the fifth most abundant element in the Earth's crust, is very active and occurs in nature in combination with other elements. The Bureau of Mines publishes individual reports for several of these calcium minerals and compounds. The commercial name for calcium fluoride is fluorspar; calcium carbonate is known as limestone; and calcium oxide and hydroxide are called lime. Information on these materials can be obtained in the "Fluorspar," "Crushed Stone," and "Lime" chapters of the "Minerals Yearbook." Other calcium compounds are covered in the chapter concerning the element with which calcium is combined; for example, calcium bromide is discussed in the "Bromine" chapter. This chapter covers 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 one company in Louisiana, one company in New York, 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 11 operations to which a survey request was sent, all responded, representing 100% of the total production shown in table 1.

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. at Exton, PA, and ASARCO Incorporated at New York, NY, also produced calcium alloys. The Pesses Co. produced calcium alloys for use in the production of iron, steel, and nickel 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. Total output in California decreased 17% from that of 1985. Natural calcium chloride production in California was much less than in Michigan. The Dow Chemical Co. and Wilkinson Chemical Corp. recovered calcium chloride from brines in Lapeer, Mason, and Midland Counties, MI. Dow completed the phaseout of all brine operations at its 80-year-old plant in Midland, MI, near midyear. Capacity at Dow's Ludington plant was expanded to produce calcium chloride pellets and flake. The closing of one plant and the expansion of another was expected to result in an overall capacity reduction, but not enough to create a supply shortage. Tahoma Chemical Co. Inc. produced calcium chloride in Washington.

Allied Chemical Corp. 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.

Allied ceased operating its calcium chloride facility in Syracuse, NY, in February as part of its phaseout of the Solvay synthetic soda ash plant. The capacity of the Syracuse plant was believed to have been 160,000 short tons per year. Allied expanded operations at its calcium chloride facility in Amherstburg, Ontario, Canada, from which it continued serving its U.S. customers. Control of the Amherstburg plant was transferred to the Henley Group spinoff of Allied-Signal Inc.

Texas United Chemical completed and began operating a new granular calcium chloride plant at Lake Charles, LA. Total capacity was reported to be 40,000 tons per year of both liquid and dry calcium chloride, 100% basis.

Calcium hypochlorite was produced by two U.S. companies: Olin Corp. and PPG Industries Inc. Total U.S. capacity for producing calcium hypochlorite was 116,500 tons per year.

Pfizer began construction of an on-site precipitated calcium carbonate (PCC) plant to supply International Paper Co.'s pulp and paper mill in Ticonderoga, NY. This will be Pfizer's second on-site plant; earlier in 1986, a PCC plant was completed for Consolidated Papers Inc.'s mill at Wisconsin Rapids, WI.

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)
1982	616,513	$61,483	236,894	$31,279	853,407	$92,762
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	[r]940,000	[r]135,200
1986	W	W	W	W	780,000	123,000

[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 a signatory of the United Nations Nuclear Nonproliferation Treaty. Calcium is used to reduce uranium dioxide, a mineral used in fuel rods in some types of 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, streets, bridges, and pavements. 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	
	1985	1986
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. 56, No. 52, 1985, p. 5; v. 57, No. 52, 1986, 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% $CaCl_2$. Prices increased over those of 1985 for the liquids but remained unchanged for other forms. Yearend 1986 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. V. 230, No. 26, 1986, p. 25.

FOREIGN TRADE

Calcium chloride was exported to 40 countries. A significant decrease in calcium chloride exports occurred primarily because of Allied's shift in production capacity from Syracuse, NY, to Amherstburg, Ontario, Canada. Crude calcium borate exports totaling 8,146 tons valued at $607,000 went to six countries, primarily to Canada. Calcium carbide in the amount of 2,032 tons valued at $912,000 was exported to 13 countries, with 64% of the exports going to Canada. Calcium hypochlorite exports to 67 countries totaled 16,748 tons valued at $23 million. The leading destinations, in descending order, were Australia, Brazil, the Netherlands, Canada, and Colombia. Calcium phosphate exports to 49 countries totaled 51,113 tons valued at $42 million. The leading destinations, in descending order, were Canada, Mexico, Colombia, and Venezuela.

Exports of other calcium compounds, including precipitated calcium carbonate, totaled 26,833 tons valued at $15 million compared with 49,000 tons valued at $25 million in 1985. Material in this category was sent to 60 countries. The leading destinations, in descending order, were the United Kingdom, Mexico, Belgium, and Canada. The combined reported customs value for calcium borate, calcium carbide, calcium chloride, calcium phosphate, and other calcium compounds totaled $85 million.

Imports for consumption of crude calcium chloride increased significantly for the second consecutive year. Crude calcium chloride imports from eight countries increased 90% compared with those of 1985 for a total increase of 557% since 1984. Once again, Canada showed large gains as a supplier of crude calcium chloride as a result of continued expansion by Allied at its Amherstburg plant in conjunction with the closure of its Syracuse, NY, plant.

In addition to a large increase in imports from the Federal Republic of Germany, three countries exported crude calcium chloride to the United States in 1986 that had not done so in 1985. These countries were Dominica, 3,615 tons; Finland, 12,406 tons; and the German Democratic Republic, 4,874 tons.

Imports of other calcium chloride in 1986 nearly equaled 1985 levels. Other calcium chloride was supplied by 11 countries, led by the Federal Republic of Germany with 61%.

For the first time in this report, import data for crude calcium chloride and other calcium chloride have been tabulated separately in table 3 because of the difference in their unit values—$100.49 and $602.27 per ton, respectively—and the significant increase in these imports since 1984.

Imports of other calcium compounds included 39,158 tons of crude calcium borate valued at $8.8 million, mainly from Turkey; 3,109 tons of calcium bromide valued at $1 million, mainly from Israel; 17,616 tons of calcium carbide valued at $5.6 million, mainly from Canada; 7,034 tons of calcium hypochlorite valued at $9.7 million, mainly from Canada and Japan; 1,566 tons of dicalcium phosphate valued at $1.3 million, mainly from the Federal Republic of Germany; 345,260 tons of crude calcium carbonate natural chalk valued at $2.1 million, mainly from the Bahamas; 5,457 tons of calcium carbonate chalk whiting valued at $1.2 million, mainly from France; 18,706 tons of precipitated calcium carbonate valued at $7.8 million, mainly from France and Japan; 329,795 tons of limestone for fertilizer manufacture valued at $2.9 million from Canada; 3,397 tons of calcium cyanamide valued at $0.9 million, mainly from Canada; and 146,244 tons of calcium nitrate valued at $16 million, mainly from Norway. Also imported were small amounts of chlorinated lime, crude calcium acetate, calcium citrate, crude calcium tartrate, calcium propionate, other calcium salts, and precipitated and satin white calcium sulfate. The combined c.i.f. value for all imported calcium compounds, including calcium chloride and metal, was $78 million.

U.S. import duties were in effect during the year for calcium bromide, calcium carbide, other calcium chloride, calcium hypochlorite, calcium molybdate, dicalcium phosphate, calcium tungstate, and other calcium compounds. Listed as duty free were calcium arsenate, crude calcium borate, crude calcium chloride, and calcium cyanide.

Calcium metal was imported from four countries. The U.S.S.R. supplied 216,316 pounds; France, 181,715 pounds; China, 165,972 pounds; and Canada, 2,167 pounds. U.S. import duties in effect during the year for calcium metal were 3.6% ad valorem for countries having most-favored-nation status (MFN), 3.0% ad valorem for less developed and developing countries, and 25% ad valorem for non-MFN.

Table 2.—U.S. exports of calcium chloride, by country

Country	1985 Short tons	1985 Value[1]	1986 Short tons	1986 Value[1]
Cameroon	1,333	$179,239	--	--
Canada	14,755	2,494,945	13,341	$2,308,561
Egypt	1,872	522,866	--	--
Mexico	786	216,595	448	132,904
Netherlands	874	138,583	595	132,530
Sweden	968	1,136,964	907	412,852
Switzerland	5	2,938	277	141,178
Trinidad and Tobago	214	48,565	2	1,872
Turkey	660	119,741	324	54,429

See footnote at end of table.

Table 2.—U.S. exports of calcium chloride, by country —Continued

Country	1985 Short tons	1985 Value[1]	1986 Short tons	1986 Value[1]
United Arab Emirates	2,713	$636,939	840	$230,666
United Kingdom	288	87,003	72	21,751
Venezuela	73	58,690	249	118,386
Other	1,602	699,888	1,113	407,118
Total	26,143	6,342,956	18,168	3,962,247

[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 Pounds	Calcium Value[1]	Crude calcium chloride Short tons	Crude calcium chloride Value[1]	Other calcium chloride Short tons	Other calcium chloride Value[1]
1982	333,054	$966,665	60,316	$2,421,557	307	$588,655
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

[1]U.S. Customs, insurance, freight.

Source: Bureau of the Census.

Table 4.—U.S. imports for consumption of calcium chloride, by country

Country	1985 Short tons	1985 Value[1]	1986 Short tons	1986 Value[1]
Crude:				
Canada	64,908	$6,977,471	111,991	$9,317,161
Germany, Federal Republic of	26	89,416	5,175	861,372
Mexico	1,572	54,489	516	12,614
Sweden	8,764	1,900,040	4,734	806,112
Other	111	37,936	20,912	3,406,134
Total	75,381	9,059,352	143,328	14,403,393
Other:				
Canada	550	294,827	363	418,256
Germany, Federal Republic of	595	238,029	1,286	460,180
Sweden	515	511,883	22	22,006
Other	696	863,237	427	363,110
Total	[2]2,355	1,907,976	2,098	1,263,552

[1]U.S. Customs, insurance, freight.
[2]Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

WORLD REVIEW

Calcium metal was produced in Canada, China, France, Japan, and the U.S.S.R., in addition to the United States. The market economy country production of calcium metal was estimated to be about 1,500 tons. Total world production was an estimated 2,000 tons.

Following a practice begun in the United States in 1985 and a worldwide trend toward alkaline papermaking, Pfizer built a 33,000-ton-per-year on-site PCC plant at Fujiwara, Japan, under an agreement with Onoda Cement Co. Ltd. Onoda Cement supplied the lime and carbon dioxide to produce PCC for Japanese papermakers, and Pfizer provided the technology and marketing experience.

[1]Physical scientist, Division of Industrial Minerals.

Cement

By Wilton Johnson[1]

U.S. cement demand increased for the fourth consecutive year reaching an all-time high of 91.5 million short tons, surpassing the 90.5-million-ton record high set in 1973. New construction put in place increased 6% to $378 billion.[2] The number of new housing units started increased only slightly to 1.8 million units with all regions of the country, except the South, experiencing gains in new units started.

Cement imports, a sensitive indicator of demand, increased 12% to a record-high level of 16.3 million tons, surpassing the record-high level of 14.5 million tons established in 1985. Clinker imports accounted for 25% of the total.

Shipments of portland and masonry cement from U.S. plants, excluding Puerto Rico, increased 5% to 87.6 million tons. All consuming regions except the South experienced gains in shipments. The Northeast and North Central regions experienced the largest gains with 14% and 13%, respectively, followed by the West with 6%.

Acquisition of U.S. cement plants by foreign firms continued at an accelerated pace. By yearend, approximately 49% of clinker and 51% of finish grinding capacity had been acquired by foreign interests compared with 32% and 35%, respectively, in 1985. At yearend, 6 of the top 10 U.S. producing companies were owned by foreign firms.

Domestic Data Coverage.—Domestic production and consumption data for cement are developed by means of the portland and masonry cement voluntary survey. Of the 141 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)

	1982	1983	1984	1985	1986
United States:[1]					
Production[2]	63,355	70,420	77,700	77,895	78,786
Shipments from mills[2 3]	64,066	70,933	80,166	83,032	87,592
Value[2 3 4] thousands	$3,263,585	$3,534,324	$4,152,258	$4,286,399	$4,407,722
Average value per ton[2 3 4]	$50.94	$49.95	$51.80	$51.61	$50.32
Stocks at mills,[2] Dec. 31	6,753	6,711	6,866	7,232	6,725
Exports	201	118	80	98	59
Imports for consumption	2,911	4,221	8,689	14,120	16,128
Consumption, apparent[5 6]	65,623	73,435	84,313	87,456	91,501
World: Production	[r]978,144	[r]1,010,392	1,037,003	[p]1,055,738	[e]1,099,894

[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 141 plants in 40 States. In addition, two companies operated two plants in Puerto Rico, manufacturing hydraulic cement.

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 San Luis Obispo and Kern 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, St. Lawrence, Lewis, Madison, and Oneida 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, Queens, and Richmond) plus Nassau, Rockland, Suffolk, and Westchester Counties.

Pennsylvania, Eastern.—All counties east of the eastern boundaries of Potter, Clinton, Centre, Franklin, and Huntingdon 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.

In order to release more data at the State level, the States of Indiana, Kansas, Maryland, Michigan, Utah, and Washington, formerly combined with other States to form producing districts, are reported individually beginning with this report.

PORTLAND CEMENT

Clinker production in the United States, excluding Puerto Rico, increased 4% to 68.6 million tons, and clinker imports received by U.S. cement producers decreased 18% to 3.2 million tons. A total of 75.2 million tons of portland cement was ground in the United States. Stocks at mills decreased by 500,000 tons to 6.3 million tons at yearend.

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 31% of total clinker production; the 10 largest producers provided a combined 52%. The 10 largest companies, in decreasing order of size of clinker production, were Lone Star Industries Inc., Gifford-Hill & Co. Inc., General Portland Inc., Ideal Basic Industries Inc., Kaiser Cement Corp., Lehigh Portland Cement Co., Dundee Cement Co., Blue Circle Inc., Southwestern Portland Cement Co., and Moore McCormack Resources Inc.

At yearend, 242 kilns at 122 plants were being operated by 44 companies and 1 State agency in the United States, excluding Puerto Rico. Annual clinker production capacity at yearend was 86.6 million tons. An average of 55 days downtime was reported for kiln maintenance and repair. The industry operated at an average 79.3% of its apparent annual capacity. Average annual clinker capacity of U.S. kilns was 340,000 tons, average plant capacity was 710,000 tons, and average company capacity was about 2.0 million tons. Three plants produced white cement. In addition, 13 plants operated grinding mills using only imported or purchased clinker, or interplant transfers of clinker. Based on the fineness to which Types I and II cements must be ground and allowing for downtime for maintenance, the U.S. cement industry's estimated annual grinding capacity was 102 million tons.

Clinker was produced by wet-process kilns at 50 plants and by dry-process kilns at 69 plants; 3 additional plants operated both wet and dry kilns. At yearend, there were 55 suspension and 21 grate preheaters in operation.

Capacity Additions Planned.—Box-Crow Cement Co. continued construction of a

1-million-ton-per-year cement plant near Midlothian, TX. The plant was expected to go on-stream early in 1987.

Florida Crushed Stone Co. continued construction of its 600,000-ton-per-year plant in Brooksville, FL. The plant also will feature a 125-megawatt power generation facility and the capacity to produce 350,000 tons per year of lime. The plant was expected to begin clinker production in early 1987.

Plant Closings.—Missouri Portland Cement Co. temporarily closed its 1-million-ton-per-year Joppa, IL, plant and used it as a distribution facility.

Corporate Changes.—SA des Cimenteries CBR, a Belgian cement company, purchased Genstar Cement Ltd.'s cement operations in Redding, CA.

Centex Cement Enterprises Inc., Dallas, TX, purchased Monolith Portland Cement Co.'s Laramie, WY, plant and formed a new subsidiary called Mountain Cement Co.

Gifford-Hill, Dallas, TX, was acquired by C. H. Beazer PLC of the United Kingdom.

R. C. Cement Co., St. Louis, MO, a subsidiary of the joint venture Rugby Portland Cement Co. PLC of the United Kingdom and Unicem S.p.A. of Italy, formed Heartland Cement Co. Heartland acquired Lehigh's Independence, KS, cement plant and all of its assets.

MPC Holdings Inc., jointly owned by Cementia Holding AG of Zurich, Switzerland, and Dalcem Beteiligungs of the Federal Republic of Germany, purchased the Joppa, IL, cement plant of Missouri Portland Cement.

Majority interest in Ideal, the Nation's third largest cement producer, was acquired by the Swiss firm Holderbank Financiere Glaris Ltd.

Texas-Lehigh Cement Co., Buda, TX, formed a joint venture with Centex Cement Corp. to produce and market cement in Texas.

Tarmac PLC, a British construction firm, acquired 60% interest in Lone Star's southeastern operations. The businesses acquired include cement, aggregate, concrete, and concrete products operations in North Carolina, South Carolina, and Virginia.

Lafarge Corp. formed a new distribution network composed of General Portland's Peninsular Div., Canada Cement Lafarge Ltd.'s Ontario Region, and the recently acquired Huron Cement Co. The distribution network was expected to cover market areas encompassing Ontario, Canada, and parts of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, and Wisconsin.

Table 2.—Portland cement production, capacity, and stocks in the United States, by district[1]

District	1985					1986				
	Plants active during year	Production[2] (thousand short tons)	Capacity[3] Finish grinding (thousand short tons)	Capacity[3] Percent utilized	Stocks[4] at mills, Dec. 31 (thousand short tons)	Plants active during year	Production[2] (thousand short tons)	Capacity[3] Finish grinding (thousand short tons)	Capacity[3] Percent utilized	Stocks[4] at mills, Dec. 31 (thousand short tons)
New York and Maine	6	3,655	3,915	93.3	304	6	4,018	4,028	99.8	276
Pennsylvania, eastern	9	4,327	5,121	84.5	360	9	4,790	5,903	81.1	344
Pennsylvania, western	4	1,272	2,466	51.5	169	4	1,435	2,310	62.1	175
Maryland	3	W	W	W	W	3	1,771	1,902	93.0	158
Ohio	6	1,738	2,603	66.7	213	6	1,657	2,603	63.6	163
Michigan	5	W	W	W	W	5	4,830	6,740	71.6	468
Indiana	4	W	W	W	W	4	2,347	2,981	78.7	221
Illinois	4	2,073	2,880	71.9	128	4	2,139	2,950	72.5	146
Georgia and Tennessee	4	2,021	2,495	81.0	227	4	2,115	2,565	82.4	226
South Carolina	3	2,276	3,447	66.0	97	3	2,252	3,447	65.3	114
Kentucky, Virginia, West Virginia	3	W	W	W	W	3	2,623	2,812	93.2	177
Florida	5	3,403	4,186	81.3	178	5	3,109	4,186	74.2	227
Nebraska, Wisconsin	4	W	W	W	W	4	W	W	W	W
Alabama	6	3,723	5,594	66.5	378	6	3,494	5,584	62.6	361
Arkansas, Louisiana, Mississippi	4	2,141	2,790	76.7	141	4	1,679	2,790	60.2	153
Utah	3	W	W	W	W	3	1,015	1,365	74.3	102
South Dakota	1	665	1,806	36.8	60	1	632	1,806	35.0	58
Iowa	4	1,642	3,072	53.4	348	4	2,006	3,072	65.2	292
Missouri	5	3,883	4,950	78.4	605	5	4,636	4,900	94.6	397
Kansas	5	W	W	W	W	5	1,747	2,485	70.2	226
Oklahoma	3	1,584	2,080	76.1	207	3	1,653	2,080	79.4	277
Texas, northern	9	5,096	5,474	93.0	364	9	3,677	5,474	67.1	294
Texas, southern	9	5,023	6,936	72.4	225	9	4,654	6,545	71.1	222
Idaho and Montana	3	W	W	W	W	3	630	975	64.5	124
Colorado and Wyoming	4	1,592	2,550	62.4	154	4	1,428	2,720	52.4	134
Alaska and Oregon	2	W	W	W	W	2	W	W	W	W
Arizona, Nevada, New Mexico	4	2,102	3,015	69.7	103	4	2,290	3,015	75.9	141
California, northern	3	2,518	3,165	79.5	119	3	2,727	3,025	90.1	130
California, southern	8	6,860	9,346	73.4	301	8	7,230	9,056	79.8	310
Hawaii	2	209	560	37.2	25	2	301	520	57.9	42
Washington	4	W	W	W	W	4	1,143	2,029	56.3	159
Total or average	139	74,637	102,282	73.0	6,776	139	75,217	102,288	73.7	6,276
Puerto Rico	2	964	2,210	43.6	35	2	1,130	2,209	51.1	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 (11 in 1985 and 13 in 1986) as follows: Alaska (1); Florida (2 in 1985 and 3 in 1986), Michigan (1), New York (1), Pennsylvania (1 in 1985 and 2 in 1986), Texas (3), and Wisconsin (2).

[2]Includes cement produced from imported clinker (1985—1,914,000 tons and 1986—1,727,000 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, 1986

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	53	4,056	3,423	84.4
Pennsylvania, eastern	2	5	--	7	16	15.0	62	4,545	4,372	96.2
Pennsylvania, western	3	1	--	4	8	6.0	22	2,058	1,482	71.9
Maryland	1	2	--	3	7	6.0	39	1,956	1,683	86.0
Ohio	2	3	1	6	10	8.0	54	2,488	1,525	61.3
Michigan	2	2	--	4	13	16.0	42	5,168	4,050	78.4
Indiana	2	2	--	4	8	9.0	55	2,790	2,181	78.2
Illinois	--	4	--	4	7	4.0	11	1,416	1,329	93.9
Georgia and Tennessee	1	3	--	4	7	7.0	36	2,303	2,060	89.4
South Carolina	2	1	--	3	7	8.0	64	2,408	2,314	96.1
Kentucky, Virginia, West Virginia	1	2	--	3	9	8.0	26	2,712	2,352	86.7
Florida	2	1	--	3	5	7.0	33	2,324	2,261	97.3
Nebraska and Wisconsin	1	1	--	2	4	W	W	W	W	W
Alabama	1	4	--	5	7	9.0	12	3,177	2,772	87.3
Arkansas, Louisiana, Mississippi	4	--	--	4	8	8.0	34	2,648	1,651	62.3
Utah	2	1	--	3	6	4.0	58	1,228	983	80.0
South Dakota	--	--	1	1	3	2.0	29	1,008	589	58.4
Iowa	--	3	--	3	5	6.0	60	1,830	1,780	97.3
Missouri	2	3	--	5	7	14.0	47	4,452	4,376	98.3
Kansas	3	2	--	5	15	7.0	61	2,128	1,755	82.5
Oklahoma	1	2	--	3	7	5.0	19	1,900	1,764	92.8
Texas, northern	5	3	--	8	20	14.0	47	4,452	3,697	83.0
Texas, southern	2	3	1	6	8	15.0	36	4,935	3,324	67.4
Idaho and Montana	3	--	--	3	4	3.0	69	888	521	58.7
Colorado and Wyoming	1	2	--	3	5	5.0	12	1,765	1,574	89.1
Alaska and Oregon	--	1	--	1	1	W	W	W	W	W
Arizona, Nevada, New Mexico	--	4	--	4	11	8.0	61	2,433	2,100	86.3
California, northern	--	3	--	3	3	10.0	57	3,083	2,705	87.7
California, southern	1	7	--	8	18	28.0	49	8,854	7,734	87.3
Hawaii	--	2	--	2	2	1.0	127	238	225	94.4
Washington	2	1	--	3	5	3.0	48	951	799	84.0
Total or average	50	69	3	122	242	255.0	55	86,586	68,635	79.3
Puerto Rico	2	--	--	2	6	6.0	11	2,129	968	45.4

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 days for maintenance, times the reported 24-hour capacity.
[3]Includes production reported for plants that added or shut down kilns during the year.

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
1985:				
Less than 1,150	25	41	19,457	7.0
1,151 to 1,700	27	58	45,283	16.3
1,701 to 2,300	24	43	44,745	16.1
2,301 to 2,800	22	49	52,596	19.0
2,801 and over	28	84	116,239	41.6
Total	126	275	278,320	100.0
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

[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	1984	1985	1986
Calcareous:			
Limestone (includes aragonite, marble, chalk)	78,484	77,627	78,995
Cement rock (includes marl)	27,010	24,255	23,495
Coral	1,103	1,277	1,040
Other	--	243	428
Argillaceous:			
Clay	6,045	5,635	5,734
Shale	3,087	3,182	3,282
Other (includes staurolite, bauxite, aluminum dross, alumina, volcanic material, other)	47	123	261
Siliceous:			
Sand and calcium silicate	1,958	1,930	1,934
Sandstone, quartzite, other	696	608	709
Ferrous: Iron ore, pyrites, millscale, other iron-bearing material	1,232	1,307	1,081
Other:			
Gypsum and anhydrite	3,967	3,959	4,103
Blast furnace slag	27	97	74
Fly ash	841	796	689
Other, n.e.c	296	311	346
Total	124,793	121,350	[2]122,169

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

MASONRY CEMENT

Production of masonry cement increased 10% to 3.6 million tons. At yearend, 99 plants were manufacturing masonry cement in the United States. Two plants producing masonry cement 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	1985			1986		
	Plants active during year	Production (thousand short tons)	Stocks[1] at mills, Dec. 31 (thousand short tons)	Plants active during year	Production (thousand short tons)	Stocks[1] at mills, Dec. 31 (thousand short tons)
New York and Maine	4	71	13	4	97	13
Pennsylvania, eastern	6	233	37	7	281	29
Pennsylvania, western	3	73	14	4	93	15
Maryland	2	W	W	2	W	W
Ohio	4	113	26	4	130	18
Michigan	5	W	W	4	271	62
Indiana	4	W	W	4	392	64
Illinois	1	W	W	1	W	W
Georgia and Tennessee	4	188	23	4	214	28
South Carolina	2	W	W	2	W	W
Kentucky, Virginia, West Virginia	4	227	13	4	294	15
Florida	4	395	22	4	415	7
Nebraska and Wisconsin	2	W	W	3	12	7
Alabama	7	256	37	7	249	24
Arkansas, Louisiana, Mississippi	3	79	10	2	69	6
Utah	1	W	W	1	W	W
South Dakota	1	4	2	1	2	1
Iowa	3	42	11	3	47	15
Missouri	4	139	26	4	160	18
Kansas	5	W	W	5	50	20
Oklahoma	3	46	11	3	52	13
Texas, northern	7	199	18	7	164	20
Texas, southern	5	64	8	5	52	8
Idaho and Montana	1	W	W	3	W	W
Colorado and Wyoming	2	W	W	2	W	W
Alaska and Oregon	--	W	W	--	W	W
Arizona, Nevada, New Mexico	3	98	5	3	90	6
California, northern	1	W	W	1	W	W
California, southern	1	W	W	1	W	W
Hawaii	1	6	1	1	7	(2)
Washington	3	W	W	3	5	5
Total or average	96	3,258	456	99	3,569	449

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1]Includes imported cement.
[2]Less than 1/2 unit.

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 78% 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 was 4.3 million British thermal units (Btu).

The average consumption of electrical energy decreased slightly to 137 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 5.5 million Btu per ton, a slight decrease from that of 1985.

Average fuel consumption for kiln firing in wet-process plants, 5.3 million Btu per ton, was 29% higher than average fuel consumption in dry-process plants, 4.1 million Btu per ton. Approximately 59% of clinker production was by the dry process.

Kilns without preheaters averaged 5.6 million Btu per ton of clinker produced; those with suspension preheaters averaged 3.9 million Btu per ton and those with grate-type preheaters averaged 5.5 million Btu per ton.

Coal accounted for 95% of kiln fuel consumption, natural gas accounted for 4%, and oil and waste fuel accounted for the remainder.

Energy-saving additives for cement production, such as fly ash and blast furnace slags, continued to be used but on a smaller scale. The use of fly ash decreased 13% to 689,000 tons. The use of slags decreased 24% to 74,000 tons.

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)
1985:						
Coal	25	13,435	20.0	2,631	--	--
Coal and oil	25	15,450	23.0	2,710	510	--
Coal and natural gas	53	28,886	43.0	4,831	--	8,020,775
Oil and natural gas	--	--	--	--	35	--
Coal, oil, natural gas	23	9,405	14.0	1,434	210	2,623,539
Total	126	67,176	100.0	11,606	755	10,644,314
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	100.00	11,226	698	12,098,284

[1]Includes Puerto Rico.
[2]Includes 1.3% anthracite, 94.5% bituminous, and 4.2% petroleum coke in 1985; 1% anthracite, 94% bituminous, and 5% petroleum coke in 1986.

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)
1985:						
Wet	53	26,066	38.8	5,227	210	4,341,724
Dry	68	37,797	56.3	5,800	525	5,471,841
Both	5	3,313	4.9	579	20	830,749
Total	126	67,176	100.0	11,606	755	10,644,314
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

[1]Includes Puerto Rico.
[2]Includes 1.3% anthracite, 94.5% bituminous, and 4.2% petroleum coke in 1985; 1% anthracite, 94% bituminous, and 5% petroleum coke in 1986.

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: 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)
1985:								
Wet	2	103	49	3,235	3,338	35.0	25,846	129.1
Dry[2]	5	548	66	5,118	5,666	59.4	39,585	143.1
Both	--	--	5	533	533	5.6	3,601	148.0
Total or average	7	651	120	8,886	9,537	100.0	69,032	138.2
Percent of total electric energy used	--	6.8	--	93.2	--	--	--	--
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	--	--	--	--

[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, 95%; by truck, 92%; and made directly from cement manufacturing plants, 68%, rather than distribution terminals.

With respect to shipments of cement from plants to terminals, the preferred modes of transportation were railroads and waterways, 42% each. Transportation by truck accounted for 13%. 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				Total shipments
			From terminal to consumer		From plant to consumer		
	In bulk	In containers	In bulk	In containers	In bulk	In containers	
1985:							
Railroad	9,089	89	1,079	1	3,464	75	4,619
Truck	4,073	185	22,885	554	48,536	3,474	75,449
Barge and boat	7,866	89	472	--	158	--	630
Unspecified[2]	520	--	6	--	36	4	46
Total	21,548	363	24,442	555	52,194	3,553	[3]80,744
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

[1]Includes Puerto Rico.
[2]Includes cement used at plant.
[3]Bulk shipments were 94.5%, and container (bag) shipments were 5.5%.

CONSUMPTION AND USES

Cement consumption in the United States, excluding Puerto Rico, increased 4% to 91.5 million tons. Domestic producers' shipments increased 5% to 87.6 million tons, which included 8.8 million tons of imported cement. Additional imports of 3.9 million tons were shipped by other importers.

Domestic cement shipments to all regions of the United States increased except for the South. The Northeast and North Central regions registered the largest increases, 14% and 13%, respectively, followed by the West with 6%.

The end-use distribution pattern for portland cement did not differ significantly from that of recent years. Ready-mixed concrete producers were the primary consumers, accounting for 72% of the total quantity shipped by domestic producers. Manufacturers of concrete products used 12% of the total to produce concrete blocks, pipes, and precast, prestressed, and other concrete products. The remainder was used by highway contractors; building material dealers; other contractors; Federal, State, and other government agencies; and other miscellaneous users.

According to the U.S. Department of Commerce, the value of U.S. construction put in place increased 6% to $378 billion.[3] Of this total value, 35% was in private housing; 25% was in private industrial and commercial buildings, including farms; 6% was in public buildings; 6% was in highways and streets; and the remainder was in other public construction and public utilities.

Total value of private construction put in place increased 5% to $307 billion. The value of residential units put in place decreased 12% to $176 billion, and industrial-commercial construction put in place decreased slightly to $93 billion. Total value of public construction put in place increased 13% to $71 billion. Public buildings increased 20% to $24 billion, while highway construction increased 5% to $21 billion. Other public construction including military facilities and conservation and development areas increased 15% to $26 billion.

Housing starts increased slightly to 1.8 million units, consisting of 1.2 million single units and 628,000 multiunits, according to Commerce. On a regional basis, housing starts decreased 6% in the South to 733,000 units, increased 17% in the Northeast to 294,000 units, increased slightly in the West to 483,000 units, and increased 23% in the Midwest to 296,000 units.

Table 11.—Portland cement shipped by producers in the United States, by district[1]

District	1985			1986		
	Quantity (thousand short tons)	Value (thousands)	Average per ton	Quantity (thousand short tons)	Value (thousands)	Average per ton
New York and Maine	3,639	$175,255	$48.16	3,812	$207,905	$54.55
Pennsylvania, eastern	4,272	236,159	55.28	4,862	265,800	54.66
Pennsylvania, western	1,263	51,310	40.62	1,428	58,387	40.88
Maryland	W	W	W	1,785	89,799	50.30
Ohio	1,769	84,929	48.00	1,706	79,383	46.53
Michigan	W	W	W	4,713	216,120	45.86
Indiana	W	W	W	2,136	92,327	43.22
Illinois	2,101	86,211	41.03	2,118	83,783	39.55
Georgia and Tennessee	2,162	101,784	47.07	2,254	108,194	48.00
South Carolina	2,207	104,705	47.44	2,306	109,529	47.49
Kentucky, Virginia, West Virginia	2,105	101,991	48.46	2,427	117,980	48.61
Florida	3,282	148,908	45.37	3,189	147,643	46.29
Nebraska and Wisconsin	W	W	W	W	W	W
Alabama	3,721	165,972	44.60	3,477	153,629	44.18
Arkansas, Louisiana, Mississippi	2,133	111,026	52.05	1,668	83,130	49.83
Utah	W	W	W	1,014	58,431	57.62
South Dakota	655	W	W	635	W	W
Iowa	1,618	77,890	48.13	1,819	86,984	47.81
Missouri	3,669	159,757	43.54	4,642	179,184	38.60
Kansas	W	W	W	1,763	91,110	51.67
Oklahoma	1,589	72,583	45.67	1,579	69,075	43.74
Texas, northern	5,287	305,355	57.75	3,707	198,397	53.51
Texas, southern	4,955	227,704	45.97	5,176	214,300	41.40
Idaho and Montana	557	30,850	55.38	707	35,599	50.35
Colorado and Wyoming	1,582	100,832	63.73	1,458	90,391	61.99
Alaska and Oregon	W	W	W	W	W	W
Arizona, Nevada, New Mexico	2,192	145,476	66.36	2,289	149,312	65.23
California, northern	2,595	158,656	61.13	2,406	142,018	59.02
California, southern	6,868	442,850	64.48	7,083	436,484	61.62
Hawaii	215	16,050	74.65	287	24,253	84.50
Washington	W	W	W	1,212	59,091	48.75
Total[2 3] or average	74,250	3,817,335	51.41	75,181	3,759,942	50.01
Foreign imports[4]	5,532	252,480	45.64	8,814	411,614	46.70
Puerto Rico	962	72,602	75.47	1,132	93,288	82.40
Grand total[3] or average	80,744	4,142,417	51.30	85,127	4,264,844	50.10

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 (11 in 1985 and 13 in 1986) as follows: Alaska (1), Florida (2 in 1985 and 3 in 1986), Michigan (1), New York (1), Pennsylvania (1 in 1985 and 2 in 1986), Texas (3), 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.

Table 12.—Masonry cement shipped by producers in the United States,[1] by district

District	1985 Quantity (thousand short tons)	1985 Value (thousands)	1985 Average per ton	1986 Quantity (thousand short tons)	1986 Value (thousands)	1986 Average per ton
New York and Maine	76	$5,074	$66.76	102	$6,996	$68.59
Pennsylvania, eastern	230	15,006	65.24	297	19,337	65.10
Pennsylvania, western	74	5,964	80.59	94	7,345	78.13
Maryland	W	W	W	W	W	W
Ohio	110	10,412	94.65	138	11,540	83.62
Michigan	W	W	W	257	17,026	66.24
Indiana	W	W	W	395	22,936	58.06
Illinois	W	W	W	W	W	W
Georgia and Tennessee	192	13,152	68.50	209	15,031	71.91
South Carolina	W	W	W	W	W	W
Kentucky, Virginia, West Virginia	229	13,402	58.52	292	17,126	58.65
Florida	316	17,137	54.23	352	21,269	60.42
Nebraska and Wisconsin	W	W	W	W	W	W
Alabama	268	18,113	67.58	267	18,165	68.03
Arkansas, Louisiana, Mississippi	80	4,803	60.03	70	4,599	65.70
Utah	W	W	W	W	W	W
South Dakota	4	W	W	4	W	W
Iowa	39	3,372	86.46	48	3,199	66.64
Missouri	139	6,630	47.69	167	7,816	46.80
Kansas	W	W	W	51	3,264	64.00
Oklahoma	43	2,854	66.37	50	3,198	63.96
Texas, northern	187	15,965	85.37	146	11,155	76.40
Texas, southern	76	6,149	80.91	64	4,636	72.43
Idaho and Montana	3	241	80.33	3	187	62.33
Colorado and Wyoming	W	W	W	W	W	W
Alaska and Oregon	W	W	W	W	W	W
Arizona, Nevada, New Mexico	99	7,468	75.43	89	6,739	75.71
California, northern	W	W	W	W	W	W
California, southern	W	W	W	W	W	W
Hawaii	7	588	84.00	7	1,078	154.00
Washington	W	W	W	6	530	88.33
Total[2] or average	3,187	213,096	66.86	3,525	231,551	65.69
Foreign imports[3]	62	3,488	56.25	72	4,616	64.11
Grand total[2] or average	3,250	216,584	66.64	3,596	236,167	65.68

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] 1984	Portland cement[2] 1985	Portland cement[2] 1986	Masonry cement 1984	Masonry cement 1985	Masonry cement 1986
Destination:						
Alabama	1,204	1,306	1,302	94	100	112
Alaska[3]	197	156	121	W	W	W
Arizona	2,001	2,318	2,400	W	W	W
Arkansas	717	773	803	44	45	48
California, northern	3,166	3,439	3,438	W	W	W
California, southern	6,150	6,691	7,844	W	W	W
Colorado	1,674	1,574	1,450	30	23	22
Connecticut[3]	759	870	1,037	16	17	21
Delaware[3]	164	194	224	11	10	12
District of Columbia[3]	105	116	142	1	1	1
Florida	6,253	6,140	6,360	480	468	499
Georgia	2,775	2,875	3,224	209	228	242
Hawaii	186	214	287	5	7	7
Idaho	276	236	291	1	1	1
Illinois	1,236	1,391	1,511	31	28	30
Chicago, metropolitan[3]	1,378	1,333	1,803	41	45	59
Indiana	1,248	1,353	1,580	76	76	97
Iowa	1,204	1,078	1,046	14	11	13
Kansas	1,243	1,293	1,218	23	20	21

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]			Masonry cement		
	1984	1985	1986	1984	1985	1986
Destination —Continued						
Kentucky	973	1,014	1,115	81	78	85
Louisiana	2,650	2,420	1,964	80	65	48
Maine	265	283	336	10	10	12
Maryland	1,351	1,503	1,666	129	139	144
Massachusetts[3]	1,292	1,395	1,686	44	45	53
Michigan	1,903	2,103	2,478	90	104	127
Minnesota[3]	1,173	1,419	1,464	40	40	47
Mississippi	790	758	827	60	57	55
Missouri	1,650	1,735	2,221	48	39	47
Montana	252	190	241	2	1	1
Nebraska	823	783	764	12	11	11
Nevada	503	637	670	--	(4)	(4)
New Hampshire[3]	314	374	387	15	15	16
New Jersey[3]	1,672	1,743	1,972	68	78	87
New Mexico	618	620	572	10	10	9
New York, eastern	488	621	670	31	36	42
New York, western	773	812	986	40	43	53
New York, metropolitan[3]	1,403	1,722	1,932	50	50	54
North Carolina[3]	1,724	1,796	1,980	224	238	264
North Dakota[3]	346	286	277	6	5	4
Ohio	2,607	2,646	3,028	129	135	174
Oklahoma	1,751	1,329	1,107	60	40	34
Oregon	609	709	626	(4)	(4)	(4)
Pennsylvania, eastern	1,649	1,774	1,994	57	63	74
Pennsylvania, western	920	1,118	1,222	60	70	77
Rhode Island[3]	197	165	199	5	4	6
South Carolina	984	1,019	1,052	116	119	136
South Dakota	224	292	332	4	4	4
Tennessee	1,371	1,480	1,655	142	154	184
Texas, northern	5,466	5,474	4,705	182	171	140
Texas, southern	5,584	5,433	4,531	123	101	74
Utah	973	1,059	940	1	2	2
Vermont[3]	145	212	172	4	4	5
Virginia	1,946	2,116	2,410	166	177	219
Washington	1,156	1,208	1,251	7	6	7
West Virginia	445	387	426	29	29	28
Wisconsin	1,418	1,240	1,475	40	39	47
Wyoming	394	413	342	2	2	1
U.S. total	80,738	83,638	87,756	3,243	3,264	3,556
Foreign countries[5]	190	177	145	103	108	105
Puerto Rico	1,000	962	1,132	--	--	--
Total shipments[6]	81,928	84,778	89,033	3,346	3,373	3,659
Origin:						
United States[7]	74,376	74,250	75,181	3,281	3,187	3,525
Puerto Rico	997	962	1,132	--	--	--
Foreign:[8]						
Domestic producers	2,509	5,532	8,814	(4)	62	72
Other	4,046	4,034	3,909	65	124	62
Total shipments[6]	81,928	84,778	89,033	3,346	3,373	3,659

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 (1984—225,000 tons; 1985—253,000 tons; and 1986—327,000 tons) used in the manufacture of prepared masonry cement.

[3]Has no cement producing plants.

[4]Less than 1/2 unit.

[5]Direct shipments by producers to foreign countries and U.S. possessions and territories; includes States indicated by symbol W.

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

[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	
	1985	1986	1985	1986	1985	1986	1985	1986
Northeast:								
New England	3,299	3,817	4.0	4.3	96	112	2.9	3.2
Middle Atlantic	7,790	8,774	9.3	10.0	340	387	10.4	10.8
Total	11,089	12,591	13.3	14.3	436	499	13.3	14.0
South:								
Atlantic	16,148	17,508	19.3	20.0	1,409	1,546	43.2	43.5
East Central	4,558	4,900	5.5	5.6	389	435	11.9	12.2
West Central	15,429	13,110	18.4	14.9	423	344	13.0	9.7
Total	36,135	35,518	43.2	40.5	2,221	2,325	68.1	65.4
North Central:								
East	10,067	11,851	12.0	13.5	427	528	13.1	14.9
West	6,886	7,321	8.2	8.3	129	147	3.9	4.1
Total	16,953	19,172	20.2	21.8	556	675	17.0	19.0
West:								
Mountain	7,046	6,906	8.4	7.9	39	36	1.2	1.0
Pacific	12,417	13,567	14.9	15.5	13	21	.4	.6
Total[3]	19,463	20,473	23.3	23.4	52	57	1.6	1.6
Grand total[4]	83,638	87,756	100.0	100.0	3,264	3,556	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]Does not include proprietary data from table 13.
[4]Data may not add to totals shown because of independent rounding.

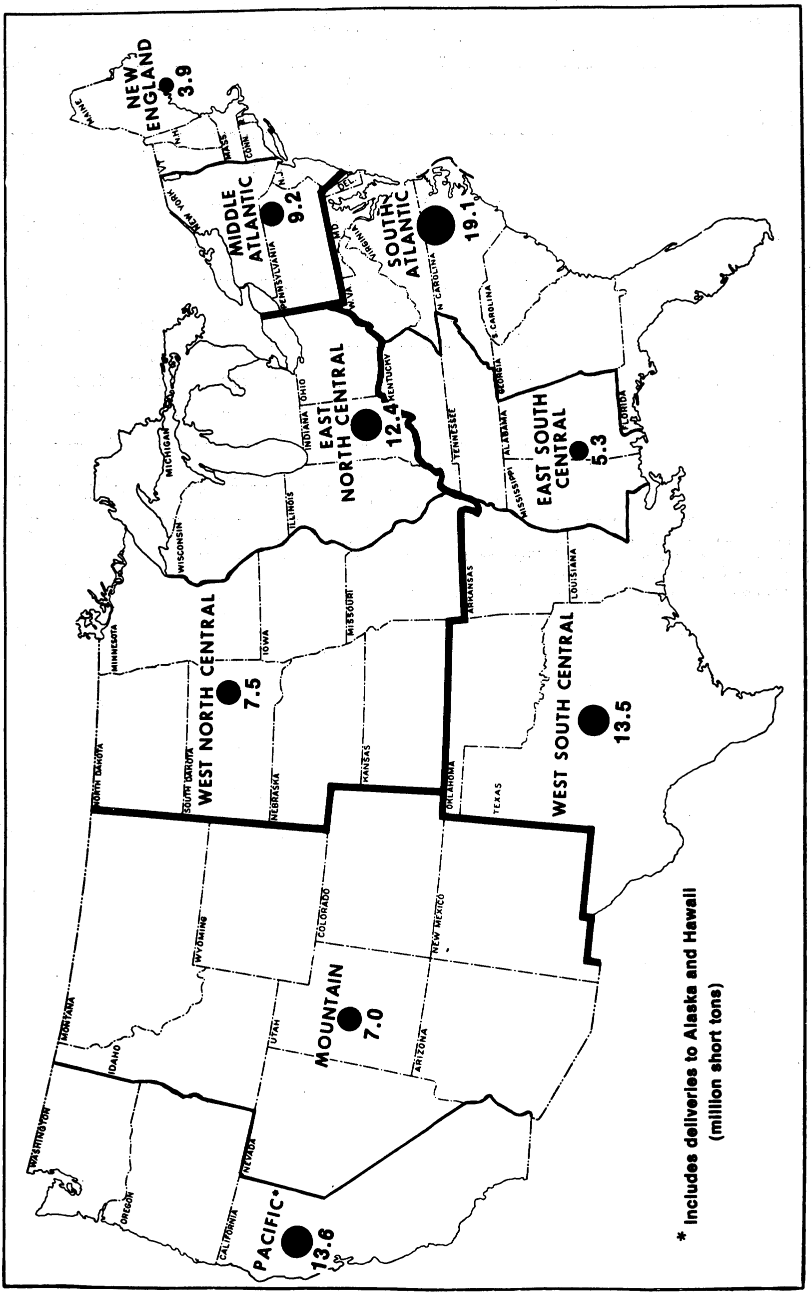

Figure 1.—Shipments of cement by geographic region of destination in 1986.

Table 15.—Portland cement shipments in 1986, 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	184	4.8	636	16.7	2,641	69.3	183	4.8	158	4.1	1	--	11	0.3	3,812
Pennsylvania, eastern	478	9.8	1,141	23.4	3,052	62.8	93	1.9	38	.8	--	--	61	1.3	4,862
Pennsylvania, western	215	15.1	267	18.7	793	55.5	102	7.1	52	3.6	--	--	--	--	1,428
Maryland	82	4.6	301	16.8	1,329	74.4	18	1.0	36	2.0	--	--	21	1.2	1,785
Ohio	171	10.0	256	15.0	1,198	70.2	76	4.4	4	.3	--	--	1	.1	1,706
Michigan	196	4.1	603	12.7	3,526	74.8	280	6.0	83	1.8	8	0.2	18	.4	4,713
Indiana	134	6.3	313	14.6	1,498	70.1	125	5.9	43	2.0	--	--	24	1.1	2,136
Illinois	43	2.1	208	9.8	1,733	81.8	63	3.0	45	2.1	--	--	27	1.2	2,118
Georgia and Tennessee	225	10.0	410	18.2	1,406	62.4	86	3.8	118	5.2	1	--	9	.4	2,254
South Carolina	61	2.6	383	16.6	1,708	74.1	39	1.7	90	4.0	1	--	24	1.0	2,306
Kentucky, Virginia, West Virginia	104	4.3	383	15.8	1,686	69.5	120	5.0	59	2.4	40	1.6	34	1.4	2,427
Florida	382	12.0	506	15.8	2,136	67.0	40	1.3	68	2.1	9	.3	48	1.5	3,189
Nebraska and Wisconsin	W	1.4	W	8.0	W	71.9	W	17.2	W	1.3	--	--	W	.2	W
Alabama	268	7.7	497	14.3	2,203	63.3	167	4.8	135	3.9	14	.4	197	5.6	3,477
Arkansas, Louisiana, Mississippi	65	3.9	157	9.4	951	57.0	110	6.6	257	15.4	8	.5	121	7.2	1,668
Utah	27	2.7	38	3.7	746	73.6	108	10.6	93	9.2	--	--	2	.2	1,014
South Dakota	8	1.3	28	4.4	359	56.6	67	10.6	120	18.9	--	--	52	8.2	635
Iowa	67	3.7	339	18.6	1,190	65.4	98	5.4	109	6.0	--	--	17	.9	1,819
Missouri	167	3.6	476	10.2	3,115	67.1	532	11.5	334	7.2	--	--	20	.4	4,642
Kansas	60	3.4	80	4.5	1,317	74.7	99	5.6	168	9.6	2	.1	37	2.1	1,763
Oklahoma	50	3.2	79	5.0	1,064	67.2	154	9.7	206	13.0	2	.1	28	1.8	1,579
Texas, northern	248	6.7	290	7.8	1,995	53.8	264	7.1	551	14.8	91	2.5	272	7.3	3,707
Texas, southern	184	3.6	409	7.9	3,773	72.9	357	6.9	245	4.7	24	.5	182	3.5	5,176
Idaho and Montana	15	2.1	47	6.6	494	69.9	35	5.0	107	15.1	--	--	9	1.3	707
Colorado and Wyoming	44	3.0	148	10.1	1,090	74.7	140	9.6	35	2.4	--	--	2	.2	1,458
Alaska and Oregon	W	3.0	W	9.5	W	74.9	W	3.8	W	1.3	--	--	W	7.5	W
Arizona, Nevada, New Mexico	82	3.6	403	17.6	1,469	64.2	73	3.2	257	11.2	--	--	5	.2	2,289
California, northern	186	7.7	298	12.4	1,807	75.1	18	.7	75	3.1	1	--	22	1.0	2,406
California, southern	197	2.8	853	12.0	5,351	75.5	22	.3	508	7.2	12	.2	142	2.0	7,083
Washington	22	1.8	77	6.4	1,007	83.1	62	5.1	16	1.3	--	--	28	2.3	1,212
Hawaii	18	6.3	42	14.6	202	70.4	2	.7	16	5.6	3	1.0	4	1.4	287
Foreign imports[3]	150	1.7	115	1.3	8,470	96.1	9	.1	53	.6	--	--	18	.2	8,814
Total[2] or average	4,162	5.0	9,911	11.8	60,385	71.9	3,751	4.5	4,099	4.4	219	.3	1,468	1.7	83,995
Puerto Rico	538	47.5	45	4.0	518	45.7	--	--	24	2.1	7	.6	1	.1	1,132

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]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	1985 Quantity (thousand short tons)	1985 Value[2] (thousands)	1985 Average per ton	1986 Quantity (thousand short tons)	1986 Value[2] (thousands)	1986 Average per ton
General use and moderate heat (Types I and II)	73,700	$3,699,651	$50.20	78,440	$3,862,869	$49.25
High-early-strength (Type III)	2,772	151,104	54.51	3,031	159,592	52.65
Sulfate-resisting (Type V)	373	22,645	60.71	433	26,295	60.72
Oil well	1,942	113,773	58.58	1,021	54,667	53.54
White	311	53,756	172.85	317	55,111	173.85
Portland slag and portland pozzolan	802	44,210	55.12	757	39,903	52.71
Expansive	35	3,380	96.57	42	3,743	89.11
Miscellaneous[3]	810	53,898	66.54	1,085	62,663	57.75
Total[4] or average	80,744	4,142,417	51.30	85,127	4,264,844	50.10

[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.

PRICES

The average reported unit mill value of all types of portland and masonry cement declined for the second consecutive year. The unit mill value of portland cement decreased slightly to $50.10 per ton. The unit mill value of masonry cement prepared at cement plants also declined slightly to $65.68.

According to Engineering News-Record (ENR), the average price of bulk portland cement shipped to 20 U.S. cities averaged $64.77 per ton, essentially the same as that reported for 1985. The ENR price quotations ranged from $49.00 per ton for Minneapolis, MN, to $75.00 per ton for Boston, MA.[4]

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
1982	$51.04	$61.56	$51.43
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

[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 possessions and territories experienced the second consecutive year of record-high imports. Combined imports of hydraulic cement and clinker increased 13% to 16.3 million tons. In decreasing order, Mexico, Canada, and Spain were the principal sources for imported cement accounting for 66% of the total. The increases were due entirely to gray cement imports. White cement and clinker both experienced declines in imports. Cement imports accounted for about 18% of U.S. apparent consumption.

Imports of white nonstaining portland cement decreased 5% to 261,000 tons, the first decline since 1982. Four countries, Canada, Denmark, Mexico, and Spain, accounted for the major portion of white cement imports.

Imports of clinker decreased 14% to 4.0 million tons. Four countries, in decreasing order, Mexico, Spain, France, and Greece, accounted for 72% of clinker imports.

Competition continued to grow among foreign cement producers for a larger share of the U.S. market. Domestic producers continued to position themselves to take advantage of the lower priced imported cement by forming joint ventures to market foreign cement in the United States. Among the more notable foreign trade developments was the petition filed in October by the American Cement Trade Alliance with the International Trade Commission (ITC) alleging that the U.S. cement industry was materially injured or threatened with material injury because imports of portland hydraulic cement and clinker from Colombia, France, Greece, Japan, the Republic of Korea, Mexico, Spain, and Venezuela were being sold in the United States at less than fair market value.

Following preliminary investigations, the ITC determined in December that there was no reasonable indication that the U.S. cement industry was materially injured by these imports.

The U.S. Department of Commerce completed its Cement Competitive Assessment study, which focused primarily on problems and issues encountered by the U.S. cement industry during the last 15 years. The study examined cement imports or other aspects of world trade only to determine their effect on domestic supplies and prices. However, by yearend, the study had not been published.

Other pertinent developments with regard to foreign trade include the following:

1. Olympic Cement Co.'s Minneapolis, MN, import terminal, formerly controlled by Apple Valley Red-e-Mix, was sold to the Spanish firm Cementos del Mar S.A. The name of the terminal was changed to Red Rock of Minnesota.

2. New York Cement Co. began selling imported cement from a silo ship anchored at the Brooklyn, NY, import terminal to supply imported cement to the New York metropolitan area.

3. Texas-Lehigh formed a joint venture with Cementos Mexicanos S.A. to market imported cement in the United States.

4. Gifford-Hill announced a long-term arrangement with Falcon Pacific Cement Co. Inc. to market cement imported from Japan through a silo ship anchored in the port of Los Angeles.

Exports of hydraulic cement and clinker declined 40% to 59,000 tons. Canada continued to be the principal recipient of U.S. cement exports receiving 93% of the total, followed by the Bahamas with 3%. The remaining 4% was shipped to 42 other countries.

Table 18.—U.S. exports of hydraulic cement and cement clinker, by country

Country	1984 Quantity (short tons)	1984 Value (thousands)	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)
Bahamas	118	$31	479	$46	1,780	$152
Bermuda	3	3	--	--	204	156
Canada	72,409	10,704	88,626	18,735	54,390	7,688
Mexico	3,464	1,525	3,903	1,477	1,121	445
Other[1]	r4,013	r1,233	r4,889	r1,220	1,061	583
Total	80,007	13,496	97,897	21,478	58,556	9,024

rRevised.
[1]Includes 58 countries in 1984; 40 in 1985; and 42 in 1986.

Source: Bureau of the Census.

Table 19.—U.S. imports for consumption of hydraulic cement and clinker, by country

(Thousand short tons and thousand dollars)

Country	1984 Quantity	1984 Value Customs	1984 Value C.i.f.[1]	1985 Quantity	1985 Value Customs	1985 Value C.i.f.[1]	1986 Quantity	1986 Value Customs	1986 Value C.i.f.[1]
Canada	2,945	116,815	128,920	3,393	131,117	145,005	3,272	123,220	133,907
Colombia	227	5,133	6,927	662	16,430	20,244	913	22,566	28,070
France	225	7,044	9,180	552	13,866	18,319	669	18,355	24,016
Greece	--	--	--	511	9,760	12,202	1,275	26,710	33,507
Japan	183	5,237	7,595	1,134	28,786	37,105	750	20,325	24,833
Korea, Republic of	332	10,046	12,129	484	26,194	29,738	456	11,814	15,202
Mexico	2,003	64,574	74,877	2,502	75,755	87,339	4,242	110,390	133,403
Spain	1,760	49,584	61,218	3,383	80,448	103,353	3,176	90,479	110,230
Venezuela	1,022	25,281	32,224	1,569	38,282	50,320	1,290	31,739	41,673
Other	149	10,493	10,412	298	16,791	20,148	276	13,395	17,586
Total	8,846	294,207	343,482	[2]14,487	437,429	523,773	16,319	468,993	562,427

[1]Cost, insurance, and freight.
[2]Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

Table 20.—U.S. imports for consumption of clinker, by country

(Thousand short tons and thousand dollars)

Country	1984 Quantity	1984 Value Customs	1984 Value C.i.f.[1]	1985 Quantity	1985 Value Customs	1985 Value C.i.f.[1]	1986 Quantity	1986 Value Customs	1986 Value C.i.f.[1]
Canada	485	16,947	19,406	746	22,156	25,763	358	10,534	12,768
Colombia	131	2,673	3,095	193	3,938	5,012	280	5,814	7,031
France	225	7,491	9,180	414	9,434	11,789	529	11,328	14,324
Greece	--	--	--	407	7,900	9,390	507	9,598	13,159
Japan	69	2,927	2,693	291	6,397	7,840	234	4,897	4,839
Mexico	477	11,608	13,077	581	14,671	16,387	1,095	19,199	23,823
Spain	523	11,885	14,860	1,656	31,877	39,917	711	13,726	17,653
Venezuela	294	5,623	7,484	290	5,570	7,022	213	4,030	4,839
Other	r10	r647	r840	r55	r1,124	r1,293	45	573	2,131
Total	[2]2,215	59,801	70,635	4,633	103,067	124,413	3,972	79,699	100,567

rRevised.
[1]Cost, insurance, and freight.
[2]Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

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	1985 Quantity	1985 Value Customs	1985 Value C.i.f.[1]	1986 Quantity	1986 Value Customs	1986 Value C.i.f.[1]
Anchorage:						
Canada	40	2,441	3,212	16	1,566	1,978
Japan	46	957	1,374	29	1,079	1,176
Korea, Republic of	49	1,984	2,766	(2)	7	8
Singapore	4	277	433	--	--	--
Total	139	5,659	7,785	45	2,652	3,162
Baltimore:						
Belgium	--	--	--	(2)	64	79
Brazil	--	--	--	(2)	1	2
Colombia	--	--	--	13	368	451
Germany, Federal Republic of	--	--	--	(2)	13	15
Greece	--	--	--	50	1,133	1,256
Japan	(2)	16	23	(2)	50	69
Mexico	6	179	219	14	313	495
Netherlands	(2)	26	28	67	1,760	1,879
Spain	105	2,836	3,824	(2)	35	40
Venezuela	84	1,055	1,377	62	1,709	2,196
Yugoslavia	--	--	--	(2)	52	98
Total[3]	196	4,112	5,471	208	5,498	6,580
Boston:						
Belgium-Luxembourg	(2)	12	15	--	--	--
Canada	60	1,819	1,855	138	4,878	5,165
Greece	--	--	--	92	2,277	2,358
Mexico	--	--	--	28	768	799
Spain	89	2,152	2,236	10	213	223
Venezuela	6	170	225	23	540	655
Total[3]	155	4,153	4,331	292	8,676	9,201
Buffalo: Canada	911	31,909	34,299	950	30,809	36,431
Charleston:						
France	(2)	17	20	--	--	--
Germany, Federal Republic of	(2)	6	7	--	--	--
Greece	--	--	--	60	1,204	1,500
Netherlands	--	--	--	(2)	17	21
Spain	130	2,449	3,240	--	--	--
Venezuela	29	499	532	--	--	--
Total[3]	160	2,971	3,799	60	1,221	1,521

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	1985			1986		
	Quantity	Value		Quantity	Value	
		Customs	C.i.f.[1]		Customs	C.i.f.[1]
Chicago:						
Canada	(2)	1	1	--	--	--
German Democratic Republic	(2)	2	3	--	--	--
Germany, Federal Republic of	(2)	43	57	(2)	118	152
Japan	(2)	6	9	--	--	--
Yugoslavia	(2)	9	16	--	--	--
Total	(2)	61	86	(2)	118	152
Cleveland:						
Canada	--	--	--	37	1,450	1,721
Netherlands	--	--	--	1	398	781
United Kingdom	--	--	--	1	27	27
Total	--	--	--	39	1,875	2,529
Detroit:						
Belgium-Luxembourg	--	--	--	(2)	28	28
Canada	477	20,901	22,268	349	17,728	18,365
Total[3]	477	20,901	22,268	349	17,755	18,393
Duluth:						
Canada	184	5,936	7,429	208	6,526	8,293
Germany, Federal Republic of	--	--	--	(2)	5	5
Total	184	5,936	7,429	208	6,531	8,298
El Paso:						
Canada	(2)	16	16	--	--	--
Malaysia	--	--	--	(2)	3	5
Mexico	541	18,653	18,653	504	18,960	18,960
Total	541	18,669	18,669	504	18,963	18,965
Great Falls:						
Canada	(2)	61	61	(2)	65	65
Germany, Federal Republic of	(2)	35	49	(2)	21	23
Total[3]	(2)	96	110	1	86	88
Honolulu:						
Japan	--	--	--	85	1,882	2,552
Korea, Republic of	52	4,600	5,035	10	368	495
Total	52	4,600	5,035	95	2,250	3,047
Houston:						
Canada	9	320	459	--	--	--
Colombia	112	1,961	2,493	152	3,345	3,822
Germany, Federal Republic of	(2)	135	169	(2)	207	256
Greece	29	711	1,108	--	--	--
Korea, Republic of	--	--	--	(2)	50	50
Mexico	--	--	--	105	1,888	2,683
Netherlands	(2)	10	13	--	--	--
Spain	518	11,887	13,937	577	15,586	17,896
Venezuela	22	668	775	(2)	7	12
Yugoslavia	1	43	59	--	--	--
Total[3]	692	15,735	19,013	835	21,083	24,719
Laredo: Mexico	68	2,368	2,328	182	5,804	5,804
Los Angeles:						
Canada	--	--	--	20	347	464
Denmark	9	662	1,032	11	764	1,130
France	3	16	19	(2)	59	66
Germany, Federal Republic of	--	--	--	(2)	93	109
Japan	344	9,002	10,543	375	10,622	12,619
Korea, Republic of	294	17,346	19,216	343	8,700	11,069
Mexico	(2)	3	3	--	--	--
Spain	256	6,288	8,973	182	4,980	6,598
Taiwan	(2)	17	31	(2)	15	19
United Kingdom	--	--	--	(2)	1	1
Yugoslavia	2	199	384	(2)	235	424
Total[3]	909	33,533	40,201	933	25,816	32,499

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	1985 Quantity	1985 Value Customs	1985 Value C.i.f.[1]	1986 Quantity	1986 Value Customs	1986 Value C.i.f.[1]
Miami:						
Bahamas	12	334	375	58	1,652	1,880
Barbados	4	129	143	--	--	--
Belgium-Luxembourg	2	101	186	3	179	332
Colombia	23	616	778	--	--	--
Costa Rica	(2)	10	11	(2)	10	11
Japan	--	--	--	(2)	39	51
Mexico	333	9,841	12,513	319	9,170	11,481
Spain	272	7,295	9,455	464	14,108	17,024
Venezuela	579	14,338	18,814	445	10,194	13,905
Total	1,225	32,664	42,275	1,289	35,352	44,684
Mobile:						
France	--	--	--	23	809	914
Greece	228	3,956	5,329	283	5,234	7,137
Mexico	--	--	--	245	3,881	4,695
Spain	681	11,811	16,141	232	4,127	5,414
Venezuela	59	1,011	1,359	--	--	--
Total	968	16,778	22,829	783	14,051	18,160
New Orleans:						
Belgium-Luxembourg	(2)	16	19	--	--	--
Canada	214	9,682	13,251	101	6,553	8,088
Colombia	--	--	--	46	900	1,134
France	394	9,572	13,172	434	12,834	15,709
Greece	--	--	--	58	1,460	1,498
Guatemala	(2)	3	6	--	--	--
Mexico	9	228	342	444	9,520	13,559
Netherlands	--	--	--	(2)	181	197
Spain	151	3,636	5,767	382	11,497	12,940
Venezuela	197	4,243	6,079	7	146	212
Total	965	27,380	38,636	1,472	43,091	53,337
New York City:						
Bahamas	--	--	--	7	222	294
Belgium-Luxembourg	--	--	--	(2)	4	5
Canada	139	2,366	3,371	65	1,311	1,965
Colombia	6	126	243	29	833	1,118
Germany, Federal Republic of	--	--	--	(2)	10	13
Greece	64	962	1,499	648	13,562	17,485
Guatemala	35	750	900	--	--	--
Italy	26	530	541	--	--	--
Japan	--	--	--	1	779	784
Mexico	--	--	--	26	425	588
Norway	46	1,753	3,981	--	--	--
Spain	576	16,625	20,877	405	13,809	17,385
Venezuela	66	1,120	1,549	72	1,683	2,061
Total	958	24,232	32,961	1,253	32,638	41,698
Nogales: Mexico	314	12,149	12,149	404	14,518	14,520
Norfolk:						
Bahamas	--	--	--	25	650	1,019
Canada	--	--	--	(2)	7	7
Colombia	--	--	--	17	474	582
France	20	1,723	1,781	25	2,357	2,591
Germany, Federal Republic of	(2)	9	12	(2)	3	3
Namibia	8	218	281	--	--	--
Spain	55	1,573	1,833	211	2,558	5,379
United Kingdom	--	--	--	(2)	2	3
Venezuela	78	1,879	2,419	90	2,251	3,099
Total	161	5,402	6,326	368	8,302	12,683
Ogdensburg: Canada	343	12,456	12,492	405	13,839	13,839
Pembina: Canada	48	2,242	2,246	48	2,025	2,025
Philadelphia:						
Germany, Federal Republic of	--	--	--	(2)	5	6
Greece	--	--	--	23	503	568
Korea, Republic of	22	880	930	--	--	--
Mexico	--	--	--	1	25	25

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	1985 Quantity	1985 Value Customs	1985 Value C.i.f.[1]	1986 Quantity	1986 Value Customs	1986 Value C.i.f.[1]
Philadelphia —Continued						
Netherlands	--	--	--	([2])	182	221
Spain	--	--	--	94	5,336	8,039
Turkey	--	--	--	([2])	2	5
Total[3]	22	880	930	119	6,053	8,864
Port Arthur:						
Greece	179	3,945	4,061	--	--	--
Mexico	--	--	--	26	662	782
Spain	6	409	586	--	--	--
Venezuela	20	476	590	159	2,911	3,636
Total[3]	205	4,830	5,238	185	3,573	4,418
Portland, ME:						
Canada	6	278	278	11	599	599
Greece	--	--	--	13	269	333
Total	6	278	278	24	868	932
Portland, OR:						
Canada	11	607	659	--	--	--
Japan	51	1,178	2,011	47	1,095	1,618
Korea, Republic of	19	489	625	37	1,382	1,749
Total[3]	81	2,274	3,296	84	2,477	3,367
Providence:						
Bahamas	4	109	165	--	--	--
Canada	--	--	--	39	1,651	1,970
Colombia	--	--	--	74	2,191	3,028
Greece	--	--	--	5	135	203
Mexico	--	--	--	78	1,839	2,947
Spain	--	--	--	67	2,364	2,971
Venezuela	55	1,383	2,115	13	370	552
Total[3]	59	1,492	2,281	276	8,550	11,671
St. Albans: Canada	548	18,007	18,007	399	13,018	13,018
San Diego:						
Canada	--	--	--	8	258	304
Japan	308	8,333	11,254	--	--	--
Mexico	368	14,008	15,720	694	22,373	25,015
Venezuela	10	413	467	--	--	--
Total	686	22,754	27,441	702	22,631	25,319
San Francisco:						
Belgium-Luxembourg	([2])	51	86	--	--	--
Canada	34	1,295	1,447	138	4,556	6,188
China	--	--	--	([2])	6	12
Italy	([2])	18	23	--	--	--
Japan	157	3,597	4,446	57	1,022	1,283
Korea, Republic of	41	895	1,164	65	935	1,830
Mexico	--	--	--	108	3,086	3,480
Yugoslavia	([2])	3	6	--	--	--
Total[3]	238	5,859	7,173	368	9,605	12,793
San Juan, PR:						
Barbados	30	1,094	1,430	42	1,472	2,015
Belgium-Luxembourg	10	841	1,292	8	585	1,009
Brazil	1	70	89	1	92	138
Colombia	74	1,747	2,126	66	1,220	1,618
Costa Rica	1	15	35	--	--	--
Denmark	2	125	228	4	326	542
Dominican Republic	19	350	485	1	16	21
Germany, Federal Republic of	2	126	191	1	55	63
Honduras	3	102	157	24	717	1,053
Mexico	--	--	--	5	134	241
Netherlands	--	--	--	1	49	71
Panama	6	280	305	--	--	--
Spain	98	2,780	3,184	3	238	598
Venezuela	84	2,812	3,541	34	1,329	1,847
Total[3]	329	10,342	13,063	191	6,233	9,216

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	1985 Quantity	1985 Value Customs	1985 Value C.i.f.[1]	1986 Quantity	1986 Value Customs	1986 Value C.i.f.[1]
Savannah:						
Germany, Federal Republic of	--	--	--	(2)	15	19
Japan	--	--	--	(2)	2	2
Spain	37	339	390	111	2,608	2,802
Venezuela	37	1,242	1,508	11	250	276
Total[3]	74	1,581	1,898	123	2,875	3,099
Seattle:						
Canada	368	14,839	16,239	335	12,392	13,423
Italy	(2)	1	2	--	--	--
Japan	227	5,696	7,446	156	3,757	4,679
Yugoslavia	(2)	8	19	(2)	10	43
Total	595	20,544	23,706	491	16,159	18,145
Tampa:						
Bahamas	--	--	--	4	102	117
Colombia	286	7,078	8,849	363	8,277	10,505
Denmark	61	W	W	41	W	W
France	136	W	W	187	W	W
Greece	11	186	206	42	932	1,169
Mexico	862	20,328	25,340	1,066	18,879	27,083
Panama	--	--	--	15	344	345
Spain	401	10,176	12,701	369	8,307	10,858
Venezuela	230	6,536	8,448	366	10,025	12,982
Total	1,987	58,631	72,760	2,453	58,151	72,262
Virgin Islands of the United States:						
Barbados	(2)	17	22	--	--	--
Colombia	18	814	865	25	1,272	1,345
Dominican Republic	6	229	263	1	21	23
Leeward and Windward Islands	(2)	6	9	4	109	173
Panama	4	177	179	--	--	--
United Kingdom	(2)	7	10	--	--	--
Venezuela	10	276	320	7	325	364
Total	38	1,526	1,668	37	1,727	1,905
Wilmington, NC:						
Colombia	142	4,094	4,889	127	3,687	4,468
Mexico	--	--	--	10	250	389
Spain	6	169	205	6	186	226
Venezuela	4	162	202	--	--	--
Total	152	4,425	5,296	143	4,123	5,083
Grand total[3]	14,487	437,429	523,773	16,319	468,993	562,427

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.

Table 22.—U.S. imports for consumption of cement and clinker

(Thousand short tons and thousand dollars)

Year	Roman, portland, other hydraulic cement Quantity	Roman, portland, other hydraulic cement Value (customs)	Hydraulic cement clinker Quantity	Hydraulic cement clinker Value (customs)	White nonstaining portland cement Quantity	White nonstaining portland cement Value (customs)	Total[1] Quantity	Total[1] Value (customs)
1982	2,369	81,710	470	18,385	90	10,791	2,929	110,886
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

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

Source: Bureau of the Census.

WORLD REVIEW

World cement production increased slightly to 1.1 billion tons. The United States accounted for 7% of world production. In decreasing order of production, China, the U.S.S.R., the United States, and Japan were the four principal producing countries accounting for 44% of world production. The 10 largest cement producing countries accounted for 61% of the world's total. Exporting countries continued to view the United States as a primary market for their excess cement. In 1986, 30 countries exported cement to the United States, 3 fewer than in 1985. However, the volume of cement imports was 1.8 million tons higher than that of 1985.

The Rock Products magazine report on the world cement industry described the following significant activities in cement plant construction, modernization, and expansion:[5]

Belgium.—Cimenteries CBR put its new 2,900-ton-per-day Antoing plant on-line. The plant contains a five-stage preheater kiln with precalciner.

Brazil.—Companhia Agro-Industrial de Monte Alegre increased its capacity by 760,000 tons per year with the addition of a new dry-process line. A flurry of modernization and expansion activity was taking place in Brazil, which will expand its installed capacity 8% by 1988 to 53 million tons per year.

China.—Guangxi Building Materials Export Supply Co. put a new 3,500-ton-per-day plant on-line at Liuzou. Construction continued on three additional plants near Canton, Shanghai, and Shunchang. These plants were expected to go on-stream by 1988 and will add more than 8,000 tons per day to China's capacity. Several other plants are in various planning or development stages that will help reach China's projected capacity of 250 million tons per year by the year 2000.

Egypt.—Alexandria Portland Cement Co. was in the process of constructing two 3,600-ton-per-day kilns at its Ameriyah plant. The first kiln was expected to be operational by June 1987 and the other early in 1988. Tourah Portland Cement Co. commissioned its 1-million-ton-per-year No. 8 line and continued work on its second 1-million-ton-per-year No. 9 kiln. Helwan Portland Cement Co.'s Assiut plant continued work on two new production lines of 4,000 tons per day each; both were expected to be commissioned in 1988. Two additional lines, 4,000 tons per day each, were also under construction at the Assiut plant. National Cement Co.'s Tabbin plant continued work on its 5,000-ton-per-day kiln scheduled to go on-stream in 1987.

India.—Jaypee Rewa Cement Co. commissioned its 3,300-ton-per-day plant in Rewa and Gujarat Ambuga Cement Ltd. put its 2,000-ton-per-day plant into operation at Ambujanagar. Gwalior Rayon Corp. Ltd. put the second line into operation at its Vicram plant; the 2,000-ton-per-day dry-process operation was designed to burn low-caloric Indian coal. Priyadarshini Cement Ltd. began production at its 1,600-ton-per-day plant in the Nalgonda District; Modi Cement Ltd. commissioned its 3,300-ton-per-day plant at Bhatapara; Cement Corp. of India Ltd. also put into operation a 3,300-ton-per-day plant at Tandur; Vasuvdatta Cement Co. commissioned a 2,000-ton-per-day plant in the Gulbarga District of Karnataka State; Avarpur Cement Ltd. completed a 3,500-ton-per-day expansion of its Chanda plant; and Raymond Cement works expanded its production line at its Bilaspur plant to 4,200 tons per day.

Malaysia.—Perak Hanjoong Simen Sdn. Bhd. completed construction on its 1.3-million-ton-per-year plant at Pedang Rengas, and Cement Industries Malaysia Sdn. Bhd. produced cement from its expanded 661,000-ton-per-year plant at Kangar.

Mexico.—The Cementos Mexicanos new 1.2-million-ton-per-year plant at Huichapan went on-line during the year.

Pakistan.—Attock Cement Pakistan Ltd. commissioned its 728,000-ton-per-year plant near Hub Chowki.

Saudi Arabia.—Saudi-Kuwait Cement Manfacturing Co. extended its cement grinding capacity by adding two 3,500-ton-per-day-capacity finish grinding mills; The Qassim Cement Co. was in the process of adding a new 720,000-ton-per-year kiln line; Yamama Saudi Cement Co. Ltd. commissioned its sixth line at its Riyadh plant increasing the capacity to 9,500 tons per day, and work continued on the 2,400-ton-per-day Qassim Cement's Buraydah plant.

Turkey.—A 600,000-ton-per-year plant at Urfa went on-stream during the year; the Kisehir Cemento Fabrinkasi TAS plant increased clinker production capacity 43% to 1,100 tons per day; and Bati Anadolu Cemento Danayii A.S. was upgrading production of its No. 2 kiln at its Izmir plant, raising production from 1,400 to 1,900 tons per day.

United Kingdom.—RTZ Cement Ltd.

started a new 1.0-million-ton-per-year dry-process plant at Ketton; RTZ increased production by 30% at its Padeswood plant by installing a high-efficiency separator at one of its mills; at its Ribblesdale plant, RTZ was converting a 1,500-horsepower raw mill to cement grinding, adding 220,000 tons to its annual finish grinding capacity.

Table 23.—Hydraulic cement: World production, by country[1]

(Thousand short tons)

Country	1982	1983	1984	1985[p]	1986[e]
Afghanistan[2]	96	14	123	85	110
Albania[e]	915	925	[3]948	[r]940	940
Algeria[e]	4,850	5,300	6,100	[r]6,720	7,200
Angola[e]	276	[r]240	[r]390	[r]390	390
Argentina	6,199	6,198	5,758	5,104	5,500
Australia	6,332	5,331	6,022	6,489	[3]6,471
Austria	5,525	5,409	5,400	5,027	5,200
Bahamas	71	29	--	--	--
Bangladesh[4]	360	338	301	265	[3]322
Barbados[e]	--	--	165	[r]240	240
Belgium	6,967	6,304	6,300	6,103	[3]7,496
Benin	347	331	331	331	331
Bolivia	358	361	315	418	330
Brazil	28,268	23,005	21,761	22,721	[3]27,885
Bulgaria	6,188	6,221	6,302	5,838	5,800
Burma	379	369	343	526	[3]478
Cameroon	584	672	NA	NA	NA
Canada	9,288	8,676	9,489	11,235	11,100
Chile	1,248	1,383	1,532	1,576	[3]1,588
China	103,697	119,325	133,468	[e]157,100	178,000
Colombia	5,546	5,204	5,816	6,294	[3]7,121
Congo	43	17	NA	64	64
Costa Rica	467	425	386	507	500
Cuba	3,487	3,562	3,689	3,508	3,300
Cyprus	1,177	1,039	940	727	[3]952
Czechoslovakia	11,381	11,572	11,607	[e]11,300	11,200
Denmark	1,951	1,827	1,839	1,917	[3]2,237
Dominican Republic	1,046	1,217	1,260	[r e]1,210	1,210
Ecuador	1,747	1,593	1,636	1,602	1,540
Egypt	4,696	6,063	7,165	6,337	[3]8,391
El Salvador	461	476	449	492	485
Ethiopia[e]	[r]160	[r]190	[r]265	[r]275	275
Fiji	97	121	108	103	102
Finland	2,053	2,102	1,814	[e]1,760	1,760
France	28,825	27,011	25,049	25,955	25,900
Gabon	193	132	229	270	[3]232
German Democratic Republic	12,920	12,987	12,737	12,795	12,840
Germany, Federal Republic of	33,155	33,583	31,867	28,393	29,200
Ghana	322	320	252	[e]380	275
Greece	14,176	15,648	14,904	15,067	15,100
Guadeloupe[e]	176	176	[r]187	[r]190	187
Guatemala	558	498	866	1,089	1,100
Haiti[e]	[3]234	238	[r]240	[r]240	200
Honduras	306	535	[r e]550	[e]550	550
Hong Kong	1,582	1,892	2,037	2,023	[3]2,465
Hungary	4,816	4,677	4,569	4,054	4,240
Iceland	137	127	130	126	125
India	24,800	27,950	32,000	36,431	35,300
Indonesia	8,268	9,025	9,765	11,112	12,100
Iran	[r e]10,470	[r e]11,000	13,011	13,739	[3]14,330
Iraq[e]	[r]6,170	[r]6,170	[r]8,800	[r]8,800	8,800
Ireland	1,742	1,638	1,518	1,606	[3]1,541
Israel	2,413	2,269	2,275	2,227	[3]2,270
Italy	43,793	43,229	41,648	40,429	[3]38,956
Ivory Coast	1,213	702	591	591	[3]855
Jamaica	233	305	288	264	255
Japan	88,943	89,167	86,928	80,311	[3]78,535
Jordan	876	1,401	2,192	2,230	[3]1,978
Kenya	[e]1,433	1,411	1,283	934	[3]1,446
Korea, North[e]	[r]8,800	[r]8,800	[r]8,800	[r]8,800	8,800
Korea, Republic of	19,717	23,459	22,501	22,514	[3]25,797
Kuwait	1,712	1,239	1,305	[e]1,200	1,300
Lebanon	1,874	1,653	1,378	[e]1,100	1,000
Liberia	88	94	93	105	110
Libya[e]	[r]4,400	[r]5,500	[r]6,600	7,200	7,200
Luxembourg	379	389	375	325	330
Madagascar	40	39	[e]39	[e]39	39
Malawi	59	78	77	[e]70	70
Malaysia	3,443	[r]3,562	3,824	3,448	[3]3,501
Mali	30	[e]22	28	21	22
Martinique[e]	220	220	220	220	220
Mauritania	([5])	([5])	--	--	--

See footnotes at end of table.

Table 23.—Hydraulic cement: World production, by country[1] —Continued

(Thousand short tons)

Country	1982	1983	1984	1985[p]	1986[e]
Mexico	21,272	18,814	20,835	23,531	[3]22,763
Mongolia	386	370	386	[e]440	440
Morocco	4,122	4,242	3,955	4,075	4,100
Mozambique	386	463	[e]496	[e]496	496
Nepal	[e]28	50	43	35	[3]102
Netherlands	3,420	3,425	3,501	3,209	3,500
New Caledonia[e]	[3]59	66	66	66	66
New Zealand	[r]861	[r]838	907	951	960
Nicaragua[e]	110	110	110	110	110
Niger[e]	42	42	42	42	42
Nigeria[e]	[r]3,970	[r]3,970	[r]3,300	[r]3,680	3,860
Norway	1,969	[r]1,837	1,705	1,764	[3]1,929
Pakistan	4,076	5,443	5,178	5,289	[3]5,753
Panama	386	360	335	336	[3]370
Paraguay	122	169	120	51	55
Peru	2,855	2,535	[e]2,425	[e]2,425	2,425
Philippines[6]	4,795	4,831	4,025	3,395	[3]3,910
Poland	17,747	17,857	18,409	16,535	[3]17,416
Portugal	[r]6,576	6,683	6,106	5,913	[3]6,001
Qatar	252	413	527	[r e]530	530
Romania	16,529	15,397	15,450	13,490	13,800
Saudi Arabia	7,885	8,957	7,882	9,149	9,370
Senegal	401	435	424	449	440
Singapore	2,971	3,476	3,110	2,195	[3]1,989
South Africa, Republic of	8,830	8,705	9,025	7,754	[3]6,885
Spain (including Canary Islands)[7]	32,594	33,771	28,038	26,673	26,500
Sri Lanka	717	[3]558	551	660	660
Sudan	202	[e]220	194	213	220
Suriname	79	82	[e]55	[e]55	55
Sweden	2,540	2,469	2,638	2,425	[3]2,336
Switzerland	[r]4,519	[r]4,561	4,609	4,689	[3]4,842
Syria	2,864	3,996	4,720	[e]3,900	3,900
Taiwan	14,806	16,325	15,690	15,893	[3]16,321
Tanzania[e]	[r]440	[r]460	[3]408	[r]330	330
Thailand	7,285	8,006	9,083	8,726	8,600
Togo	308	256	268	313	320
Trinidad and Tobago	209	430	447	362	350
Tunisia	1,965	3,142	3,061	3,372	3,600
Turkey	17,392	14,986	17,348	19,380	22,000
Uganda[e]	19	22	22	22	22
U.S.S.R	136,335	141,268	143,453	144,096	149,000
United Arab Emirates	2,447	2,280	4,415	[e]4,400	4,400
United Kingdom	14,288	14,767	14,860	14,704	14,770
United States (including Puerto Rico)	64,341	71,347	78,699	78,859	[3]79,916
Uruguay	726	442	368	346	[3]375
Venezuela	5,988	4,899	5,272	5,159	4,940
Vietnam[e]	[r]880	[3]1,023	[r]1,210	1,430	1,700
Yemen (Sanaa)	261	661	937	[e]940	940
Yugoslavia	10,712	10,573	10,268	[e]9,950	9,900
Zaire	596	565	583	[e]530	530
Zambia	170	171	266	349	[3]368
Zimbabwe	635	[r]639	([8])	([8])	NA
Total	[r]978,144	[r]1,010,392	1,037,003	1,055,738	1,099,894

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.
[1]Table includes data available through July 7, 1987.
[2]Data are for the year beginning Mar. 21 of that stated.
[3]Reported figure.
[4]Data are for the year ending June 30 of that stated.
[5]Revised to zero.
[6]Converted from officially reported data provided in terms of 94-pound cement bags.
[7]Excludes natural cement.
[8]Revised to "Not available."

TECHNOLOGY

Cement.—The Bureau of Mines conducted research to remove the alkalies from cement kiln dust (CKD) to make it more acceptable for recycling. Kiln dust samples used in the experiment included a cyclone product from Arkansas and baghouse products from California and Missouri. The research examined two alkali volatilization methods: sintering, and melting at various temperatures for converting CKD into materials for making portland cement and a useful potassium product. The report concluded that several degrees of alkali removal could be achieved and that portland cement made from either sintered or melted kiln dusts exhibited strength equal to or greater than the American Society for Testing and Materials standards.[6]

Krupp Industrietechnik GmbH, a West German equipment manufacturer, introduced a newly developed disk crusher. It is a rotary machine that uses centrifugal force to move the feed through the crushing zone. Using two pendulating disks, the crusher is particularly suited for use in secondary and tertiary crushing and for grinding difficult-to-break, sticky, and moist feed. The centrifugal action provides an appreciably higher throughput rate than conventional cone crushers.[7]

Kobe Steel Ltd. and Nihon Cement Co. Ltd. developed a computer-aided plant simulation training system composed of two consoles—one for the instructor and one for the trainee. The system allows the trainee to experience the entire plant operation from startup to shutdown within a 2-hour period.[8]

The results of emerging technological innovations stemming from efforts to improve energy efficiency in the cement industry were described in a paper presented at the 28th Cement Technical Conference of the Institute of Electrical and Electronics Engineers, Salt Lake City, UT, May 1986. The paper detailed increases in production capacity of 55% to 68% and improved energy efficiency of 25% to 30% using high-efficiency separators and high-pressure grinding rollers.[9]

Concrete.—The National Materials Advisory Board, National Research Council, completed a study on concrete durability. The study, conducted at the request of the U.S. Department of Defense and the National Aeronautics and Space Administration, examined existing concrete production practices, evaluated available technologies for producing durable concrete, and identified existing and emerging technologies for improving the durability of concrete used in a variety of environmental conditions.[10]

Master Builders Inc. reported development of an admixture that allows concrete placement at ambient temperatures of as low as 20° F without freezing. According to the company, the material, called pozzutec, is a low-temperature accelerator formulated to speed up setting time and produce high-early and ultimate strengths in concrete placed at and exposed to below-freezing temperatures. Treated concrete, once it has reached initial set, will not freeze if the temperature falls below 20° F, and will continue to set while gaining strength.[11]

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[1]Mineral specialist, Division of Industrial Minerals.
[2]U.S. Department of Commerce, International Trade Administration. Construction Review. V. 33, No. 2, Mar.-Apr. 1987, pp. 19-27.
[3]Work cited in footnote 2.
[4]Engineering News-Record. ENR Materials Prices. V. 218, No. 2, Jan. 8, 1987, pp. 30-34.
[5]Rock Products. Cement International. V. 90, No. 4, Apr. 1987, pp. 39-65.
[6]Wilson, R. D., and W. E. Anable. Removal of Alkalies From Portland Cement Kiln Dust. BuMines RI 9032, 1986, pp. 1-10.
[7]World Cement. V. 17, No. 7, Sept. 1986, p. 321.
[8]Pit and Quarry. Computer Aids in Cement Industry Training Program. V. 79, No. 7, Jan. 1987. p. 46.
[9]Von Seebach, M., and L. Schneider. Update on Finish Grinding With Improved Energy Efficiency. World Cement, v. 17, No. 8, Oct. 1986, pp. 336-346.
[10]National Materials Advisory Board, National Research Council. Concrete Durability a Multibillion-Dollar Opportunity. Mar. 1987, pp. 1-94.
[11]Pit and Quarry. Admix Resists Freezing in Temperatures as Low as 20° F. V. 50, No. 6, Oct. 1986, p. 36.

Chromium

By John F. Papp[1]

In 1986, reported chromium consumption was 327,018 short tons. The reported consumption of chromite by the chemical and metallurgical industry decreased as did that of the refractory industry. Metallurgical industry production includes ferrochromium produced as part of the National Defense Stockpile (NDS) conversion program. Imports of chromite and chromium ferroalloys increased compared with those of 1985. In previous years, annual reported chromium consumption was calculated as chromium contained in reported consumption of refractory and chemical ore plus chromium ferroalloys and metal. The basis for this calculation changed owing to the combination of metallurgical and chemical ore consumption categories. Reported chromium consumption in 1986 was calculated as chromium contained in reported consumption of ore plus chromium ferroalloys and metal.

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. In 1986, 66% of the metallurgical companies, 83% of the refractory companies, and 100% of the chemical companies reported chromite consumption. Consumption was estimated for the remaining 34% of the metallurgical industry.

Table 1.—Salient chromium statistics

(Thousand short tons, gross weight)

	1982	1983	1984	1985	1986
CHROMITE					
United States:					
Exports	8	11	55	101	92
Reexports	57	5	4	4	1
Imports for consumption	507	190	305	414	488
Consumption	558	320	512	560	e427
Stocks, Dec. 31: Consumer	546	456	327	300	e314
World: Production	r9,348	r9,063	10,756	p11,630	e11,394
CHROMIUM FERROALLOYS[1]					
United States:					
Production[2]	119	36	95	110	105
Exports	5	4	15	10	6
Reexports	(3)	2	1	1	1
Imports for consumption	148	282	434	335	398
Consumption	262	388	395	369	365
Stocks, Dec. 31: Consumer	26	26	25	31	30
World: Production	r2,638	r2,753	r3,283	p3,378	e3,327

eEstimated. pPreliminary. rRevised.
[1]High- and low-carbon ferrochromium plus ferrochromium-silicon.
[2]Includes chromium metal, exothermic chromium additives, and other miscellaneous chromium alloys.
[3]Less than 1/2 unit.

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-six percent of those companies responded to both surveys. Production for the remaining 34% was estimated.

Legislation and Government Programs.—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 92,028 tons of chromium ore to produce 35,212 tons of ferrochromium at a cost of about $17.6 million in 1986; 137,015 tons of ore to 49,463 tons of ferrochromium in 1985; and 125,628 tons of ore to 50,254 tons of ferrochromium in 1984. At yearend 1986, GSA was negotiating a contract for the conversion of chromium ore to ferrochromium in 1987 and 1988 with an option to extend conversion into 1989. The new contract was to call for the conversion of 137,747 tons of chromium ore into about 61,220 tons of ferrochromium in 1987; 133,827 tons of chromium ore into about 59,479 tons of ferrochromium in 1988; and the option for 124,627 tons of chromium ore into about 55,390 tons of ferrochromium in 1989.

The U.S. Geological Survey collected and published descriptive and grade-tonnage models of chromium mineral deposits in 1986. Two descriptive models were presented covering stratiform and podiform deposits. Two grade and tonnage models were presented: a minor podiform model covering 435 domestic deposits and a major podiform model covering 174 foreign deposits.[2]

The U.S. Department of Defense studied the U.S. ferroalloy production industry to determine the effects of a loss of domestic ferroalloy capacity. The study found that under peacetime or mobilization conditions, there was adequate ferrochromium production capacity worldwide to compensate for any loss of U.S. capacity. However, U.S. mobilization combined with South African supply disruption would result in severe ferrochromium shortages requiring use of the NDS. The study found NDS chromium materials adequate for 15 months of supply. A disruption of African and European supplies would require the development of domestic chromite resources and construction of ferrochromium processing capacity.[3]

Under title III of the Defense Production Act, the U.S. Department of Defense began drafting a request for proposals for the purchase of high-purity chromium metal from superalloy scrap to stimulate domestic recycling of superalloys that contain chromium. The procurement was to be processed in two phases. The first was to identify sources with acceptable grade and quantity for strategic applications; the second was to include negotiations for fixed price contracts with sources that successfully demonstrate capabilities under the first phase.

The President ordered implementation of sanctions against the Republic of South Africa as required by the Comprehensive Anti-Apartheid Act of 1986 (Public Law 99-440). The Customs Service held ferrochromium imports from the Republic of South Africa while the U.S. Department of the Treasury decided which commodities listed under iron and steel in the Tariff Schedule of the United States would be banned. Treasury decided that ferrochromium would be excluded from the ban. The act provided that sanctions could be lifted, based on annual reports of progress toward ending apartheid made by the President to Congress.

The Food and Drug Administration amended the color additive regulations to permit the safe use of chromium oxide green as a color additive in contact lenses.

The Environmental Protection Agency (EPA) solicited information that would help EPA determine whether or not there was a need for standards to reduce public exposure to chromium emissions from comfort cooling towers. The EPA also issued a final rule that established limitation guidelines on chromium effluent into navigable waterways. The guideline is based on best conventional pollution control technology and covers the ferroalloy manufacturing industry. In other separate studies, the EPA assessed the health effects of trivalent chromium and hexavalent chromium, and reported results of a ferroalloy-producing electric arc furnace particulate emissions study. In addition, EPA published a guidance document for the reregistration of chromated arsenical wood preservative pesticide products.[4]

The U.S. Department of Commerce and the Bureau of Mines studied consumption and intensity of use trends for chromium by industrial end use. Intensity of use, or intensity, as used in the study means the quantity of material used per unit of production. The study found that U.S. chromium intensity of use and consumption has declined over the 1977-82 time period. The decline was attributed to a lower steel intensity combined with a greater importation of steel. The amount of chromium in alloy and stainless steels was found to remain at a stable percentage.[5]

At the request of the Aviation and Materials Subcommittee of the House of Representatives, the Bureau of Mines studied the importance of the Republic of South Africa and its neighboring countries as suppliers of chromium. The study found that the NDS was adequate to meet U.S. demand until new supply sources could be developed should total disruption of chromium from the Republic of South Africa and Zimbabwe occur.[6] The Bureau also studied availability of chromium from the Republic of South Africa. The study found that the Republic of South Africa controls access to 87% of the total available chromite products evaluated and that other market economy country (actual or potential) chromite producers, in total, do not possess sufficient current production capacity, nor a level of resources that are sufficient to replace the current dominance of the Republic of South Africa as a supplier of chromite.[7]

Table 2.—U.S. Government stockpile goals and yearend inventories for chromium in 1986

(Thousand short tons, gross weight)

Material	Stockpile goals	Physical inventory		
		Stockpile-grade	Nonstockpile-grade	Total
Chromite, metallurgical	3,200	1,847	257	[1]2,103
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

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

Source: Federal Emergency Management Agency.

DOMESTIC PRODUCTION

The major marketplace products of chromium are alloys, chemicals, chromium ore, and metal. In 1986, the United States produced chromium alloys, chemicals, and metal. No chromium ore was mined domestically.

Occidental Petroleum Corp. purchased Diamond Shamrock Chemical Corp., making the new company Occidental Chemicals Corp. Occidental paid $800 million for the chemical company, which produces sodium dichromate and other chromium chemicals.

Elkem Metals Co. announced plans to invest $3 million in a briquetting plant for its Marietta, OH, plant. The new plant was to produce chromium-aluminum briquets. Elkem also sought to increase use of the powerplant associated with that plant.

Stratcor Minerals Corp. completed purchase of Umetco Minerals Corp., Union Carbide Corp.'s U.S. operation. Stratcor became the U.S. representative for ferrochromium produced by Tubatse Ferrochrome (Pty.) Ltd. in the Republic of South Africa and owned by South African Manganese Amcor Ltd. Union Carbide retained its chromium operations in Zimbabwe and continued to represent Union Carbide Southern Africa, owner of Zimbabwe Mining and Smelting Co. (ZIMASCO), a low- and high-carbon ferrochromium producer in Zimbabwe, through Union Carbide Carbon Products Div.

SKW Alloys Inc. planned to convert one of its two furnaces at Niagara Falls, NY, to silicon metal production at a cost of $7 million. SKW was to continue production of ferrochromium-silicon at the rate of about 5,000 tons per year.

Foote Mineral Co. was for sale. Foote was a majority-owned subsidiary of Newmont Mining Corp. Foote had closed its Graham, WV, plant, where it produced chromium briquets.

Moore McCormack Resources Inc. put its Globe Metallurgical Div. up for sale. Globe stopped low-carbon ferrochromium production in 1985 and high-carbon in 1986, but retained the capability to restart production should conditions change.

The industrial group of International Minerals & Chemicals Corp., a U.S. company, was sold to an investment group and became Applied Industrial Minerals Corp. The sale included the Lavino chromite mine, in the Republic of South Africa, and IMC Trading, the U.S. representative for ferrochromium from Zimbabwe Alloys Ltd. (Zimalloys), in Zimbabwe. The sale also included a U.S. ferroalloy plant co-owned with Allegheny Ludlum Steel Corp.

Allegheny International Corp. sold its shares in Consolidated Metallurgical Industries Ltd. (CMI), a ferrochromium producer in the Republic of South Africa. S.A. des Minerais of Luxembourg purchased the ferrochromium assets of Almet Inc. from Allegheny International, including the CMI representation agreement. The new company owning those assets is Almet Div. of Minerais U.S. Inc.

Davis Refractories Inc. ceased operation. It sold its plant and materials by auction. Harbison-Walker Refractories, a division of Dresser Industries Inc. closed its Baltimore, MD, plant.

Kaiser Refractories, a subsidiary of Kaiser Aluminum & Chemical Corp., was purchased by its employees and Kelso & Co., an investment banking company. The new company was named National Refractories & Minerals Corp., which took over the Moss Landing, CA, and Columbiana, OH, chromium refractory producing plants. Kaiser retained the Plymouth Meeting, PA, plant, which it subsequently sold for nonrefractory use.

Table 3.—Principal producers of chromium products in 1986, 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	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.
General Refractories Co	Lehi, UT.
Harbison-Walker Refractories, a division of Dresser Industries Inc	Hammond, IN, and Baltimore, MD.[1]
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]Baltimore plant closed in August 1986.

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
1985:				
Low-carbon ferrochromium High-carbon ferrochromium Chromium concentrate	99,027	62,556	94,470	18,775
Ferrochromium-silicon Chromium metal Other[1]	10,536	5,637	14,002	4,786
Total	109,563	68,193	108,472	23,561

See footnotes at end of table.

Table 4.—Production, shipments, and stocks of chromium ferroalloys and chromium metal in the United States —Continued

(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

[1]Includes exothermic chromium additives and other miscellaneous chromium alloys.

CONSUMPTION AND USES

Domestic consumption of chromite ore and concentrate was 427,238 tons in 1986. Of the total chromite consumed, the chemical and metallurgical industry used 377,300; and the refractory industry, 49,938. Much of the chromite consumed and ferrochromium produced by the metallurgical industry was part of the NDS conversion program. (See the "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 1986 was in stainless steel. Of the 371,757 tons of chromium ferroalloys, metal, and other chromium-containing materials reported consumed, stainless steel accounted for 79%; full-alloy steel, 8%; superalloys, 3%; and other end uses, 10%. Chromium ferroalloys, metal, and other chromium material consumption decreased 1.2% on a gross weight basis compared with that of 1985, but increased 1.7% on a contained weight basis suggesting a shift to higher chromium content materials.

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 decreased 20% compared with that of 1985.

The chemical industry consumed chromite for manufacturing chromates, 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: Gross weight (short tons)	Chemical and metallurgical industry: Average Cr_2O_3 (percent)	Refractory industry: Gross weight (short tons)	Refractory industry: Average Cr_2O_3 (percent)	Total: Gross weight (short tons)	Total: Average Cr_2O_3 (percent)
1982	478,416	39.1	79,760	36.4	558,176	38.9
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

Table 6.—U.S. consumption of chromium ferroalloys and metal in 1986, by end use

(Short tons, gross weight)

End use	Ferrochromium		Ferrochromium silicon	Other	Total
	Low-carbon	High-carbon			
Steel:					
Carbon	2,425	3,190	W	W	5,615
Stainless and heat-resisting	9,995	277,910	7,135	418	295,458
Full-alloy	4,788	25,620	1,089	70	31,567
High-strength, low-alloy and electric	1,720	1,999	W	W	3,719
Tool	1,086	4,293	228	--	5,607
Cast irons	837	6,284	W	W	7,121
Superalloys	4,383	3,509	W	3,111	11,003
Welding materials[1]	458	710	--	116	1,284
Other alloys[2]	180	296	W	1,941	2,417
Miscellaneous and unspecified	251	9	6,220	1,486	7,966
Total[3]	26,123	323,820	14,672	[4]7,142	371,757
Chromium content	17,442	182,033	5,139	5,694	210,308
Stocks, Dec. 31	5,509	22,981	1,460	[5]1,840	31,790

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 4,749 tons of chromium metal.
[5]Includes 1,169 tons of chromium metal.

STOCKS

Reported consumer stocks of chromite increased from 300,187 tons in 1985 to 313,795 tons in 1986. Chemical and metallurgical industry stocks increased, whereas refractory industry stocks declined. Producer stocks of chromium ferroalloys, metal, and other materials declined from 23,561 tons in 1985 to 14,105 tons in 1986. Consumer stocks decreased from 31,790 tons in 1985 to 31,790 tons in 1986. At the 1986 annual rate of chromium ferroalloy and metal consumption, producer plus consumer stocks represented a 1.5-month supply.

Table 7.—U.S. consumer stocks of chromite, December 31, by industry

(Short tons, gross weight)

Industry	1982	1983	1984	1985	1986
Chemical and metallurgical	432,348	379,744	257,702	251,552	274,796
Refractory	113,233	75,832	69,619	48,635	38,999
Total	545,581	455,576	327,321	300,187	313,795

Table 8.—U.S. consumer stocks of chromium ferroalloys and metal, December 31, by product

(Short tons, gross weight)

Product	1982	1983	1984	1985	1986
Low-carbon ferrochromium	3,459	3,474	3,375	5,482	5,509
High-carbon ferrochromium	21,793	20,948	19,946	24,115	22,981
Ferrochromium-silicon	1,237	1,294	1,422	1,289	1,460
Other[1]	2,593	954	1,559	1,280	1,840
Total	29,082	26,670	26,302	32,166	31,790

[1]Includes chromium briquets, chromium metal, exothermic chromium additives, and other miscellaneous chromium alloys.

PRICES

The price of both South African and Turkish chromite ore was unchanged. The published price of South African Transvaal chromite, 44% Cr_2O_3 (no specific chromium-to-iron ratio), remained at a range of $40 to $42 per metric ton, f.o.b. South African ports. The published price of Turkish chromite remained at $125 per metric ton, f.o.b. Turkish ports.

The price of domestic chromium ferroalloy remained unchanged. The published price of electrolytic chromium metal declined from $3.75 per pound to a range of $3.00 to $3.75 per pound in June, after which it increased to a range of $3.15 to $3.75 in October, where it remained during the last quarter. The published price of imported high-carbon ferrochromium containing 50% to 55% chromium declined from a range of 42.5 to 44.0 cents per pound to a range of 38.0 to 38.5 cents per pound in July, where it remained until December. The price increased to a range of 38.25 to 38.75 cents per pound in December. The published price of imported high-carbon ferrochromium containing 60% to 65% chromium declined from a range of 46 to 47 cents per pound to a range of 41.5 to 43.25 cents per pound. The published price of imported low-carbon ferrochromium declined from a range of 86 to 87 cents per pound, to a range of 81 to 83 cents per pound in May. It then increased to a range of 83 to 85 cents per pound in December.

Table 9.—Price quotations for chromium materials at beginning and end of 1986

Material	January	December
	Cents per pound of chromium	
U.S. charge chromium (50% to 55% chromium)	(1)	(1)
Imported charge chromium (50% to 55% chromium)	42.5-44	38.25- 38.75
Imported charge chromium (60% to 65% chromium)	46 -47	41.5 - 43.25
U.S. charge chromium (66% to 70% chromium)	54	54
U.S. low-carbon ferrochromium (0.025% carbon)	100	100
U.S. low-carbon ferrochromium (0.05% carbon)	95	95
Imported low-carbon ferrochromium (0.05% carbon)	86 -87	83 - 85
Simplex (low-carbon ferrochromium)	100	100
	Cents per pound of product	
Electrolytic chromium metal	375	315 -375
Ferrochromium-silicon	r38.6	38.6

rRevised.
[1]Price listing suspended in 1984.

Source: Metals Week.

FOREIGN TRADE

Exports of chromium materials from the United States included chromite ore, chromium metal, ferroalloys, chemicals, and pigments.

Imports 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: Quantity (short tons)	Exports: Value (thousands)	Reexports: Quantity (short tons)	Reexports: Value (thousands)
1982	8,165	$1,574	56,830	$9,172
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

Source: Bureau of the Census.

Table 11.—U.S. exports of chromium materials, by type

Type	1984 Quantity (short tons)	1985 Quantity (short tons)	1986 Quantity (short tons)	1986 Value (thousands)	Principal destinations, 1986
Chromite ore and concentrate	54,928	100,810	92,108	$4,143	Sweden (91%); Mexico (8%).
Metal and alloys:					
Chromium metal[1]	259	222	321	2,972	Japan (32%); Ghana (18%); Belgium-Luxembourg (14%); United Kingdom (13%); Mexico (8%).
Chromium ferroalloys	[2]15,388	[3]10,262	[4]6,035	5,693	Canada (63%); Mexico (10%); Venezuela (10%); Spain (7%).
Chemicals:					
Chromic acid	5,672	3,881	5,596	8,944	Republic of Korea (19%); Japan (17%); Canada (12%); Taiwan (11%).
Potassium chromate and dichromate	72	71	21	21	Republic of Korea (81%); Chile (10%).
Sodium chromate and dichromate	18,321	9,726	15,837	9,943	China (37%); Republic of Korea (20%); Colombia (14%); Taiwan (9%).
Pigments	2,062	1,928	2,491	7,618	Canada (22%); Federal Republic of Germany (17%); Philippines (9%); Japan (8%); Taiwan (6%); Republic of Korea (5%).

[1]Wrought and unwrought and waste and scrap.
[2]Contained 9,996 tons of chromium.
[3]Contained 6,277 tons of chromium.
[4]Contained 3,496 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			More than 40% but less than 46% Cr_2O_3			46% or more Cr_2O_3			Total[1]		
	Gross weight (short tons)	Cr_2O_3 content (short tons)	Value (thousands)	Gross weight (short tons)	Cr_2O_3 content (short tons)	Value (thousands)	Gross weight (short tons)	Cr_2O_3 content (short tons)	Value (thousands)	Gross weight (short tons)	Cr_2O_3 content (short tons)	Value (thousands)
1985:												
Albania	15,673	5,396	$485	2,315	972	$132	--	--	--	17,988	6,368	$617
Canada	--	--	--	4	2	1	--	--	--	4	2	1
Finland	--	--	--	22,838	10,330	1,140	--	--	--	22,838	10,330	1,140
Japan	--	--	--	48	19	4	--	--	--	48	19	4
Philippines	41,399	12,917	3,179	--	--	--	--	--	--	41,399	12,917	3,179
South Africa, Republic of	32,533	12,951	1,266	142,474	63,228	6,135	126,182	59,094	$5,854	301,189	135,273	13,255
Turkey	30,905	11,282	1,974	--	--	--	--	--	--	30,905	11,282	1,974
Total[1]	120,510	42,545	6,904	167,679	74,554	7,412	126,182	59,094	5,854	414,371	176,191	20,170
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

[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)			High-carbon ferrochromium (3% or more carbon)		
	Gross weight (short tons)	Chromium content (short tons)	Value (thousands)	Gross weight (short tons)	Chromium content (short tons)	Value (thousands)
1985:						
Brazil	--	--	--	10,362	5,589	$3,860
Canada	--	--	--	145	99	58
Finland	--	--	--	8,851	4,658	3,534
Germany, Federal Republic of	4,445	3,178	$4,803	1,240	778	632
Greece	--	--	--	4,082	2,489	2,238
Italy	169	123	206	--	--	--
Japan	513	337	541	602	398	589
Netherlands	78	56	86	772	344	[r]225
Philippines	--	--	--	6,483	3,896	2,844
South Africa, Republic of	5,151	3,062	3,889	198,320	105,178	78,427
Sweden	[r]6,504	4,730	7,063	--	--	--
Turkey	4,094	2,795	4,135	26,932	17,340	13,152
Yugoslavia	--	--	--	13,998	9,065	7,155
Zimbabwe	4,781	3,244	4,253	33,043	21,752	19,058
Total[1]	[r]25,736	17,525	24,976	304,829	171,587	[r]131,772
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

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

Source: Bureau of the Census.

Table 14.—U.S. imports of selected chromium materials, by type

Type	1984	1985	1986		Principal sources, 1986
	Quantity (short tons)	Quantity (short tons)	Quantity (short tons)	Value (thousands)	
Metal and alloys:					
Chromium metal[1]	4,677	3,954	4,485	$21,647	United Kingdom (45%); Japan (22%); China (21%); France (8%).
Ferrochromium-silicon	[2]7,942	[3]3,940	[4]9,221	5,743	Zimbabwe (52%); Republic of South Africa (48%).
Chemicals:					
Chromic acid	2,456	4,905	4,626	7,520	Federal Republic of Germany (58%); Netherlands (16%); Italy (8%); China (6%); Mexico (5%); Japan (4%).
Chromium carbide	181	123	101	784	Japan (38.6%); United Kingdom (35.6%); Federal Republic of Germany (25.7%).
Potassium chromate and dichromate	554	639	827	1,038	United Kingdom (71%); Federal Republic of Germany (17%); U.S.S.R. (9%).
Sodium chromate and dichromate	4,617	10,836	7,657	4,103	U.S.S.R. (22%); Turkey (21%); Italy (16%); Republic of South Africa (16%); United Kingdom (16%).

See footnotes at end of table.

Table 14.—U.S. imports of selected chromium materials, by type —Continued

Type	1984 Quantity (short tons)	1985 Quantity (short tons)	1986 Quantity (short tons)	1986 Value (thousands)	Principal sources, 1986
Pigments:					
Chrome green	53	202	26	$43	United Kingdom (62%); Canada (35%).
Chrome yellow	2,560	r3,181	2,131	3,061	Canada (77%); Federal Republic of Germany (12%).
Chrome oxide green	1,999	r1,511	2,828	5,481	United Kingdom (39%); Federal Republic of Germany (30%); Japan (15%); Romania (9%); China (5%).
Hydrated chromium oxide green	18	13	--	--	
Molybdenum orange	1,013	1,077	826	1,754	Canada (86%); Japan (7%); Republic of Germany (5%).
Strontium chromate	197	431	131	267	Belgium-Luxembourg (39%); Federal Republic of Germany (23%); Spain (18%); France (16%).
Zinc yellow	1,186	1,731	1,420	1,751	Norway (41%); Hungary (24%); Canada (20%); Federal Republic of Germany (13%).

[1]Wrought and unwrought and waste and scrap.
[2]Contained 3,032 tons of chromium.
[3]Contained 1,493 tons of chromium.
[4]Contained 3,532 tons of chromium.

Source: Bureau of the Census.

Table 15.—U.S. import duties for chromium-containing materials

Item	TSUS No.	Most favored nation (MFN) Jan. 1, 1986	Most favored nation (MFN) Jan. 1, 1987	Non-MFN Jan. 1, 1986
Ore: Chrome ore and concentrate	601.15	Free.	No target duty	Free.
Metal and alloys:				
Low-carbon ferrochromium	606.22	3.3% ad valorem	3.1% ad valorem	30% ad valorem.
High-carbon ferrochromium	606.24	1.9% ad valorem	No target duty	7.5% ad valorem.
Ferrosilicon chromium	606.42	10% ad valorem	10% ad valorem	25% ad valorem.
Chrome metal[1]	632.18	3.9% ad valorem	3.7% ad valorem	30% ad valorem.
Chemicals:				
Potassium chromate and dichromate	420.08	1.5% ad valorem	1.5% ad valorem	3.5% ad valorem.
Sodium chromate and dichromate	420.98	2.5% ad valorem	2.4% ad valorem	8.5% ad valorem.
Chromium carbide	422.92	4.4% ad valorem	4.2% ad valorem	25% ad valorem.
Chromic acid	423.0092	3.9% ad valorem	3.7% ad valorem	Do.
Pigments:				
Chrome green	473.10	do	No target duty	Do.
Chrome yellow	473.12	do	do	Do.
Chromium oxide green	473.14	do	3.7% ad valorem	Do.
Hydrated chromium oxide green	473.16	do	do	Do.
Molybdenum orange	473.18	do	No target duty	Do.
Strontium chromate	473.19	do	3.7% ad valorem	Do.
Zinc yellow	473.20	do	No target duty	Do.

[1]Includes wrought, unwrought, waste and scrap chromium metal.

Note.—The special tariff treatment programs, Generalized System of Preferences, Least Developed Developing countries, Caribbean Basin Economic Recovery Act, and the United States-Israel Free Trade Area Implementation Act of 1985, apply to many of these items.

WORLD REVIEW

Australia.—Australis Mining NL continued exploration in the Gascoyne Mineral Field, Western Australia. Australis started a 10-hole drilling project at its Omega prospect. Monarch Petroleum NL explored for chromite in the Pilbara Mineral Field, Western Australia. Monarch sampled stream sediments at its Lionel prospect.

Brazil.—Brazil was the site of the 4th International Ferroalloys Conference (INFACON 86). The conference included reports on chromite resources (Vale do Jacurici, Bahia State, Brazil), chromite processing (heavy media separation and sintering), traditional ferrochromium production (Ferrochrome Philippines Inc. and Ferro Alloys Corp. Ltd. (FACOR), India), chromite reduction chemistry, nontraditional smelting and processing (plasma and bottom blowing), and a world demand perspective.

Associação Brasileira dos Produtores de Ferroligas (ABRAFE) reported that Cia. de Ferro-Ligas da Bahia S.A. (FERBASA) increased its high-carbon ferrochromium production capacity from about 90,000 tons in 1984 to about 130,000 tons in 1985. Low-carbon ferrochromium capacity is about 13,000 tons; ferrochromium-silicon, about 9,000 tons.

FERBASA reportedly decided to invest $10.5 million on developing its chromium ore resources.

Canada.—A feasibility study was conducted on the production of ferrochromium from Bird River chromite concentrate in a submerged-arc electric furnace. The study found that a 46% to 51% ferrochromium could be produced from concentrates of Bird River chromite with a chromium recovery of about 80% to 91%. The Bird River chromite deposit is in Manitoba.

China.—Chinese geologists reported the discovery of chromite in Junggar Basin in northern Xinjiang Uygur Autonomous Region. The deposit was reported to contain 2 million tons of ore.

Cuba.—A chromite ore processing plant capable of producing about 37,400 tons per year of concentrate from about 50,000 tons per year of feed was built at the Merceditas Mine in Holguín Province. The Czechoslovak-built plant cost about $12 million. Cuba plans a new mine at Amores, in Holguín Province, that will produce chromite ore feedstock for the new processing plant. This new mine was planned to start production in 1987 at a rate of about 10,000 tons per year. Cuba produces primarily refractory-grade chromite.

European Economic Community (EEC).—The EEC raised its 1986 duty-free quotas of not less than 4% carbon ferrochromium from 7,716 tons to 11,023 tons, and of not less than 6% carbon ferrochromium from 231,485 tons to 314,159 tons. The 1987 quotas were set at 3,252 tons of less than 0.01% carbon ferrochromium; 11,023 tons of 4% to 6% carbon; and 132,277 tons (for January through April) of over 6% carbon. The ferrochromium tariff does not apply to EEC member countries, to European Free Trade Association affiliate countries (Finland and Sweden), or to Lomé Agreement countries (Zimbabwe).

France.—The Chromium Association met on November 6-7 at Paris, France. The stainless steel market was the major subject of discussion.

Germany, Federal Republic of.—Bayer AG, an international chemical producer based in the Federal Republic of Germany; a producer of chromium chemicals in Brazil, the Federal Republic of Germany, and the Republic of South Africa; and an owner of chromite mines in Brazil and the Republic of South Africa purchased over 90% of Hermann C. Starck Berlin KG (a producer of charge-grade ferrochromium in the Federal Republic of Germany). Starck was expected to continue operation as a separate legal entity.

Electrowerk Weisweiler GmbH announced its plan to stop ferrochromium production for the first 3 months of 1987. The planned shutdown resulted from weak market conditions.

India.—OMC Alloys Ltd., a subsidiary of Orissa Mining Corp. Ltd., after starting ferrochromium production in 1985 at its plant at Bamnipal in Orissa State, experienced technical difficulties that delayed its operation until 1986. OMC had to replace a defective heat exchanger.

Indian Metals and Ferro Alloys Ltd. (IMFA) continued construction of its second ferrochromium plant. This plant is near Choudhar, Cuttack District, Orissa State. IMFA also continued to build an electrical powerplant that is to supply power to the Choudhar plant and its already operating ferrochromium plant at Therubali, Koraput District, Orissa State. The Therubali plant has been limited to operating at 15% of capacity, owing to electrical power supply limitations.

India Chromium Metals Private Ltd., at Rourkela, Sundargarh District, Orissa State, started production of electrolytically produced chromium metal. The plant has a capacity of about 39 tons per year of metal produced from 28 electrodeposition cells, each capable of producing about 9 pounds of metal per day from a chromic acid solution. The process used at the plant was based on technology developed by the Central Electro-Chemical Research Institute at Karaikudi and cost about $560,000.

Japan.—The Takase at Okayama and Hirose at Tottori chromite ore mines have closed, or plan suspending or scaling down their mining operations.

Awamura Metal Industry Co. Ltd. announced its intention to cease ferrochromium production. Awamura, in Uji, has a ferrochromium production capacity of about 36,000 tons per year from one 25,000-kilovolt-ampere furnace. Awamura has already idled four other furnaces, the last two in 1984.

Kawasaki Steel Corp. continued testing a rotary kiln reduction process for low-grade chromium ore fines. The process was being tested at Kawasaki's Mizushima plant. After smelting, the product was to be fed into a steelmaking converter.

New Caledonia.—Chromical S.A., the Tiebaghi Mine operator, reported reserves at about 600,000 tons of chromite grading at 35% to 37% chromic oxide (Cr_2O_3) content. Reserves at Tiebaghi were reported at about 500,000 tons when production started in 1982.

Oman.—Exploration resulted in locating 320 chromium mineral deposits. Oman has delayed plans to develop its chromite resources.

Pakistan.—The Baluchistan Development Authority undertook a feasibility study for the production of ferrochromium in Baluchistan Province.

Philippines.—Ferrochemicals Co. considered the installation of a 9,000-kilovolt-ampere furnace for the production of ferrochromium. Both Ferrochemicals and Ferrochrome Philippines Inc. (FPI) experienced strikes.

South Africa, Republic of.—Rand Mines Ltd., a chromium mining company, acquired shares in Vansa Vanadium S.A. Ltd., a vanadium mining company. Vansa took a majority share (122,600 shares) of the Winterveld Mine with Rand retaining a minority share (100,000 shares). Rand retains exclusive sales rights of Winterveld ore for 15 years and owns 42% of Vansa.

Batlhako Ferrochrome (Pty.) Ltd., in Bophuthatswana, was ready at yearend to start production, with an annual high-carbon ferrochromium production capacity of about 20,000 tons. Production was to be from one conventional electric arc furnace. Batlhako Ferrochrome was expected to use ore from the Batlhako Mining Co., operator of the previously inactive Ruighoek Mine. Batlhako Mining is a wholly owned subsidiary of South African Manganese Amcor Ltd. (Samancor). Batlhako Ferrochrome is a joint venture of Samancor with others. The mine and smelter were expected to employ about 540 people.

Ferrometals Ltd., a subsidiary of Samancor, installed two decarburizing process vessels. These electric furnaces are bottom-blown with oxygen to reduce the carbon content of high-carbon (charge-grade, about 6% to 8% carbon) ferrochromium to a range of from 0.5% to 2%. Typically, high-carbon ferrochromium is 4% carbon or more; low-carbon, 0.75% carbon or less. Thus, this decarbonized ferrochromium represents a new intermediate carbon grade. The total annual furnace capacity was about 50,000 tons.

Producers of low-carbon ferrochromium in the Republic of South Africa, using the traditional ferrosilicon reduction process, include Middelburg Steel & Alloys Holdings (Pty.) Ltd. (MSA) and Feralloys Ltd. MSA was modernizing its low-carbon ferrochromium production facilities. Upon completion targeted for 1987, MSA will have increased its low-carbon ferrochromium annual production capacity from about 36,000 tons to about 50,000 tons.

CMI was listed on the Johannesburg Stock Exchange and was traded on the London Unlisted Securities Market by its parent Johannesburg Consolidated Investment Co. Ltd. (JCI). JCI holds 66% of CMI; Anglo American Corp., 25%; DAB Investment, 4%; and Allegheny International, 4%. Allegheny sold its share in CMI and terminated its sales agreement (see the "Domestic Production" section), and Jubilee Prospectors were selling a portion of their holdings in CMI. CMI produced high-carbon (charge-grade) ferrochromium with an annual capacity of about 150,000 tons. It is the Republic of South Africa's only producer of granular material. CMI used a highly efficient process which utilizes 100% chromite fines feedstock, smelts in closed furnaces, and recovers energy from those furnaces using preheating kilns.

Sweden.—Ferrolegeringar Trollhätteverken AB, a low-carbon ferrochromium producing subsidiary of the Metallurg Group Inc., situated at Trollhättan, ceased production of ferrochromium. The Trollhättan plant had been producing 25,000 to 30,000 tons of ferrochromium annually with a capacity of about 40,000 to 50,000 tons.

SwedeChrome AB, a joint venture to produce high-carbon ferrochromium and supply power as hot water and surplus gas, started operation of its plant by producing pig iron. Pig iron was produced in the process of developing stable operating conditions for the two furnaces. The plant uses plasma torch heating technology developed by SKF Steel Engineering AB and previously applied to stainless steel dust recovery. Ferrochromium production was expected in 1987, at which time different ores were to be tested in the process.

Turkey.—Bilfer Madencilik AS completed construction of a plant at Kuluncak to produce chromite ore concentrate, and continued construction on a second plant, situated at Eskikoy, targeted for startup in 1987. Each plant has an initial production capacity of about 30,000 tons per year, and potential capacity of 50,000 to 60,000 tons per year per plant. The Kuluncak concentrator produces a refractory-grade concentrate that is shipped to Iskenderum for export. These concentrators were expected to produce refractory-grade concentrate.

Exploration for chromite was carried out by Egemetal Madencilik AS in cooperation with Bomar Resources Inc. and Etibank in the Bursa area and by MTA, the state exploration agency.

Etibank continued development of a high-carbon ferrochromium plant at Elâzig. The plant was to increase capacity from 50,000 tons per year to 150,000 tons per year.

United Arab Emirates.—The United Arab Emirates Petroleum Ministry reported the discovery of about 25,000 tons of extractable chromite near Masfut and Wadi Al-Showka.

United Kingdom.—The United Kingdom reportedly achieved its objective to dispose of 25% of its strategic stockpile. Before sales began, the stockpile included about 35,000 tons of chemical-grade chromium ore; about 26,000 tons of high-carbon ferrochromium; and about 4,000 tons of low-carbon ferrochromium. When South African sanctions were being discussed, stockpile sales were suspended. When sales restarted, the British Independent Steel Producers Association stated its support in favor of maintaining a strategic stockpile.

Zimbabwe.—Zimalloys continued operation of its Netherburn Mine and opened two new operations, the Inyala chrome mine and the Great Dyke Mine. All three of these mines are in the northern Great Dyke area. Of Zimalloys demand for 11,000 tons per month of chromite ore, Netherburn was to supply about 4,000 tons; Inyala, 2,000 tons; Great Dyke, 500 tons; and other Great Dyke operations, the remainder. The Netherburn and Great Dyke Mines extract from the Great Dyke seam, the Inyala Mine from a podiform deposit.

The Inyala chrome mine, 120 kilometers south of Zvishavane in the Mberengwa Communal Lands, was opened by Zimalloys. Mine renovation cost US$1.9 million. Production was expected to be about 1,000 tons per month of lumpy ore for ferrochromium-silicon production plus 1,000 tons per month of concentrate for low-carbon ferrochromium production. The Inyala Mine was to provide 20% of Zimalloy's requirements at its smelter, situated at Gweru. The mine was expected to employ about 100 people. The podiform nature of the deposit permits a mining cost advantage over that of Great Dyke seam deposits.

The Great Dyke Mine, which closed in 1976, was reopened in 1986 by Zimalloys. The property continued to be owned by Rio Tinto (Zimbabwe) Ltd. The Great Dyke was expected to produce about 500 tons per month of high chromic oxide, high chromium-to-iron ratio ore for low-carbon ferrochromium production. The 48% to 50% chromic oxide content ore could be upgraded to 51% before smelting. Only the Northern Dyke area provided ore of this quality. The Great Dyke Mine provided this ore closer to the surface and in a thicker seam (about 120 millimeters) than any other Zimalloys operations on the Northern Dyke, all of which have been closed owing to high mining costs. The mine renovation took about 1 year and cost about US$200,000. The mine was expected to employ about 90 people.

The Ngesi Chrome Mining Cooperative opened underground operations at its Ngesi Mine, 80 kilometers east of Battlefields on the Northern Great Dyke. The mine was 1 of 18 mining cooperatives producing chromite in Zimbabwe. The Ngesi Cooperative was assisted by the Zimbabwe Mining Development Corp. and by the Ministry of Mines. The Ngesi Mine was expected to produce about 200 tons of ore per month.

Zimalloys restarted its S1 ferrochromium-silicon furnace owing to strong demand. The S1 had been closed since 1982. Zimalloys also converted its A3 high-carbon ferrochromium furnace to ferrochromium-silicon production. Zimalloys planned to convert its S1 furnace to high-carbon ferromanganese production, to be used to supply the local market.

ZIMASCO, currently operating five 18.5-megawatt furnaces with a 12.5-megawatt furnace on standby, planned to increase its production capacity from about 160,000 tons per year to about 175,000 tons per year of high-carbon ferrochromium. The increased capacity was to be achieved without increasing consumption of chromium ore by installation of a remelting furnace with which to recover fines resulting from crushing operations.

Table 16.—Chromite: World production, by country[1]

(Thousand short tons, gross weight)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Albania[e]	744	755	794	909	940
Brazil[3]	304	171	282	[e]303	315
Cuba[4]	30	37	41	[r e]40	51
Cyprus	3	--	--	--	--
Finland[4]	380	271	492	[e]500	500
Greece[5]	32	30	68	65	68
India	[r]401	[r]397	466	617	680
Iran[e]	45	55	55	55	55
Japan	12	9	8	13	[6]12
Madagascar	49	50	66	140	110
New Caledonia	55	101	93	87	[6]80
Pakistan	4	7	3	6	5
Philippines	355	294	288	300	202
South Africa, Republic of[4 7]	[r]2,680	[r]2,762	3,756	4,077	3,840
Sudan[e]	21	22	22	[6]10	9
Turkey	499	381	537	[r e]660	660
U.S.S.R.[e 8]	3,240	3,240	3,240	3,240	3,250
Vietnam[e]	18	18	20	17	17
Zimbabwe	476	463	525	591	600
Total	[r]9,348	[r]9,063	10,756	11,630	11,394

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

[1]Table includes data available through May 5, 1987.

[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: 1982—736; 1983—517; 1984—782; 1985—780 (revised, estimated); and 1986—780 (estimated).

[4]Direct-shipping lump ore plus concentrates and foundry sand.

[5]Exports of direct-shipping ore plus production of concentrates.

[6]Reported figure.

[7]Includes production by Bophuthatswana, which was as follows, in thousand short tons: 1982—295; 1983—302; and 1984—442.

[8]Estimates for 1985 are based in part on crude chromium ore output reported in Soviet sources as 3,700,000 short tons.

WORLD RESERVES

The Geological Survey of Bahia, Brazil, conducted studies of chromite resources in the Vale do Jacurici District. This district produced about one-half of Brazil's chromite ore in 1986. In 1970, Brazil's Geological Survey identified 30 million tons of chromite resources in the district. The current study estimates potential reserves at 28 million tons at a median Cr_2O_3 content of 48.8%. The chromite was found to contain chromite cumulates of 80% chromite, in grains of 0.2 to 0.8 millimeter and averaging 0.4 millimeter in size. The deposits were found to be 8 to 10 meters thick, of consistent character, and only tectonically perturbed in lateral continuity.[8]

TECHNOLOGY

The 18 papers presented at a Bureau of Mines briefing on chromium and chromite, held June 4-5, 1985, at Oregon State University, Corvallis were published.[9] Among the topics covered was a statistical study of the chromium content of U.S.-produced stainless and heat-resisting steel, the major U.S. end use of chromium. U.S.-produced stainless and heat-resisting steel was found to contain about 17% chromium on the average over all grades from 1962 to 1983. Papers also discussed the chromite resources of 10 market economy countries, the conterminous United States, and Alaska. It was estimated that about 716 million short tons of chromite could be produced from the resources analyzed in the market economy countries. Chromium resources of the conterminous United States were found to include about 1.8 million tons of Cr_2O_3 contained in 16.1 million tons of low-iron chromite-bearing material and 13.7 million tons of Cr_2O_3 contained in 152.7 million tons of high-iron chromite-bearing material. Most of the resource was in the Western United States. In situ chromium resources in Alaska were estimated at about 3.4 million to 4.3 million tons of Cr_2O_3 mostly in geographically remote and dispersed deposits ranging from about 5% to 10% Cr_2O_3. Recovery of coproduct chromite from nickel-bearing laterites in the Western United States was studied. Using sizing plus magnetic and gravity separation, recoveries of up to 50%, at concentrate grades of 35% to 40%, were achieved from residues of ores from which nickel and cobalt had been recovered. Low recoveries and grades were attributed to the fine size of the residue. Chromite from Alaska and the Northwestern United States was characterized and beneficiated. The Cr_2O_3 content of chromite ranged from 15% to 64% among deposits, although chromite from a single deposit was usually more uniform. Beneficiation characteristics, grade, general recovery, and classification of chromite concentrate were determined. Conventional and column flotation of Montana and California chromite resources was investigated. Four conventional flotation techniques using oleic-hydrogen floride, oil emulsion, carboxymethylcellulose-tall oil, and amine flotation reagent schemes were applied. Column flotation using similar reagent schemes was applied to one sample and was found to produce higher concentrate grade and better recovery. A method to recover chromium chemicals from low-grade domestic chromite from Alaska, Montana, and Oregon was devised. Chromite containing silicon and aluminum impurities that prohibited conventional processing was reacted with sodium hydroxide (NaOH) under an oxidizing condition to form sodium chromate (Na_2CrO_4). Pyrometallurgical processing of domestic chromium resources was reviewed. Submerged-arc smelting was preferred over open-bath smelting owing to higher productivity, lower apparent electrical energy and electrode consumption, smoother furnace operation, and less refractory wear. Open-bath smelting often resulted in higher chromium content of the metal product. Chromium was recovered using prereduction. Chromium recovery from superalloy scrap using a pyrometallurgical oxidation-reduction process was also reviewed. Carbonyl processing was used to upgrade Montana chromite to 51% Cr_2O_3 content and a 4:1 chromium-to-iron ratio. Processing cost was estimated at $127 per ton of concentrate produced for a 1,000-ton-per-day plant. In-plant recycling of chromium-bearing specialty steelmaking wastes was studied. Electric furnace and argon-oxygen decarburization vessel dusts, grinding swarf, and mill scale were processed to recover about 90% of the chromium content by mixing these materials with coke breeze, pelletizing, and smelting. A cost analysis of the process showed it to be economical. Chromium needs and uses, and Bureau research related to specific areas where chromium could be conserved, including the efficient use of chromium in metal alloys and refractory mixes, were reviewed. A new method of preparing chromium alloy coatings was developed. Chromium particles were occluded in an electrodeposited nickel-iron alloy matrix via an aqueous electroplating bath. Subsequent heat treatment homogenized the coatings with up to 21% chromium. A cast-on hard facing to iron-base castings for wear protection was developed. By reducing wear, materials can be conserved. Ferrochromium and white iron were cast onto plowshares and bucket wheel excavators using an efficient polystyrene pattern casting technique. Corrosion of steel coatings, and of stainless steel, under varying conditions to determine material performance was studied in order to develop information that would permit efficient use of the material. Research on substitutes for chromium in corrosion- and oxidation-resistant stainless steels in low- and high-temperature environments was reviewed. Partial substitutes for chromium in certain stainless steel grades were identified. Research on chromium loss due to wear was reviewed. Partial substitutes for chromium in certain stainless steel grades were identified. Research on chromium loss owing to wear was reviewed. Chromium was found not effective at reducing wear even under corrosive conditions. Heat treatment and wear-resistant coatings were found effective at reducing wear and thereby conserving chromium contained in the treated or coated material. Recycling of chromite-containing refractories was studied in order to reduce U.S. dependence on foreign sources of refractory-grade chromite. Refractories produced from domestic recycled chromite and improved with the addition of minor amounts of other materials were found in many applications to be satisfactory substitutes for chromite refractories produced from imported chromite ore.

The Bureau of Mines researched processing technology for domestic chromium resources. Fine-bubble column flotation of deslimed Stillwater Complex chromite ore produced a 44.7% Cr_2O_3 concentrate at 87.1% recovery, whereas conventional flotation produced a 40.4% Cr_2O_3 concentrate at 85.4% recovery.[10] Investigation of dielectric separation of chromite from olivine host rock resulted in poor separation in a single pass that was attributed to the relatively variable composition of these minerals.[11]

Bureau of Mines research on partial replacement of chromium in stainless steel examined alloys containing chromium in the range of from 8% to 9%, nickel from 11% to 14%, additions of molybdenum up to 5%, copper up to 2%, and vanadium up to 2%, for corrosion-resistant applications; and silicon up to 5%, and aluminum up to 2% for heat-resistant applications. The corrosion, oxidation, and mechanical properties of chromium- and nickel-containing iron alloys were characterized. It was found that as much as one-half of the chromium could be replaced in some applications.[12] The Bureau researched electrolytic preparation of iron-nickel-chromium alloys using a particle occlusion and heat-treatment method.[13]

Chromium recovery from scrap and waste was discussed as part of the Bureau of Mines current program to encourage recycling and alleviate waste disposal problems.[14] Research was conducted on the treatment of superalloy scrap with zinc to increase its leaching rate. Superalloy was dissolved in molten zinc, and the zinc was distilled, leaving a friable product that was leached for its component metals.[15] The recovery of chromium from spent catalysts was also studied. Chromium lost in spent high-temperature-shift catalysts was estimated at 529 tons per year. Up to 92% of the chromium contained in such catalysts was recovered as sodium chromate.[16]

The Bureau of Mines investigated the effects of aluminum and silicon alloying elements on oxidation kinetics and morphology of oxides. The addition of these alloying elements improved the oxidation and thermal shock resistance of low-chromium alloys.[17] Also studied was the correlation of abrasive wear with the alloy additions in low-alloy steels. Chromium was found to be not significant in affecting wear.[18] In research on the transference of hard particles, chromium carbide hard facings were applied to investment casting surfaces. The carbides dissolved upon casting to form white iron. The chromium carbide coatings were found to exhibit promising structures and contain discrete carbide particles within a low-alloy steel matrix, but were not thick enough for mining applications.[19] Electrochemically determined thermodynamic properties of nickel chromite and cobalt chromite were published.[20]

The results of a magnetic survey of chromite occurrences in the Krishna District of Andhra Pradesh State, India, were reported. The chromite deposit was found to have magnetic properties owing to its magnetite content. Those magnetic properties distinguished the deposit from host rock and implied extension of the chromite deposit.[21] The beneficiation processes used by Mysore Minerals Ltd. to produce chemical-grade chromite concentrate at its Byrapur plant and by FACOR to produce metallurgical-grade chromite concentrate were described.[22] The beneficiation of Zimbabwe podiform chromite ore sized less than 2 inches in diameter, using a ferrosilicon-water heavy medium in cone, drum, and cyclone plants, was described.[23] The recovery of chromite fines from tailings dumps was reported. An elutriation-supplemented spiral-concentration procedure produced a 45.9% Cr_2O_3 and 0.89% silica concentrate at 55% recovery of Cr_2O_3 from tailings.[24]

The merits of chromite as a foundry sand in steel casting were described.[25] Production of ferrochromium for use in the production of stainless steel was reviewed considering technological changes in stainless steel production and the potential impact of high electrical energy costs.[26] An economic review of ferrochromium in a global context found that in world trade ferrochromium was likely to continue to replace chromium ore for metallurgical use. This trend could be changed by the development of a direct (i.e., chromium ore to raw stainless steel) production process. Based on current reserves and production rates, southern Africa was expected to increase its share of chromium to world markets.[27]

The production of ferrochromium by traditional electric arc furnace technology and by nontraditional methods, such as plasma, rotary kiln, and blast furnace technologies, have been studied. The solid state reduction of chromite, as occurs in prereduction processes, was proposed and experimentally substantiated. Benefits to the ferrochromium industry of using a prereduction process were identified.[28] The energy savings achievable through preheating and prereduction in conjunction with traditional smelting, was studied using a computerized model. The use of an externally heated shaft furnace to increase prereduction-based energy savings was suggested.[29] The sintering process developed by FERBASA for the economically efficient use of less than 2-millimeter-diameter chromite ore concentrate with charcoal was described.[30] The production of a new grade of ferrochromium by decarburizing charge-grade high-carbon ferrochromium using a modified CLU (Creusot-Loire-Ugine Aciers) process was described. Decarburization is accomplished by bottom-blowing of a mixture of gases including oxygen and steam.[31] The reduction mechanism of chromium ore sintered with carbon was studied.[32] The facility that started production of ferrochromium from lump ore at Outokumpu Oy's Tornio works in 1985 was described. The new process line includes heavy media separation of ore at the minesite, and static preheating and energy recovery at the smelter.[33] The FPI plant, designed by Outokumpo Oy, and modification to it were described. The FPI facility included a pelletizing plant, a preheating rotary kiln, and a closed electric submerged-arc furnace.[34] The FACOR ferrochromium plant at Randia, India, and its mine and beneficiation plant were described. FACOR crushed, ground, sized, beneficiated, and agglomerated chromium ore, which was then smelted. The cast product was broken, crushed, sized, and stored for shipment.[35]

The feasibility of ferrochromium production from Canadian chromite using traditional submerged electric arc furnace technology was studied. It was found that the Canadian chromite could be used to produce a high-carbon ferrochromium ranging from 46% to 51% chromium at chromium recoveries ranging from 76% to 91%. The cost of such a product was estimated to exceed that of South African ferrochromium, ranging from 50% to 120%.[36] The behavior of impurities in high-carbon ferrochromium production was studied. The chemistry of carbon, silicon, sulfur, phosphorus, and nitrogen in the electric submerged-arc furnace was reviewed and methods for minimizing ferrochromium impurities were outlined.[37] The industrial practice and economics of dense media separation applied to ferrochromium recovery from ferrochromium-slag mixtures by Hellenic Ferroalloys S.A. were described.[38]

Plasma technology development for producing ferrochromium was reported. Chromite derived from the Stillwater Complex was successfully smelted in a direct current transferred-arc plasma furnace. A chromium recovery of about 90% was achieved in producing 46% chromium ferrochromium from chromite grading 39% Cr_2O_3 with a 1.43 chromium-to-iron ratio.[39] In-flight and in-bath reduction of chromium ore in transferred-arc plasma furnaces were studied and compared. It was found that the in-bath reduction process achieved complete reduction, whereas the in-flight process did not.[40] The general features of conventional electric submerged-arc furnace and the characteristics of several transferred-arc and nontransferred-arc devices currently in commercial use were described. Production of ferrochromium in a commercial scale transferred-arc furnace developed by Mintek and Middelburg Steel has been in progress since 1983. Production of ferrochromium in a commercial scale nontransferred-arc furnace developed by SKF Steel was scheduled to start production in 1987.[41]

The development of direct current electric transferred-arc plasma smelting technology, ranging from 100-200-kilovolt-ampere to 3.2-megavolt-ampere furnaces, at Mintek was described. The plasma furnace was found to offer greater flexibility in feed materials, but required more control compared with that of the traditional submerged-arc furnace.[42] Exploitation of the feed flexibility of the direct current transferred-arc plasma furnace to produce new grades of ferrochromium was described. Ferrochromium produced by the plasma process was lower in silicon, sulfur, phosphorus, and titanium compared with that produced by the submerged-arc process.[43] An argon-stabilized transferred-arc furnace developed by Davy McKee Corp. was described and identified as potentially useful for the smelting of chromium concentrates resulting from the extraction of UG-2 seam ore processed for its platinum content.[44] A non-transferred-arc plasma generator and its incorporation in a ferrochromium production process developed by SKF Steel called Plasmachrome process was described. The process was to be used by SwedeChrome AB to produce ferrochromium in 1987.[45] The continuous preparation of chromite ore feedstock for this plasma process was described.[46]

Research on nonconventional methods of ferrochromium production was reported in the following areas: rotary kiln furnace reduction of chromite being developed by Nippon Kokan K.K.;[47] top and bottom blown converter furnace being developed by Nippon Steel Corp.;[48] and modified iron blast furnace being developed by Kawasaki.[49] The effect of the presence of nickel during decarburization of high-carbon ferrochromium was studied.[50]

Chromium removal from wastewater and from waste pickle acid was studied. A solid supported liquid membrane was used to recover chromium from simulated electroplating rinse water as sodium chromate.[51] An electrodialytic process that uses bipolar membrane technology has been developed to recover stainless steel pickling solutions. The process leaves chromium as a dry metal hydroxide.[52]

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Clays

By Sarkis G. Ampian[1]

Total quantity of clays sold or used by domestic producers decreased slightly in tonnage but rose 8% in value to a new record high of $1.10 billion. Clays in 1 or more of 6 classification categories, ball clay, bentonite, common clay and shale, fire clay, fuller's earth, or kaolin, were produced in 44 States and Puerto Rico during 1986. Clay production, as in 1985, was not reported in Alaska, Delaware, the District of Columbia, Hawaii, Rhode Island, Vermont, or Wisconsin. The leading seven States, in descending order, were Georgia, Ohio, North Carolina, Texas, California, Alabama, and South Carolina. The erratic disparity in costs between fuels, such as oil and natural gas, was still a major concern to clay producers and manufacturers striving to lower their overhead. Industrywide efforts to both economize and to obtain alternative competitive fuels persisted during the year. However, at midyear, because of declining oil prices coupled with the overabundance of inexpensive natural gas, clay manufacturers were looking toward making advantageous long-term fuel purchase commitments. Environmental restrictions and associated cost combined with persistent high capital costs continued to affect production.

Production of common clay and shale was relatively unchanged because the upturn in construction due to a combination of declining interest rates and improving business climate was offset by declining building rates in the oil-producing States of Colorado, Louisiana, Oklahoma, and Texas. Common clay and shale is used chiefly in clay building materials—brick, portland cement, floor and wall tile, lightweight aggregates, and vitrified sewer pipe. Of the specialty clays, only kaolin increased to a record-high level while ball clay, bentonite, fire clay, and fuller's earth all declined because of the softening of the overall economy. Production of bentonite and fire clay declined because their major consumers, the steel, oil and gas exploration, and foundry industries, were still in transition to lower production levels.

Kaolin accounted for 19% of the clay production but 64% of the clay value. Kaolin production of 8.5 million short tons was a record-high level.

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 1,056 operations covered by the survey, 1,034 responded, representing 98% of the total clay and shale production sold or used shown in table 1.

Table 1.—Salient U.S. clays and clay products statistics[1]

(Thousand short tons and thousand dollars)

	1982	1983	1984	1985	1986
Domestic clays sold or used by producers:					
Quantity	35,345	40,858	43,702	44,974	44,620
Value	$825,064	$931,092	$1,032,127	$1,011,377	$1,095,179
Exports:					
Quantity	2,619	2,484	2,699	2,780	2,913
Value	$267,700	$254,237	$295,733	$309,871	$351,161
Imports for consumption:					
Quantity	24	21	32	41	38
Value	$4,514	$3,488	$4,868	$5,981	$7,501
Clay refractories shipments: Value	$559,655	$595,299	$782,308	$629,738	$529,268
Clay construction products shipments: Value	$923,459	$1,160,543	$1,342,196	$1,427,851	$1,601,640

[1]Excludes Puerto Rico.

Table 2.—Clays sold or used by producers in the United States in 1986, by State[1]

(Short tons unless otherwise specified)

State	Ball clay	Ben- tonite	Common clay and shale	Fire clay	Fuller's earth	Kaolin	Total	Total value
Alabama	--	W	1,886,574	110,482	--	80,371	[2]2,077,427	[2]$14,828,248
Arizona	--	16,191	184,919	--	--	--	201,110	1,366,226
Arkansas	--	--	783,588	W	--	190,785	[3]974,373	[3]8,997,727
California	W	125,217	2,228,871	--	--	95,048	[4]2,449,136	[4]33,288,772
Colorado	--	500	235,782	6,051	--	--	242,333	1,523,079
Connecticut	--	--	156,680	--	--	--	156,680	975,207
Florida	--	--	227,243	--	463,246	35,414	725,903	43,260,551
Georgia	--	--	2,516,322	--	531,848	6,778,492	9,826,662	669,199,737
Idaho	--	W	W	W	--	1,644	[2 3 5]1,644	W
Illinois	--	--	282,993	--	W	--	[6]282,993	[6]1,091,609
Indiana	--	--	743,859	--	--	--	743,859	3,043,873
Iowa	--	--	486,309	--	--	--	486,309	1,420,979
Kansas	--	24,090	879,358	--	--	--	903,448	5,295,181
Kentucky	W	--	721,111	W	--	--	[3 4]721,111	[3 4]3,450,418
Louisiana	--	--	331,982	--	--	--	331,982	7,669,853
Maine	--	--	46,000	--	--	--	46,000	90,000
Maryland	W	--	361,729	--	--	--	[4]361,729	[4]1,757,132
Massachusetts	--	--	139,995	--	--	--	139,995	871,199
Michigan	--	--	1,402,446	--	--	--	1,402,446	5,684,283
Minnesota	--	--	W	--	--	W	W	W
Mississippi	W	311,044	616,672	--	W	--	[4 6]927,716	[4 6]13,538,041
Missouri	--	--	1,130,333	185,758	W	4,676	[6]1,320,767	[6]6,650,298
Montana	--	182,607	39,212	--	--	--	221,819	5,881,704
Nebraska	--	--	221,153	--	--	--	221,153	668,380
Nevada	--	10,313	--	--	W	W	[6 7]10,313	[6 7]583,519
New Hampshire	--	--	W	--	--	--	W	W
New Jersey	--	--	120,000	12,524	--	--	132,524	2,065,919
New Mexico	--	--	58,081	2,103	--	--	60,184	170,121
New York	--	--	618,968	--	--	--	618,968	3,074,611
North Carolina	--	--	2,606,679	--	--	51,000	2,657,679	10,970,024
North Dakota	--	--	W	--	--	--	W	W
Ohio	--	--	2,659,675	173,110	--	--	2,832,785	11,515,409
Oklahoma	--	--	992,702	--	--	--	992,702	2,328,697
Oregon	--	--	203,596	--	--	--	203,596	288,920
Pennsylvania	--	--	1,189,121	44,670	--	W	[7]1,233,791	[7]5,060,538
Puerto Rico	--	--	110,997	--	--	--	110,997	222,845
South Carolina	--	--	923,165	--	W	1,063,088	[6]1,986,253	[6]37,980,265
South Dakota	--	W	118,718	--	--	--	[2]118,718	[2]375,112
Tennessee	615,649	--	548,641	--	W	--	[6]1,164,290	[6]25,227,698
Texas	38,367	32,824	2,423,685	19,670	W	W	[4 6]2,514,546	[4 6 7]11,724,068
Utah	--	7,680	296,867	--	--	--	304,547	2,048,029
Virginia	--	--	855,977	--	34,000	--	889,977	7,699,648
Washington	--	--	249,469	2,676	--	--	252,145	1,559,767
West Virginia	--	--	214,980	--	--	--	214,980	469,708
Wyoming	--	1,738,412	23,223	--	--	--	1,761,635	51,822,807
Undistributed	233,156	364,165	141,401	34,783	880,884	248,964	1,903,353	89,661,827
Total	887,172	2,813,043	29,979,076	591,827	1,909,978	8,549,482	44,730,578	1,095,402,029

W Withheld to avoid disclosing company proprietary data; included with "Total" and/or "Undistributed."
[1]Includes Puerto Rico.
[2]Excludes bentonite.
[3]Excludes fire clay.
[4]Excludes ball clay.
[5]Excludes common clay.
[6]Excludes fuller's earth.
[7]Excludes kaolin.

Table 3.—Number of mines[1] from which producers sold or used clays in the United States in 1986, by State

State	Ball clay	Bentonite	Common clay and shale	Fire clay	Fuller's earth	Kaolin	Total
Alabama	--	1	25	5	--	7	38
Arizona	--	5	8	--	--	--	13
Arkansas	--	--	18	1	--	4	23
California	1	5	54	1	--	5	66
Colorado	--	1	27	8	--	--	36
Connecticut	--	--	2	--	--	--	2
Florida	--	--	3	--	4	1	8
Georgia	--	--	15	--	7	83	105
Idaho	--	1	2	1	--	1	5
Illinois	--	--	9	--	2	--	11
Indiana	--	--	16	--	--	--	16
Iowa	--	--	11	--	--	--	11
Kansas	--	1	20	--	--	--	21
Kentucky	5	--	11	2	--	--	18
Louisiana	--	1	8	--	--	--	9
Maine	--	--	3	--	--	--	3
Maryland	1	--	7	--	--	--	8
Massachusetts	--	--	3	--	--	--	3
Michigan	--	--	5	--	--	--	5
Minnesota	--	--	1	--	--	2	3
Mississippi	1	4	20	--	2	--	27
Missouri	--	--	14	37	2	1	54
Montana	--	11	5	1	--	--	17
Nebraska	--	--	5	--	--	--	5
Nevada	--	6	--	--	--	2	8
New Hampshire	--	--	1	--	--	--	1
New Jersey	--	--	1	1	--	--	2
New Mexico	--	--	4	2	--	--	6
New York	1	--	11	--	--	--	12
North Carolina	--	--	51	--	--	2	53
North Dakota	--	--	2	--	--	--	2
Ohio	--	--	52	16	--	--	68
Oklahoma	--	--	18	--	--	--	18
Oregon	--	--	8	--	--	--	8
Pennsylvania	--	--	34	15	--	1	50
South Carolina	--	--	25	--	1	17	43
South Dakota	--	2	1	--	--	--	3
Tennessee	18	--	7	--	3	--	28
Texas	1	10	64	3	1	1	80
Utah	--	3	12	--	1	--	16
Virginia	--	--	14	--	1	--	15
Washington	--	--	8	3	--	--	11
West Virginia	--	--	3	1	--	--	4
Wyoming	--	119	2	--	--	--	121
Total	28	170	610	97	24	127	1,056

[1]Includes both active and idle operations.

DOMESTIC PRODUCTION, PRICES, AND FOREIGN TRADE, BY TYPE OF CLAY

KAOLIN

Domestic production of kaolin increased 10% to 8.5 million tons while its reported value increased over 16% to $695.8 million. Both the reported output and value were record highs. The average unit value of all grades of kaolin increased about 6% to $81.39 per ton. Kaolin was produced in 13 States. Two States, Georgia and South Carolina, accounted for nearly 92% of total production. Arkansas ranked third; California, fourth; and Alabama, fifth. Both Alabama and Arkansas produce refractory- and alum-grade kaolins. Kaolin producers reported major domestic end uses for their clay as follows: paper coating, 33%; paper filling, 19%; face brick, 9%; refractories, 8%; fiberglass and insulation, 5%; rubber, 4%; and catalysts and chemicals, 2% each.

Kaolin is defined as a white, claylike material approximating the mineral kaolinite. It has a specific gravity of 2.6 and a fusion point of 1,785° C. The other kaolin-group minerals, such as halloysite and dickite, are encompassed.

Kaolin production was buoyed by the continued growth of the overall economy, particularly the high rates of paper production. Capacity increases in both water-washed and calcined grades that occurred in the early 1980's were beginning to come into line, and most major producers were operating at near capacity. Capacity expansions were being undertaken by many producers to meet the anticipated future demands of the paper industry. Kaolin sales for refractory uses continued to recover slowly. The refractory industry was still undergoing long-range modifications brought about by changes in technology. The trend from lower quality fire clays to high-performance high-alumina refractories, such as made from kaolin grogs and/or calcines is most encouraging for the kaolin industry. Production of the three paper-grade kaolins increased in 1986 about 5% from 5.08 million tons to 5.31 million tons. Delaminated kaolin and water-washed production increased 24% and 3%, respectively, while low-temperature calcined production decreased about 11%. All grades of air-float kaolin increased 14%.

All Georgia water-washed kaolin producers and South Carolina air-float producers continued their ongoing modernization and energy-use reduction plans to reduce operating overhead. Notable exceptions to the above were the activities of Engelhard Corp.'s Performance Minerals Group, Anglo-American Clays Corp. (a subsidiary of ECC America Inc.), and Burgess Pigment Co. in their Georgia operations. Engelhard announced a major expansion program of both its calcined kaolin grades and its ancillary equipment at its McIntyre complex, scheduled to be completed in 1987. Calcined extender pigments are used by the paper, paint, plastics, and rubber industries. Anglo-American scheduled for completion by yearend, at its Sandersville operation, a 65% increase in production facilities for opacifying pigments and a 25% increase in drying capacity for three grades of high-brightness coating clays. Burgess Pigment, also in Sandersville, increased calcined clay capacity of products for the paint and plastics industries.

Statistical Process Control programs, designed to efficiently produce consistently high-quality products, were initiated by Engelhard at its McIntyre facility; by C-E Minerals Inc. at its Andersonville, GA, refractory calcine complex; and by Albion Kaolin Co. at its air-float operation in Hephzibah, GA.

Two major kaolin acquisitions were noted during the year. United States Borax & Chemical Corp., owned by the British company Rio Tinto Zinc Corp. Ltd., purchased all the capital stock of Ottawa Silica Co., which includes its Kosse, TX, sand-kaolin operation. In the other acquisition, Sibelco's Unimin Corp. absorbed Tammsco Inc. as a wholly owned subsidiary. Unimin assets now include a primary kaolin mine and processing facility in North Carolina.

Development plans also continued for the proposed kaolin mining and processing venture near Redwood, MN. Plans call for the kaolin to be used principally in manufacturing portland cement with minor amounts for the local filler and extender markets. Present plans include a 100,000-ton-per-year production facility.

Exports of kaolin, as reported by the U.S. Department of Commerce, increased nearly 15% to 1.58 million tons valued at $213 million, despite a relatively strong U.S. dollar and foreign competition. Kaolin, including calcined material, was exported to 73 countries, 3 more than in 1985. The major recipients were Japan, 29%; Canada, 23%; the Netherlands, 10%; Italy, 8%; and Mexico, 5%. Kaolin producers reported end uses for their exports as follows: paper coating, 55%; paper filling, 15%; refractories, 15%; paint, 8%; rubber, 3%; and other, including ceramics and plastics, the remainder.

Kaolin imports for consumption increased over 10% to 10,332 tons valued at $1.18 million. The unit price of kaolin imported from the United Kingdom, the leading source country, increased over 10% to $113.28 per ton.

Kaolin prices quoted in the trade journals remained unchanged. Chemical Marketing Reporter, December 29, 1986, quoted prices as follows:

Water-washed, fully calcined, bags, carload lots, f.o.b. Georgia, per ton	$255.00
Paper-grade, uncalcined, bulk, carload lots, f.o.b. Georgia, per ton:	
No. 1 coating	94.00
No. 2 coating	75.00
No. 3 coating	73.00
No. 4 coating	70.00
Filler, general purpose, same basis per ton	58.00
Delaminated, water-washed, uncalcined, paint-grade, 1-micrometer average, same basis, per ton	182.00
Dry-ground, air-floated, soft, same basis, per ton	60.00
National Formulary, powder, colloidal, bacteria controlled, 50-pound bags, 5,000-pound lots, per pound	.24

Table 4.—Kaolin sold or used by producers in the United States, by State

State	1985		1986	
	Short tons	Value	Short tons	Value
Alabama	111,886	$1,959,747	80,371	$2,396,169
Arkansas	140,271	8,877,441	190,785	7,152,537
California	28,138	760,752	95,048	2,371,925
Florida	36,323	2,843,000	35,414	2,771,146
Georgia	6,345,205	534,980,001	6,778,492	635,219,813
Idaho	1,505	W	1,644	W
Missouri	56,701	1,701,030	4,676	47,134
North Carolina	76,864	1,943,619	51,000	1,442,490
South Carolina	866,812	35,309,338	1,063,088	35,588,061
Other[1]	129,617	7,240,830	248,964	8,859,945
Total	7,793,322	595,615,758	8,549,482	695,849,220

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	1985		1986	
	Short tons	Value	Short tons	Value
Air-float	1,275,733	$66,136,128	1,454,675	$78,092,960
Calcined[1]	1,108,098	116,319,429	1,185,088	166,701,281
Delaminated	735,503	72,075,882	915,641	56,809,167
Unprocessed	914,263	14,419,612	1,121,499	14,712,850
Water-washed	3,759,725	326,664,707	3,872,579	379,532,962
Total	7,793,322	595,615,758	8,549,482	695,849,220

[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
1985				
Georgia and Alabama	432,495	$10,565,958	[1]532,275	[1]$91,979,229
Other	[2]90,537	[2]8,691,212	[3]52,791	[3]5,083,030
Total	523,032	19,257,170	585,066	97,062,259
1986				
Georgia and Alabama	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

[1]Excludes Alabama.
[2]Includes Arkansas, Idaho, and Missouri.
[3]Includes Pennsylvania, South Carolina, and Texas.

Table 7.—Georgia kaolin sold or used by producers, by kind

Kind	1985		1986	
	Short tons	Value	Short tons	Value
Air-float	739,563	$31,824,375	913,849	$35,111,526
Calcined[1]	945,106	100,875,939	915,581	159,331,295
Delaminated	735,503	72,075,882	915,641	56,809,167
Unprocessed	196,312	5,594,126	210,336	7,297,076
Water-washed	3,728,721	324,609,679	3,823,085	376,670,749
Total	6,345,205	534,980,001	6,778,492	635,219,813

[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	1985 Air-float	1985 Unprocessed[1]	1985 Water-washed[2]	1985 Total	1986 Air-float	1986 Unprocessed[1]	1986 Water-washed[2]	1986 Total
Domestic:								
Adhesives	7,413	--	73,399	80,812	26,438	--	23,978	50,416
Aluminum sulfate and other chemicals	243	109,923	351	110,517	--	110,000	--	110,000
Animal feed	88	--	1,264	1,352	30,012	--	--	30,012
Asphalt tile and linoleum	3,776	--	--	3,776	13,512	--	43	13,555
Catalysts (oil refining)	60,767	253	106,717	167,737	46,016	--	17,153	63,169
Electrical porcelain	13,086	--	--	13,086	12,346	--	1,043	13,389
Face brick	--	25,943	55,285	81,228	--	--	18,930	18,930
Fiberglass and mineral wool	109,130	--	61,373	170,503	168,994	--	61,045	230,039
Fine china and dinnerware; crockery and earthenware	15,518	1,453	--	16,971	20,510	1,377	--	21,887
Firebrick, blocks and shapes	2,901	940	--	3,841	62,565	2,723	95	65,383
Floor and wall tile, ceramic	8,412	--	--	8,412	8,250	2,899	5,719	16,868
Flue linings; high-alumina brick and specialties; glazes, glass, enamels	--	3,064	--	3,064	--	28,800	--	28,800
Foundry sand	--	--	364	364	--	--	--	--
Grogs and calcines, refractory	1,544	260,567	--	262,111	--	252,709	464	253,173
Ink	W	--	W	W	--	--	W	W
Kiln furniture, refractory and mortar cement	W	W	--	W	W	W	W	W
Medical, pharmaceutical, cosmetic	1,233	--	1,202	2,435	--	--	1,291	1,291
Paint	21,734	--	150,825	172,559	12,787	--	207,203	219,990
Paper coating	--	--	2,263,846	2,263,846	--	--	2,313,664	2,313,664
Paper filling	27,107	--	1,144,228	1,171,335	178,920	--	1,153,431	1,332,351
Plastics	5,648	--	35,414	41,062	3,600	--	37,397	40,997
Pottery	9,224	726	--	9,950	31,497	689	--	32,186
Roofing granules	21,878	--	--	21,878	26,249	--	--	26,249
Rubber	92,709	1,213	28,962	122,884	31,011	--	20,656	51,667
Sanitary ware	122,630	12,353	728	135,711	128,918	11,705	6,442	147,065
Miscellaneous, air-float:								
Common brick, fertilizers, gypsum products, pesticides and related products, roofing and structural tile, other uses not specified	66,083	--	--	66,083	48,212	--	--	48,212
Miscellaneous, unprocessed:								
Fertilizers, pesticides and related products, other uses not specified	--	4,731	--	4,731	--	54,866	--	54,866
Miscellaneous, water-washed:								
Gypsum products, pesticides and related products, waterproofing and sealing, fertilizers, other uses not specified	--	--	100,181	100,181	--	--	167,502	167,502
Undistributed	20,805	49,337	90	70,232	18,495	--	4,275	22,770
Total	611,929	470,503	4,024,229	5,106,661	868,332	465,768	4,040,331	5,374,431

Exports:								
Paint	77,883	--	30,438	108,321	124	--	112,446	112,570
Paper coating	23,297	--	766,392	789,689	27,386	--	776,962	804,348
Paper filling	8,206	--	137,049	145,255	5,065	--	222,479	227,544
Plastics	--	--	19,223	19,223	40	--	--	40
Refractories	--	138,640	281	138,921	--	190,000	--	190,000
Rubber	235	--	885	1,120	--	--	--	--
Undistributed	18,013	--	18,002	36,015	12,902	--	56,657	69,559
Total	127,634	138,640	972,270	1,238,544	45,517	190,000	1,168,544	1,404,061
Grand total	739,563	609,143	4,996,499	6,345,205	913,849	655,768	5,208,875	6,778,492

W Withheld to avoid disclosing company proprietary data; included with "Undistributed."
[1]Includes high-temperature calcined.
[2]Includes low-temperature calcined and delaminated.

Table 9.—South Carolina kaolin sold or used by producers, by kind

Kind	1985		1986	
	Short tons	Value	Short tons	Value
Air-float[1]	504,330	$31,670,613	506,705	$31,298,499
Unprocessed	362,482	3,638,725	556,383	4,289,562
Total	866,812	35,309,338	1,063,088	35,588,061

[1]Includes water-washed.

Table 10.—South Carolina kaolin sold or used by producers, by kind and use

(Short tons)

Kind and use	1985	1986
Air-float:[1]		
Adhesives	14,528	17,483
Animal feed and pet waste absorbent	5,333	3,603
Ceramics[2]	13,542	3,637
Fertilizers and pesticides and related products	33,855	6,732
Fiberglass	67,095	99,393
Paint	364	580
Paper coating and filling	1,843	8,644
Plastics	13,051	9,581
Rubber	188,945	235,142
Refractories[3]	30,052	5,693
Other uses[4]	85,495	82,743
Exports[5]	50,227	33,474
Total	504,330	506,705
Unprocessed: Face brick and other uses	362,482	556,383
Grand total	866,812	1,063,088

[1]Includes water-washed.
[2]Includes floor and wall tile, pottery, and roofing granules.
[3]Includes refractory calcines and grogs; refractory mortar and cement; high-alumina refractories; and firebrick, blocks and shapes.
[4]Includes animal oil; catalysts (oil refining); chemical manufacturing; ink, medical; sewer pipe; and unknown uses.
[5]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	1985 Air-float	1985 Unprocessed[1]	1985 Water-washed[2]	1985 Total	1986 Air-float	1986 Unprocessed[1]	1986 Water-washed[2]	1986 Total
Domestic:								
Adhesives	21,941	--	75,632	97,573	43,921	--	25,978	69,899
Aluminum sulfate and other chemicals	243	202,424	3,017	205,684	--	155,352	--	155,352
Animal feed	5,421	--	5,686	11,107	33,615	--	3,259	36,874
Brick, common and face	6,692	487,694	--	494,386	6,655	645,289	236	652,180
Catalysts (oil and gas refining)	110,864	2,100	106,970	219,934	107,528	--	17,153	124,681
Cement, portland	--	133,977	1,140	135,117	--	204,339	--	204,339
China and dinnerware	13,908	1,453	729	16,090	20,209	1,377	3,000	24,586
Crockery and other earthenware	W	--	--	W	W	W	--	W
Electrical porcelain	24,810	--	312	25,122	16,773	--	4,043	20,816
Fertilizers[3]	26,165	--	2,937	29,102	--	--	4,846	4,846
Fiberglass, mineral wool and other insulation	223,472	--	80,079	303,551	268,387	--	98,990	367,377
Firebrick, blocks and shapes	5,713	936	4	6,653	66,031	2,723	95	68,849
Floor and wall tile; ceramic glazes, glass, enamels	18,571	--	--	18,571	20,331	5,194	5,719	31,244
Flue linings, high-alumina brick and specialties	22,807	92,191	--	114,998	661	87,903	400	88,964
Foundry sand	925	--	39	964	412	--	--	412
Grogs and calcines, refractory	4,790	286,034	--	290,824	2,794	388,562	464	391,820
Gypsum products and wallboard	4,721	--	3,696	8,417	14,983	3,257	806	19,046
Ink	W	--	W	W	--	--	W	W
Kiln furniture, refractory and mortar cement	45,195	49,337	--	94,532	20,903	35,936	1,389	58,228
Linoleum and asphalt tile	27,183	--	6,000	33,183	13,512	--	4,043	17,555
Medical, pharmaceutical, cosmetic	2,408	--	1,396	3,804	1,629	--	1,291	2,920
Paint	14,099	3,938	181,643	199,680	13,367	3,789	233,373	250,529
Paper coating	--	--	2,266,846	2,266,846	--	--	2,315,664	2,315,664
Paper filling	120,596	--	1,052,582	1,173,178	187,564	--	1,153,431	1,340,995
Pesticides and related products	7,848	15,344	44,037	67,229	7,004	11,509	2,265	20,778
Plastics	18,699	--	35,414	54,113	13,181	--	37,397	50,578
Pottery	13,159	726	1,546	15,431	35,041	689	465	36,195
Roofing granules	22,779	--	1,000	23,779	26,868	--	1,000	27,868
Roofing and structural tile	371	--	--	371	348	--	--	348
Rubber	230,507	--	83,484	313,991	266,153	--	21,794	287,947
Sanitary ware	124,095	12,353	730	137,178	130,689	11,705	6,601	148,995
Waterproofing and sealing	--	--	W	W	--	--	W	W
Miscellaneous	54,210	7,653	68,528	130,391	53,017	12,481	191,833	257,331
Total	1,172,192	1,296,160	4,023,447	6,491,799	1,371,576	1,570,105	4,135,535	7,077,216

See footnotes at end of table.

Table 11.—Kaolin sold or used by producers in the United States, by use —Continued

(Short tons)

Use	1985 Air-float	1985 Unprocessed[1]	1985 Water-washed[2]	1985 Total	1986 Air-float	1986 Unprocessed[1]	1986 Water-washed[2]	1986 Total
Exports:								
Ceramics	3,387	--	2,381	5,768	13,337	--	5,804	19,141
Foundry sand, grogs and calcines; other refractories	11,293	141,135	281	152,709	1,700	212,000	--	213,700
Paint	466	--	112,007	112,473	124	--	118,087	118,211
Paper coating	23,297	--	766,392	789,689	27,386	--	776,962	804,348
Paper filling	8,448	--	136,871	145,319	5,120	--	222,479	227,599
Plastics	--	--	19,223	19,223	40	--	--	40
Rubber	38,848	--	885	39,733	31,403	--	19,863	51,266
Miscellaneous	17,802	--	18,807	36,609	3,989	1,782	32,190	37,961
Total	103,541	141,135	1,056,847	1,301,523	83,099	213,782	1,175,385	1,472,266
Grand total	1,275,733	1,437,295	5,080,294	7,793,322	1,454,675	1,783,887	5,310,920	8,549,482

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.

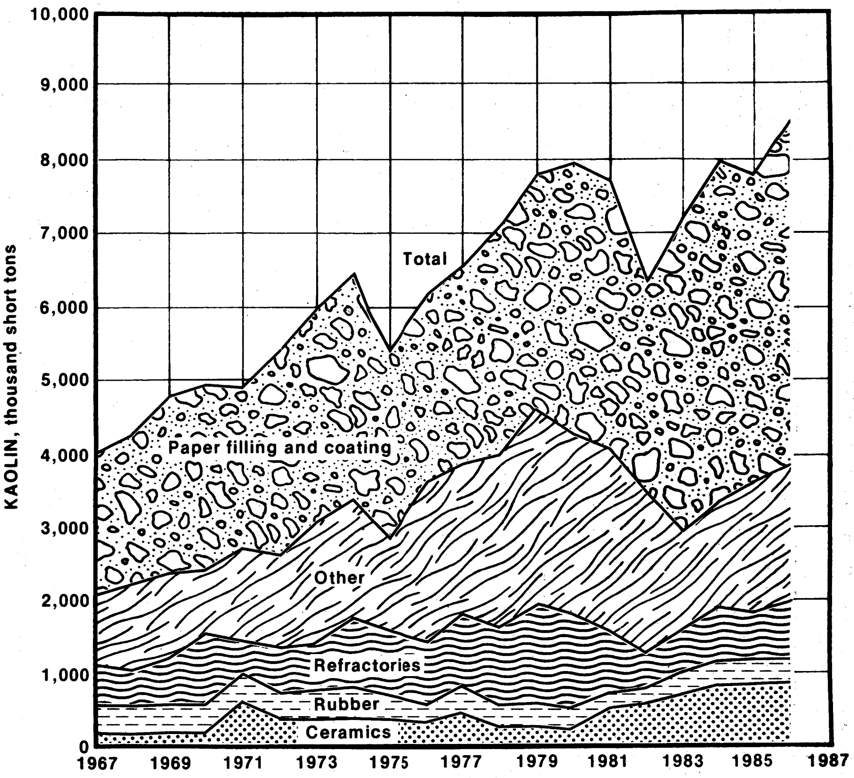

Figure 1.—Kaolin sold or used by domestic producers for specified uses.

BALL CLAY

Reported production of domestic ball clay decreased slightly to over 887,000 tons valued at $35 million. Tennessee provided about 70% of the Nation's output, followed, in order of production, by Kentucky, Mississippi, Texas, and Maryland. Production increased in Kentucky and Texas and decreased in the other States. The principal ball clay markets were ceramics, chiefly dinnerware, pottery, sanitary ware, and wall tile. Domestic producers also continued to enjoy a strong export market, despite a relatively strong U.S. dollar, usually over 10% of total production. Continued recovery of the domestic construction industry, encouraged by competitively low interest rates and the improved overall economy during the first three quarters of the year when combined with the downturn experienced in the last quarter, was largely responsible for the slight decreased demand for ball clays.

Ball clay is defined as 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 were also cautiously increasing their capabilities to produce, store, and ship (mostly by rail slurry-tank car) water-slurried ball clay for ceramic markets or adopting this capability. The new slurry production plant completed by H. C. Spinks Clay Co. Inc. in 1985 at its Gleason, TN, complex was well into production during the year. The state-of-the-art fully automated facility, with the capability to load a 53,000-liter tank car in 30 minutes, was reportedly operating at full capacity.

The average unit value for ball clay reported by domestic producers increased slightly to $38.99. Chemical Marketing Reporter, December 29, 1986, listed ball clay prices, unchanged from those of 1985, 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 decreased over 10% to 161,000 tons valued at $6.1 million. Unit value increased 15% to $38.18 from $33.21 per ton in 1985. Shipments were made to 26 countries, a decrease of 4 from those of 1986. The major recipients were Mexico, 73%; Canada, 19%; and Ecuador and Japan, 2% each. The large Mexican ceramic market continued to be partially supplied by its domestic clay because of international financial difficulties, and its ceramic exports, predominantly to the United States, are fabricated largely with U.S. and domestic clays.

Ball clay imports for consumption, again almost entirely from the United Kingdom, more than doubled to nearly 3,000 tons valued at $309,000. The unit value of these imports decreased nearly 11% to $104.18 per ton.

Table 12.—Ball clay sold or used by producers in the United States, by State

State	Air-float		Unprocessed		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
1985						
Tennessee	[1]502,301	[1]$20,463,910	162,254	$4,136,759	664,555	$24,600,669
Other[2]	203,634	9,036,635	33,490	1,070,953	237,124	10,107,588
Total	705,935	29,500,545	195,744	5,207,712	901,679	34,708,257
1986						
Tennessee	[1]426,150	[1]18,896,723	189,499	5,025,280	615,649	23,922,003
Other	[2]266,380	[2]10,521,659	[3]5,143	[3]144,271	271,523	10,665,930
Total	692,530	29,418,382	194,642	5,169,551	887,172	34,587,933

[1]Includes water-slurried.
[2]Includes Kentucky, Maryland, Mississippi, and Texas.
[3]Includes California, Kentucky, and Mississippi.

Table 13.—Ball clay sold or used by producers in the United States, by use

(Short tons)

Use	1985			1986		
	Air-float[1]	Unprocessed	Total	Air-float[1]	Unprocessed	Total
Adhesives	W	--	W	W	--	W
Animal feed	W	W	13,943	W	--	W
Crockery and other earthenware	W	W	W	W	W	W
Drilling mud	W	--	W	W	--	W
Electrical porcelain	42,240	--	42,240	12,097	1,917	14,014
Fiberglass and catalysts (oil refining)	W	W	W	W	W	W
Fine china and dinnerware	27,491	--	27,491	25,245	--	25,245
Firebrick, blocks and shapes	W	W	W	W	W	W
Floor and wall tile	97,586	31,466	129,052	98,605	29,700	128,305
Glazes, glass, enamels	1,606	--	1,606	2,602	--	2,602
Grogs and calcines, high-alumina, mortar and cement, other refractories	91,791	13,837	105,628	90,621	6,313	96,934
Kiln furniture	1,708	--	1,708	2,223	--	2,223
Paper coating and filling	5,532	--	5,532	W	--	W
Pesticides and related products	W	--	W	W	--	W
Pottery	140,375	63,118	203,493	152,360	65,841	218,201
Rubber	W	W	W	W	W	W
Sanitary ware	114,788	38,309	153,097	94,933	54,543	149,476
Miscellaneous	130,540	23,479	[2]140,076	113,316	22,920	136,236
Exports	52,278	25,535	77,813	100,528	13,408	113,936
Total	705,935	195,744	901,679	692,530	194,642	887,172

W Withheld to avoid disclosing company proprietary data; included with "Total" and/or "Miscellaneous."
[1]Includes water-slurried.
[2]Incomplete total; difference included in totals for specific uses.

FIRE CLAY

Fire clay sold or used by domestic producers decreased 39% to 592,000 tons, the lowest reported figure in over 10 years, valued at $12.2 million. Fire clay is defined as detrital material, either plastic or rock-like, 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 commonplace. Most plants continued to be either operating intermittently or on minimal production schedules. The clay refractory industry has been in a period of low production since 1982, reflecting lower demand by major consumers—steel, nonferrous metals, ceramics, glass, and minerals processing. The fire clay industry's problems were further exacerbated by the technological changes in steelmaking processes that require more higher alumina-based refractories, either direct-fired or specialties, which contain less fire clay. These uncertainties in the fire clay industry resulted in the attempted divestiture of refractory manufacturing and mining operations of Dresser Industries Inc. and USG Corp. The sale of Dresser's Harbison-Walker Refractories division to N. C. Fitzpatrick Acquisitions Corp., New York, and USG's A. P. Green Refractories Co. division to Adience Equities Inc., Pittsburgh, PA, were both canceled at yearend because of financial difficulties. The sale of Allied-Signal Inc.'s North American Refractories Co., subject to financing last year, to Kirtland Capital Corp. was consummated in April.

A notable exception to the industry retrenchment was the completion of A. P. Green's expansion at its Sulfur Springs, TX, high-alumina brick and specialties manufacturing facility. The new state-of-the-art plant was already operating at full capacity. In other actions, A. P. Green shut down its manufacturing plants in Philadelphia, PA, and Pueblo, CO.

Fire clay production was reported from mines in 12 States, 2 less than in 1985. Six States, Missouri, Ohio, Alabama, Pennsylvania, Arkansas, and Texas, in order of volume, accounted for about 94% of the total domestic output. Production decreased significantly in all major producing States and ceased in West Virginia.

Exports of fire clay decreased about 16% to over 189,000 tons valued at $15.0 million. The unit value of the exported clay only decreased slightly to $79.42 indicating that, despite a decrease in exports, the trend of shipping a higher percentage of higher quality material continued. Fire clay was exported to 26 countries, 2 more than in 1985. Japan received 23%, Belgium-Luxembourg, 22%; Australia and Canada, 12% each; and Mexico, 10%. No imports for consumption were again reported for fire clay.

The unit value for fire clay, reported by producers, ranged from about $7.00 to $28.00 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	1985		1986	
	Short tons	Value	Short tons	Value
Alabama	130,000	$3,217,200	110,482	$3,113,913
Colorado	20,384	166,330	6,051	80,395
Missouri	283,697	5,072,854	185,758	3,333,844
Montana	503	2,641	--	--
New Jersey	10,166	250,079	12,524	265,919
New Mexico	2,767	16,547	2,103	13,458
Ohio	241,045	4,442,140	173,110	3,720,655
Pennsylvania	80,610	772,095	44,670	781,657
Texas	21,196	156,190	19,670	139,400
Utah	500	3,300	--	--
Washington	--	--	2,676	27,854
West Virginia	98,064	2,794,824	--	--
Other[2]	85,482	1,092,536	34,783	738,474
Total	974,414	17,986,736	591,827	12,215,569

[1]Refractory uses only.
[2]Includes Arkansas (1986), California (1985), Idaho, and Kentucky.

BENTONITE

Bentonite production decreased 12% to 2.8 million tons valued at $91.4 million, a decline of over 10% in value. Decreases in production of nearly 18% in Wyoming and over 28% in Montana, the first- and second-largest swelling-bentonite-producing States, accounted for most of the decline. Domestic consumption for drilling mud, foundry sand, and pelletizing iron ore all declined.

Bentonite was again produced in 13 States. The high-swelling or sodium bentonites continued to be produced, in descending order, chiefly in Wyoming and Montana. The calcium or low-swelling bentonites continued to be produced in the other States. 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 to cancel or defer planned enlargements and/or modernizations. Most plants continued sporadic operation at new lower production levels. The industry depression continued to be caused by lower oil and gas drilling activities during the year, exacerbated by the downturn in demand by the steel and foundry industries. These three industries traditionally consume about 90% of the total domestic output.

The major and captive producers of bentonite also were attempting to diversify their product lines to compete in other marketing areas or restructuring in order to minimize the deleterious effects of industry overcapacity. In this regard, Dresser and Halliburton Co. merged their domestic and worldwide drilling-fluid business in a 60-40 joint venture. The Halliburton unit is Federal Bentonite, IMCO Services Div., which it acquired in 1984 from Aurora Industries Inc., a subsidiary of Panhandle Eastern Corp. Dresser and IMCO both have bentonite mining and processing interests in Wyoming. IMCO also has mines and mills in Montana and a grinding facility in Minnesota dedicated to the taconite pelletizing industry. Another similar event was the sale of the industrial operations of International Minerals & Chemical Corp. (IMC), Northbrook, IL, to Applied Industrial Materials Corp., Mundelein, IL, at yearend. The transaction included IMC's sodium- and calcium-bentonite mines and mills in Wyoming and Mississippi, respectively, and its Mississippi absorbent clay mining and processing operations.

On December 29, 1986, 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 increased slightly to $32.48 per ton. Per-ton values reported in the various producing States ranged from $12 to over $68, but the average value reported by the larger producers was near the Montana average of about $31.65.

Bentonite exports decreased over 9% to 581,000 tons valued at $44.6 million. The unit value of exported bentonite increased over 9% to $76.74 per ton; this was attributed to higher percentages of the costlier drilling-mud and foundry grades shipped over the lower cost iron ore pelletizing grades. Domestic bentonite producers continued to face increased competition in foreign markets; in particular, the Canadian iron ore markets where Mediterranean bentonites continue to make inroads into an area traditionally served by domestic producers.

Bentonite was exported to 66 countries, 1 less than in 1985. The major recipients were Canada, 38%; Japan, 14%; the Netherlands, 5%; and Australia and the United Kingdom, 4% each. Domestic bentonite producers reported their exports were drilling mud, 49%; foundry sand, 42%; and other, 9%.

Activated clay exports, available for the first time in 1986, showed that over 27,000 tons of material valued at $31.8 million was exported to 53 countries. The unit value of the exported clay was nearly $1,200 per ton. The leading recipients were Brazil, 21%; Canada, 12%; Mexico and Sweden, 9% each; and the United Kingdom, 8%.

Bentonite imports for consumption and exports consisted mostly of both untreated clay and chemically or artificially activated material. The total bentonite imports decreased over 30% to nearly 16,000 tons. The chemically activated category, slowly increasing in quantity for the past several years, decreased over 10% to 13,040 tons valued at $3.9 million, primarily because of decreased shipments from Canada, which were over 81% less than those of 1985. Imports from Mexico and the Federal Republic of Germany increased 9% and nearly tripled, respectively. Mexican imports usually comprise more than 70% of total activated clay imports. The chemically activated bentonite was imported from 11 countries, 5 more than in 1985, with Mexico supplying 90%; Canada and the Federal Republic of Germany, 9%; and the remaining countries, 1%.

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
1985						
Alabama and Mississippi	342,781	$9,356,924	--	--	342,781	$9,356,924
Arizona	31,924	713,571	900	$27,000	32,824	740,571
California	92,379	6,681,403	20,511	1,349,102	112,890	8,030,505
Colorado	74	740	6	60	80	800
Kansas	--	--	24,000	888,000	24,000	888,000
Montana	--	--	254,398	8,232,639	254,398	8,232,639
Nevada	--	--	79,861	3,775,947	79,861	3,775,947
Texas	30,791	637,227	15,971	212,470	46,762	849,697
Utah	--	--	14,006	420,721	14,006	420,721
Wyoming	--	--	2,116,085	63,064,643	2,116,085	63,064,643
Other	(1)	(1)	[2]171,593	[2]6,565,338	[r]171,593	[r]6,565,338
Total	497,949	17,389,865	2,697,331	84,535,920	3,195,280	101,925,785
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	--	--	[2]220,776	[2]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

[r]Revised.
[1]Revised to zero.
[2]Includes Idaho and South Dakota.

Table 16.—Bentonite sold or used by producers in the United States, by use

(Short tons)

Use	1985			1986		
	Non-swelling	Swelling	Total	Non-swelling	Swelling	Total
Domestic:						
Adhesives	2,000	6,938	8,938	--	11,302	11,302
Animal feed	38,265	92,219	130,484	43,262	69,164	112,426
Catalysts (oil refining)	5,748	2,470	8,218	5,232	147	5,379
Cement, portland	--	W	W	--	W	W
Drilling mud	17,913	1,168,728	1,186,641	5,193	1,031,555	1,036,748
Filtering, clarifying, decolorizing:						
Animal oils, mineral oils and greases, vegetable oils	36,500	3,071	39,571	152,749	2,110	154,859
Desiccants	--	--	--	12,930	--	12,930
Foundry sand	206,388	522,199	728,587	215,004	401,784	616,788
Glazes, glass, enamels	--	W	W	--	--	--
Medical, pharmaceutical, cosmetic	--	3,968	3,968	--	7,321	7,321
Oil and grease absorbents	34,448	45	34,493	8,557	--	8,557
Paint	--	7,161	7,161	--	8,446	8,446
Pelletizing (iron ore)	--	290,567	290,567	--	262,419	262,419
Pesticides and related products	897	235	1,132	1,163	4,214	5,377
Water treatment and filtering	--	--	--	4,424	935	5,359
Waterproofing and sealing	3,432	119,876	123,308	4,901	53,062	57,963
Miscellaneous[1]	126,302	79,334	205,636	72,141	57,403	129,544
Total	471,893	2,296,811	2,768,704	525,556	1,909,862	2,435,418
Exports:						
Drilling mud	--	117,130	117,130	--	183,934	183,934
Foundry sand	24,978	142,420	167,398	52,760	104,972	157,732
Other[2]	1,078	140,970	142,048	9,245	26,714	35,959
Total	26,056	400,520	426,576	62,005	315,620	377,625
Grand total	497,949	2,697,331	3,195,280	587,561	2,225,482	2,813,043

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous."
[1]Includes chemical manufacturing; fiberglass; firebrick, blocks and shapes; gypsum products; mineral wool and insulation; paper coating and filling; pet waste absorbents; plastics; rubber; ink; uses not specified; and data indicated by symbol W.
[2]Includes animal feed, face brick, paint, plastics, waterproofing and sealing, and uses not specified.

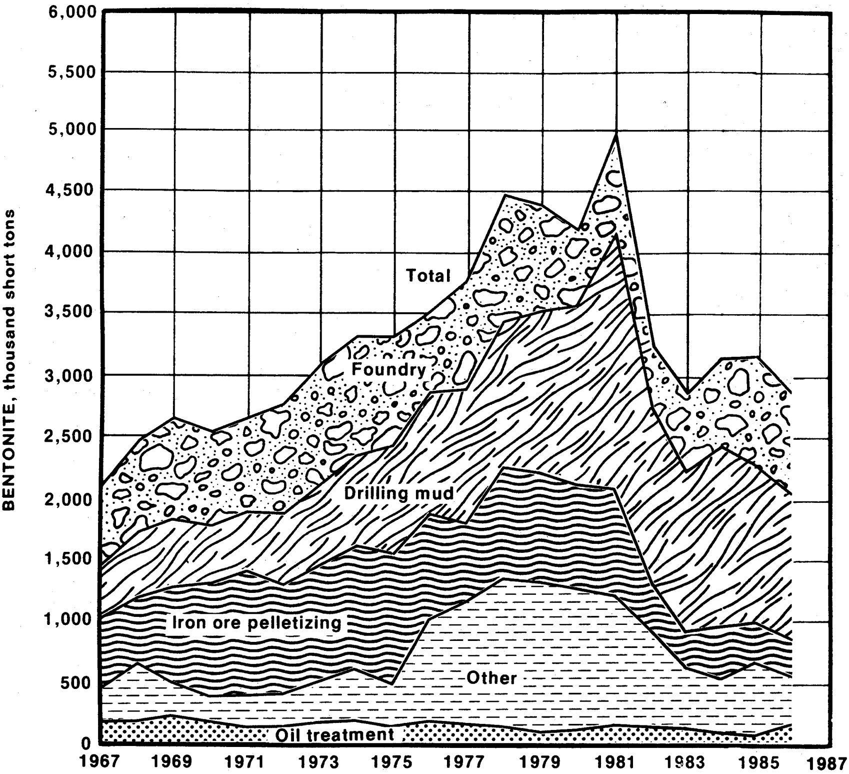

Figure 2.—Bentonite sold or used by domestic producers for specified uses.

FULLER'S EARTH

Production of fuller's earth decreased 7% to over 1.9 million tons valued at $125 million. This decrease in production and that reported in 1984 were the only declines registered by the industry in over 10 years. Most of the decrease was caused by a 33% decline in gelling-grade production in Georgia. The average unit value increased 4% to $65.70 per ton. Production was again reported from operations in 10 States. The two top producing States, Georgia and Florida, in descending order, accounted for 52% of domestic production. All States, except Georgia, Mississippi, Missouri, Nevada, South Carolina, and Texas showed gains in production. Increases in consumption occurred in pet waste absorbents while consumption of oil and grease absorbents declined.

Fuller's earth is defined as 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.

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.

Industrywide enlargements, modernizations, acquisitions, and/or mergers, which were either canceled or deferred until overall economic conditions improved, were starting to be acted upon again. Generally, the absorbent-producing companies enjoyed a good year while the gell-grade producers experienced a mixed year. In this regard, Oil-Dri Corp. of America, Chicago, IL, acquired 100% ownership of Favorite Products Co., the largest marketer of cat litter in Canada. Oil-Dri also added reserves and installed a fine-grinding mill at its Georgia plant to produce the new generation of absorbent and absorbent materials requiring finer clays. Mid-Florida Mining Co., Ocala, FL, packagers of excess absorbent at the GSX Services of South Carolina Inc., Pinewood, SC, landfill complex, closed down its operation because of a combination of economic and political uncertainties. The Indiana-based Lowe's Inc., a major absorbent producer, changed its name to Edward Lowe Industries Inc. after a restructuring of the company. The subsidiaries Lowe's Southern Clay Inc. and Lowe's Southern Clay of California Inc. will be merged into the new corporation and operate under the Lowe's Southern Clay Div.

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 $70 to $80 per ton; montmorillonite prices ranged from about $25 to $88.

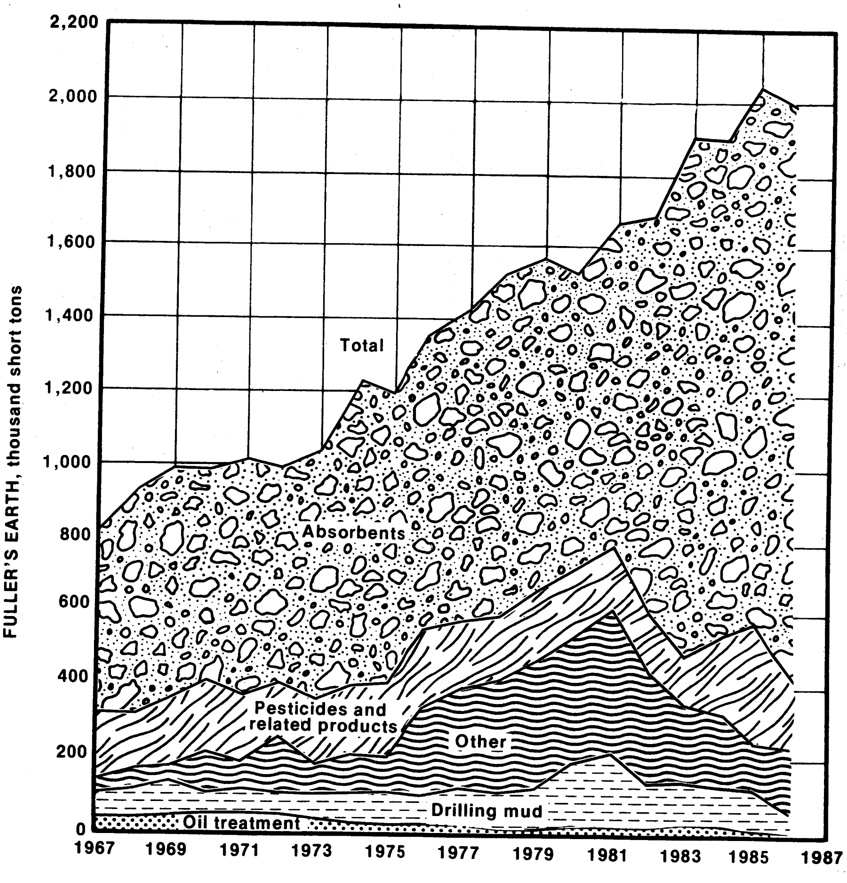

Figure 3.—Fuller's earth sold or used by domestic producers for specified uses.

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
1985						
Florida	387,076	$29,451,978	--	--	387,076	$29,451,978
Georgia	386,737	25,333,176	206,296	$9,294,984	593,033	34,628,160
Virginia	--	--	28,000	2,940,000	28,000	2,940,000
Other	[1]146,819	[1]8,293,241	[2]904,353	[2]54,155,576	1,051,172	62,448,817
Total	920,632	63,078,395	1,138,649	66,390,560	2,059,281	129,468,955
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
Virginia	--	--	34,000	3,000,000	34,000	3,000,000
Other	[1]139,554	[1]8,172,908	[2]741,330	[2]49,187,912	880,884	57,360,820
Total	920,772	62,623,260	989,206	62,853,129	1,909,978	125,476,389

[1]Includes Illinois, Nevada (1986), and Texas.
[2]Includes Illinois, Mississippi, Missouri, Nevada (1985), South Carolina, and Tennessee.

Table 18.—Fuller's earth sold or used by producers in the United States, by use

(Short tons)

Use	1985			1986		
	Attapulgite	Montmorillonite	Total	Attapulgite	Montmorillonite	Total
Domestic:						
Adhesives	2,740	--	2,740	6,874	--	6,874
Drilling mud	106,980	--	106,980	34,720	--	34,720
Fertilizers	46,899	10,482	57,381	36,247	7,379	43,626
Filtering, clarifying, decolorizing mineral oils and greases	15,321	--	15,321	13,579	--	13,579
Medical, pharmaceutical, cosmetic	94	--	94	379	--	379
Oil and grease absorbents	291,612	309,015	600,627	264,673	200,694	465,367
Paint	3,244	--	3,244	19,885	--	19,885
Pesticides and related products	92,266	164,546	256,812	71,314	92,675	163,989
Pet waste absorbents	214,800	566,869	781,669	348,710	610,457	959,167
Other[1]	22,782	23,400	46,182	13,132	--	13,132
Miscellaneous[2]	17,417	27,094	44,511	47,387	61,462	108,849
Total	814,155	1,101,406	1,915,561	856,900	972,667	1,829,567
Exports:						
Drilling mud	156	--	156	106	--	106
Oil and grease absorbents	61,518	18,701	80,219	23,917	3,031	26,948
Pesticides and related products	8,418	971	9,389	4,937	2,589	7,526
Pet waste absorbents	27,382	11,434	38,816	29,505	9,571	39,076
Miscellaneous[3]	9,003	6,137	15,140	5,407	1,348	6,755
Total	106,477	37,243	143,720	63,872	16,539	80,411
Grand total	920,632	1,138,649	2,059,281	920,772	989,206	1,909,978

[1]Includes desiccants (1986), paper filling (1985), roofing granules, roofing tiles (1986), and tamping dummies (1986).
[2]Includes common brick (1985); catalysts (oil refining, 1985); chemical manufacturing (1985); glazes, glass, and enamels (1985); gypsum products; mortar and cement refractories; plastics; pottery (1985); sanitary ware (1985); and wallboard (1986).
[3]Includes paint and uses not specified.

Exports of fuller's earth went to 32 countries, 1 less than in 1985, but the quantity increased over 16% to 121,000 tons valued at $9.6 million. The unit value of exported fuller's earth decreased nearly 10% over that of 1985 to $79.39, which was attributed to a smaller percentage of the high-cost gelling and drilling-mud grades exported in 1986 compared with the percentage of absorbent grades shipped. The major recipients were Canada, 69%; the Netherlands, 15%; and Singapore, 4%. A minor amount of fuller's earth was imported, mostly from the United Kingdom.

A repeat of the nearly 4,000 tons of drilling-mud-grade attapulgite imported through the Port of New Orleans did not materialize this year. Imports of gelling-grade clays into markets traditionally served by domestic producers caused considerable concern.

COMMON CLAY

Domestic sales or use of common clay and shale decreased slightly to 30.0 million tons valued at $136 million, an increase of 3%. Output rose in California, Georgia, and Ohio, and declined in North Carolina and Texas, the major producing States. Common clay and shale represented about 70% of the quantity and 15% 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 $4.53 per ton. The unit value ranged from $2 to nearly $25.

Common clay is defined as 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 were proceeding cautiously during the year. Mergers and/or acquisitions of domestic heavy clay producers were quite active. The construction industry, the biggest consumer of heavy clay products, such as brick, lightweight aggregate, portland cement, sewer pipe, and tiles, was generally experiencing strong sales the entire year. The large inventories accumulated during the slack winter months were worked off early in the year, and by the second quarter, production was proceeding briskly, largely spurred on by the low prevailing interest rates. Notable exceptions to these good times were lower building rates in the depressed oil-producing States of Colorado, Louisiana, Oklahoma, and Texas.

In acquisitions, Marley PLC, a British building products company, acquired General Shale Products Corp., Johnson City, TN, one of the Nation's largest brick producers. The Glen-Gery Corp., Reading, PA, another of the biggest brick manufacturers, purchased in 1979 by Ibstock-Johnson Ltd., a British brickmaker, continued adding U.S. brick interests. This time it acquired the manufacturing assets, sales activities, and trade names of Hanley Brick Inc., Summerville, PA. Hanley Brick has been operating since 1893 and has a production capacity of 50 million brick equivalents per year. An Australian brickmaker, Boral Ltd., purchased the assets and business of Ashe Brick Co. of Van Wyck, SC. Boral also advanced to 100% ownership of Birmingham Clay Inc. of Alabama, previously a 50%-owned associate. In another Boral move, Merry Companies Inc., Augusta, GA, changed its name to Boral Bricks Inc. A Toronto, Canada-based maker of bricks, Jannock Ltd., purchased the four plants and mines in North Carolina and South Carolina capable of producing about 250 million bricks per year from Boren Clay Products Co., Greensboro, NC. Jannock, in 1985, acquired Richtex Corp. of Columbia, SC.

Exceptions to the industrywide slowdown in expansions and modernizations were those announced by Acme Brick Co., Glen-Gery, Midland Brick Co., Morin Brick Co., Port Costa Materials Inc., Kansas Brick and Tile Inc., and Henry Brick Co. Inc. Acme Brick's new state-of-the-art brick plants in Tulsa, OK, and near Houston, TX, became fully operational, approaching 100% of designed capacity. Glen-Gery's new oxygen-injection system at Bigler, PA, was successful in achieving faster carbon burnout, eliminating brick discoloration, and gaining needed additional production capacity. A new mantle burner and a burning of rice hulls in its kiln's main burner enabled Port Costa to develop an economical method of controlling escalating production costs and survive as the area's lowest cost lightweight aggregate and brick producer. Midland Brick was setting up a new ceramic tile plant, using local clays, next to its brick factory in Redfield, IA, to complement its brick line by producing Italian-style products. Morin Brick in Lewiston, ME, was awaiting environmental approval prior to embarking on its long delayed and needed expansion. Hanley Brick completed an entirely new grinding plant at Selma, AL, capable of handling indigenous clays and shales. The new plant is void of both screens and additional heaters usually required to process the incoming moist feeds. In closures, Glen-Gery listed its Brazil, IN, plant, and Grand Lodge Clay Products Inc. ceased operations near Lansing, MI.

A final determination was made by the International Trade Administration (ITA) that all manufacturers, producers, and exporters of Mexican bricks, except Ladrillera Industrial S.A. and Tex Mex de México S.A., which have no determined bounties or grants, were subject to a 1.75% ad valorem surcharge on all items. The ITA instructed the U.S. Customs Service to require a cash deposit on shipments from these other firms entered or withdrawn from warehouses, for consumption on or after the date of publication of this notice, December 2, 1986. These stipulations were to remain in effect until publication of the final results of the next administrative review.[2]

Table 19.—Common clay and shale sold or used by producers in the United States,[1] by State

State	1985		1986	
	Short tons	Value	Short tons	Value
Alabama	1,630,739	$7,962,196	1,886,574	$9,318,166
Arizona	153,608	762,708	184,919	971,190
Arkansas	911,335	1,891,739	783,588	1,845,190
California	2,062,256	17,809,172	2,228,871	22,393,865
Colorado	282,411	1,575,560	235,782	1,436,684
Connecticut	106,033	631,873	156,680	975,207
Florida	248,680	779,176	227,243	1,695,847
Georgia	1,732,742	5,488,744	2,516,322	7,657,913
Illinois	265,467	876,123	282,993	1,091,609
Indiana	739,711	2,776,446	743,859	3,043,873
Iowa	503,298	2,449,931	486,309	1,420,979
Kansas	854,177	4,437,709	879,358	4,397,191
Kentucky	661,176	2,305,585	721,111	3,450,418
Louisiana	333,619	7,016,609	331,982	7,669,853
Maine	49,500	99,555	46,000	90,000
Maryland	336,085	1,646,991	361,729	1,757,132
Massachusetts	264,538	1,388,090	139,995	871,199
Michigan	1,477,309	5,513,822	1,402,446	5,684,283
Mississippi	850,706	3,292,143	616,672	2,747,815
Missouri	1,204,854	3,497,245	1,130,333	3,269,320
Montana	24,190	60,369	39,212	101,724
Nebraska	244,228	718,214	221,153	668,380
New Jersey	120,000	1,800,000	120,000	1,800,000
New Mexico	57,048	144,167	58,081	156,663
New York	699,764	3,129,207	618,968	3,074,611
North Carolina	2,611,455	8,533,367	2,606,679	9,527,534
Ohio	1,873,037	6,138,465	2,659,675	7,794,754
Oklahoma	996,522	2,337,657	992,702	2,328,697
Oregon	188,026	284,626	203,596	288,920
Pennsylvania	1,061,607	4,520,686	1,189,121	4,278,881
Puerto Rico	118,192	263,568	110,997	222,845
South Carolina	1,029,178	2,385,886	923,165	2,392,204
South Dakota	117,065	309,052	118,718	375,112
Tennessee	579,069	1,312,029	548,641	1,305,695
Texas	3,919,159	18,317,566	2,423,685	10,609,847
Utah	317,725	2,085,283	296,867	1,751,735
Virginia	786,295	4,036,908	855,977	4,699,648
Washington	242,914	1,402,107	249,469	1,531,913
West Virginia	233,269	547,627	214,980	469,708
Wyoming	185,917	1,081,562	23,223	316,529
Other[2]	95,421	324,908	141,401	419,360
Total	30,168,325	131,934,671	29,979,076	135,902,494

[1]Includes Puerto Rico.
[2]Includes Idaho (1986), Minnesota, New Hampshire, and North Dakota.

CONSUMPTION AND USES

The manufacture of heavy clay products including (1) building brick; sewer pipe; and drain, roofing, structural, terra cotta, and other tile; (2) portland cement clinker; and (3) lightweight aggregate accounted for 39%, 20%, and 8%, respectively, of total domestic consumption. In summary, nearly 70% of all clay produced was consumed in the manufacture of these clay- and shale-based construction materials.

Heavy Clay Products.—The value reported for shipments by the Bureau of the Census of heavy clay products increased 12% to about $1.6 billion. The million standard brick count for building or common face brick increased by 9%. Shipments of clay floor and wall tile increased 20%, while vitrified clay and sewer pipe fittings decreased 19%. Increases in common clay and shale used in building brick manufacturing occurred in most States with total domestic production increasing 6%. Increases were largely under 15% with an average State upturn of under 20%.

Table 20.—Clays sold or used by producers in the United States[1] in 1986, 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 absorbents	--	8,557	W	--	465,367	--	473,924
Pet waste absorbents	--	W	W	--	959,167	--	959,167
Other[2]	--	71,333	138,530	--	37,654	--	247,517
Ceramics and glass:							
Catalysts (oil refining)	W	5,379	--	--	--	124,681	130,060
Crockery and other earthenware	W	--	11,139	--	--	W	11,139
Electrical porcelain	14,014	--	35	--	--	20,816	34,865
Fine china and dinnerware	25,245	--	--	--	--	24,586	49,831
Glazes, glass, enamels	2,602	--	--	--	--	566	3,168
Mineral wool and insulation, fiberglass	W	W	--	--	--	367,377	367,377
Pottery	218,201	--	8,337	1,878	--	36,195	264,611
Roofing granules	--	--	103,485	--	W	27,868	131,353
Sanitary ware	149,476	--	--	--	--	148,995	298,471
Other[2]	47,845	26,940	1,000	--	135	22,002	97,922
Chemical manufacturing	--	1,443	--	--	--	155,352	156,795
Civil engineering and sealing	--	63,322	79,860	--	--	13,696	156,878
Drilling mud	W	1,036,748	--	--	34,720	782	1,072,250
Fillers, extenders, binders:							
Adhesives	W	11,302	--	--	6,874	69,899	88,075
Animal feed	W	112,426	500	--	--	36,874	149,800
Fertilizers	--	372	--	--	43,626	4,846	48,844
Gypsum products and wallboard	--	--	--	--	W	19,046	19,046
Ink	--	W	--	--	--	W	W
Medical, pharmaceutical, cosmetic	--	7,321	--	--	379	2,920	10,620
Paint	--	8,446	50	--	19,885	250,529	278,910
Paper coating	W	W	--	--	--	2,315,664	2,315,664
Paper filling	W	W	--	--	--	1,340,995	1,340,995
Pesticides and related products	W	5,377	3,948	--	163,989	20,778	194,092
Plastics	--	W	--	--	W	50,578	50,578
Rubber	W	W	7,780	--	--	287,947	295,727
Other[2]	74,584	10,905	18,634	--	25,218	171,340	300,681
Filtering, clarifying, decolorizing:							
Animal oils, mineral oils and greases, vegetable oils	--	154,859	--	--	13,579	560	168,998
Desiccants	--	12,930	--	--	40	--	12,970

See footnotes at end of table.

Table 20.—Clays sold or used by producers in the United States[1] in 1986, by use—Continued

(Short tons)

Use	Ball clay	Bentonite	Common clay and shale	Fire clay (refractory only)	Fuller's earth	Kaolin	Total
Floor and wall tile:							
Ceramic	128,305	52	96,949	--	--	30,678	255,984
Quarry tile	--	--	206,083	--	--	--	206,083
Other	--	--	883	15,609	--	22,889	39,381
Heavy clay products:							
Brick, common	156	4,983	4,010,013	--	--	16,989	4,032,141
Brick, face	--	--	11,798,111	12,131	--	635,191	12,445,433
Drain tile	--	--	47,724	--	--	--	47,724
Flower pots	--	--	40,105	--	--	--	40,105
Flue linings	--	--	42,914	60,833	--	28,800	132,547
Portland and other cements	--	697	8,554,728	--	--	204,339	8,759,764
Roofing tile	--	137	6,961	--	160	--	7,258
Sewer pipe, vitrified	--	--	565,328	145	--	17,730	583,203
Structural tile	--	--	27,298	--	--	348	27,646
Terra cotta	--	--	998	--	--	--	998
Other	--	--	116,253	--	--	419	116,672
Lightweight aggregate:							
Concrete block	--	--	2,426,201	--	--	--	2,426,201
Highway surfacing	--	--	194,866	--	--	--	194,866
Structural concrete	--	--	1,002,268	--	--	--	1,002,268
Other	--	--	62,929	--	--	--	62,929
Pelletizing iron ore	--	262,419	--	--	--	--	262,419
Refractories:							
Firebrick, blocks and shapes	W	2,123	140,892	283,210	--	68,849	495,074
Foundry sand	--	616,788	--	56,901	--	412	674,101
Grogs and calcines	W	--	--	60,033	--	391,820	451,853
High alumina brick and specialties	7,328	--	--	62,944	--	60,164	130,436
Kiln furniture	2,223	305	--	--	--	3,797	6,325
Mortar and cement, refractory	W	24	242,018	2,228	45,977	54,431	344,678
Other[2]	99,846	--	--	--	--	--	99,846
Other[3]	3,411	10,230	--	26,662	12,797	25,468	78,568
Exports	113,936	377,625	22,256	9,253	80,411	1,472,266	2,075,747
Total	887,172	2,813,043	29,979,076	591,827	1,909,978	8,549,482	44,730,578

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]Includes tamping dummies and uses not specified.

Table 21.—Shipments of principal structural clay products in the United States

Product	1982	1983	1984	1985	1986
Unglazed common and face brick:					
Quantity ____ million standard brick	4,407	5,792	6,510	6,605	7,204
Value ____ million	$504	$704	$836	$887	$972
Unglazed structural tile:					
Quantity ____ million standard brick	49	30	32	55	72
Value ____ million	$6	$5	$7	$12	$28
Vitrified clay and sewer pipe fittings:					
Quantity ____ million standard brick	325	375	397	368	298
Value ____ million	$52	$64	$79	$78	$66
Unglazed, salt-glazed, ceramic-glazed structural facing tile including glazed brick:					
Quantity ____ million standard brick	11	W	W	W	W
Value ____ million	$8	W	W	W	W
Clay floor and wall tile including quarry tile:					
Quantity ____ million standard brick	296	333	340	370	444
Value ____ million	$354	$388	$421	$450	$536
Total value[1] ____ do	$923	$1,161	$1,342	$1,428	$1,602

W Withheld to avoid disclosing company proprietary data.
[1]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census Report Form M32-D (86), Current Industrial Reports—Clay Construction Products.

Table 22.—Common clay and shale used in building brick production in the United States, by State

State	1985		1986	
	Short tons	Value	Short tons	Value
Alabama	784,324	$3,585,969	865,906	$4,034,526
Arizona and New Mexico	137,851	390,099	137,740	407,962
Arkansas	518,199	1,387,518	486,068	1,421,375
California	379,976	2,039,790	485,354	8,095,174
Colorado	280,611	1,572,065	234,462	1,423,154
Connecticut and New Jersey	226,033	2,431,873	276,680	2,775,207
Georgia	1,458,993	4,429,239	2,003,505	5,597,706
Idaho and Washington	[1]130,117	[1]351,137	149,317	646,517
Illinois	116,840	462,611	118,675	561,858
Indiana and Iowa	315,833	829,789	391,850	1,010,698
Kansas	173,832	459,968	229,216	601,563
Kentucky	285,266	1,299,938	307,918	1,409,109
Louisiana	111,237	273,845	98,982	253,463
Maine, Massachusetts, New Hampshire	193,572	1,014,908	199,995	1,093,499
Maryland and West Virginia	376,537	1,714,440	388,472	1,781,917
Michigan and Minnesota	54,771	168,528	148,206	538,794
Mississippi	751,920	2,980,254	515,854	2,415,116
Missouri	74,025	291,796	98,471	423,519
Nebraska and North Dakota	183,586	439,974	217,351	559,753
New York	134,551	136,451	145,391	146,191
North Carolina	2,250,402	7,625,482	2,290,572	8,671,986
Ohio	972,163	3,423,479	1,617,522	4,492,329
Oklahoma	543,935	1,491,028	462,895	1,374,819
Oregon	17,848	37,838	19,840	51,446
Pennsylvania	782,491	3,020,028	885,694	2,621,105
South Carolina	688,556	1,523,674	608,616	1,606,223
Tennessee	416,599	788,947	430,668	951,776
Texas	1,705,625	8,450,837	1,114,128	4,581,541
Utah	191,430	1,402,828	126,357	920,910
Virginia	680,724	1,948,756	729,196	2,188,494
Wyoming	35,917	466,562	23,223	316,529
Total	14,973,764	56,439,651	15,808,124	62,974,259

[1]Washington only.

Lightweight Aggregates.—Consumption of clay and shale in the manufacture of lightweight aggregate decreased about 22% to nearly 3.7 million tons. The downturn in overall construction of commercial building and slackening of highway resurfacing was largely responsible for the decrease in demand. Concrete block, the largest category (66% of total production), declined 7% while the second-biggest consuming area, structural concrete with 27% of total production, decreased 29%. The third largest segment, highway surfacing (5% of production), declined over 64%, and the other category, the smallest segment consisting essentially of new market areas, such as recreational and horticultural uses, also declined about 55%.

Refractories.—All types of clay were used in manufacturing refractories. Bentonite, kaolin, and fire clay accounted for 28%, 26%, and 21%, 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 decreased significantly and constituted 5% of total clay produced. The continued use of high-alumina clay-based refractories, mostly calcined kaolin grogs, in monoliths, compensated for the decline in production of the more conventional refractory bricks and shapes. 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 mainly in the manufacture of paper, rubber, paint, adhesives, and plastics. 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 feed.

Of the total clay produced, 11% was used in filler applications; of this, kaolin accounted for 90%; fuller's earth, 5%; bentonite, 3%; and ball clay, common clay and shale, and fire clay, the remaining 2%. Kaolin consumed as fillers increased to under 5.0 million tons. An approximate 28% increase in paint and a 14% increase in paper filling, which together constitute 32% 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 4% increase. The total quantity of fuller's earth used in pesticides and related products, such as fungicides, decreased 36% from that of 1985.

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 77% of its entire output. Demand for clays in pet waste absorbents, representing 57% of absorbent uses, increased 18%. Use in floor absorbents, chiefly to absorb hazardous oily substances, accounted for another 28% of the absorbent demand, which decreased from that of 1985. A sharp increase in the use of pet waste absorbents offset the decline in the industrial sector, which consumes large quantities of floor absorbents.

Drilling Mud.—Demand for clays in rotary-drilling muds decreased 17% to about 1.1 million tons and accounted for 2% of total clay production. This decrease reflects 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 softened further at yearend because of additional overproduction and price cutting. 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 ball clay and kaolin were used in specialized formulations.

Floor and Wall Tile.—Common clay and shale, ball clay, kaolin, and fire clay, in order of volume, were used in manufacturing floor, wall, and quarry tile. This end-use category accounted for 1% of the total clay production. The competitive and/or declining interest during 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 decreased nearly 10% to about 262,000 tons. Inroads of inexpensive foreign bentonites into the Great Lakes markets traditionally served by U.S. bentonite producers, lower production levels, metal imports, and changing technology have all combined to reduce the demand for domestic bentonite in this category.

Ceramics.—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, decreased slightly to 1.39 million tons. The yearend downturn in residential housing, large consumers of whiteware and sanitary ware, partially offset the strong demand for these products earlier in the year.

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	
1985						
Alabama and Arkansas	708,200	190,857	14,683	--	913,740	$4,321,766
California	131,897	237,737	--	15,049	384,683	3,364,460
Florida and Indiana	192,210	43,200	13,000	--	248,410	689,528
Kansas, Kentucky, Louisiana	412,713	124,844	25,250	8,126	570,933	9,916,737
Massachusetts, Mississippi, Missouri	221,385	75,156	36,461	--	333,002	1,779,111
Montana and New York	208,650	178,250	--	--	386,900	2,455,240
North Carolina	210,000	140,000	--	--	350,000	881,000
Ohio, Oklahoma, Pennsylvania	186,536	45,448	1,460	--	233,444	640,219
Utah and Virginia	146,772	32,249	5,707	1,040	185,768	2,395,170
Texas	194,315	345,117	449,821	114,683	1,103,936	2,355,859
Total	2,612,678	1,412,858	546,382	138,898	4,710,816	28,799,090
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
Massachusetts, Mississippi, 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
Utah and Virginia	187,112	51,820	14,809	1,040	254,781	3,025,714
Texas	181,969	32,301	142,965	48,002	405,237	1,686,181
Total	2,426,201	1,002,268	194,866	62,929	3,686,264	42,656,061

Table 24.—Shipments of refractories in the United States, by product

Product	Unit of quantity	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)
CLAY REFRACTORIES					
Superduty fire clay brick and shapes	1,000 9-inch equivalent.	26,509	$33,517	21,968	$26,697
Other fire clay including semisilica brick and shapes, glasshouse pots, tank blocks, feeder parts, upper structure parts used only for glass tanks.	do	65,959	50,272	56,685	40,603
High-alumina (50% to 60% Al_2O_3) brick and shapes made of calcined diaspore or bauxite.[1]	do	71,271	138,314	65,716	118,042
Insulating firebrick and shapes	do	16,577	16,429	--	--
Ladle brick	do	45,261	23,778	30,330	9,985
Sleeves, nozzles, runner brick, tuyeres	do	31,935	27,996	25,279	29,327
Hot-top refractories	Short tons	W	W	W	W
Kiln furniture, radiant heater elements, potter's supplies, other miscellaneous-shaped refractory items.	do	XX	25,333	27,185	21,965
Refractory bonding mortars	do	XX	40,478	79,042	37,156
Plastic refractories and ramming mixes, containing up to 87.5% Al_2O_3.[2]	do	XX	43,346	75,893	36,669
Castable refractories	do	XX	87,434	207,150	78,075
Gunning mixes	do	XX	38,450	144,882	37,497
Other clay refractory materials sold in lump or ground form.[3 4]	do	XX	104,391	502,625	93,252
Total clay refractories		XX	629,738	XX	529,268
NONCLAY REFRACTORIES					
Silica brick and shapes	1,000 9-inch equivalent.	5,728	13,608	4,582	11,825
Magnesite and magnesite-chrome brick and shapes.	do	24,512	113,426	19,467	94,933
Chrome and chrome-magnesite brick and shapes.	do	30,322	125,325	22,914	82,347
Shaped refractories containing natural graphite.	Short tons	12,924	30,552	11,548	32,728
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.	1,084	37,209	1,557	31,669
Other mullite, kyanite, sillimanite, or andalusite brick and shapes.	do	3,506	18,319	2,825	15,980
Other extra-high (over 60%) alumina brick and fused bauxite, fused alumina, dense-sintered alumina shapes.[6]	do	64,425	48,113	4,141	63,508
Silicon carbide brick, shapes, kiln furniture	do	1,284	38,834	979	28,880
Refractory bonding mortars	Short tons	XX	11,942	21,094	11,539
Hydraulic-setting nonclay refractory castables	do	21,130	20,363	19,023	18,227
Plastic refractories and ramming mixes	do	XX	79,740	120,306	75,922
Gunning mixes	do	XX	109,180	364,806	150,950
Dead-burned magnesia or magnesite[3 7]	do	XX	141,836	250,990	64,347
Dead-burned dolomite	do	XX	23,111	324,691	46,393
Other nonclay refractory material sold in lump or ground form.[3]	do	XX	63,169	280,886	74,655
Total nonclay refractories		XX	874,727	XX	803,903
Grand total refractories		XX	1,504,465	XX	1,333,171

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 MQ32-C (86), Current Industrial Reports—Refractory.

Table 25.—U.S. exports of clays in 1986, by country

(Thousand short tons and thousand dollars)

Country	Ball clay		Bentonite		Fire clay		Fuller's earth		Kaolin		Clays, n.e.c.		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Argentina	--	--	(1)	84	--	--	--	--	18	3,353	1	1,310	19	4,747
Australia	(1)	10	25	1,277	23	1,649	(1)	4	13	3,663	1	557	62	7,160
Belgium-Luxembourg	--	--	(1)	81	42	3,266	2	273	36	5,633	1	288	81	9,541
Brazil	(1)	17	11	2,092	--	--	(1)	13	4	2,092	10	13,586	25	17,800
Canada	30	1,273	223	12,459	23	1,764	83	6,035	362	34,332	45	4,436	766	60,299
Chile	(1)	93	4	526	--	--	(1)	5	7	1,494	(1)	66	11	2,184
Colombia	--	--	3	201	(1)	20	(1)	2	7	1,515	5	4,062	15	5,800
Ecuador	3	254	1	143	--	--	--	--	4	444	1	224	9	1,065
Finland	--	--	--	--	--	--	--	--	23	4,351	(1)	81	23	4,432
France	--	--	(1)	124	1	160	(1)	47	10	2,370	1	425	12	3,126
Germany, Federal Republic of	(1)	73	(1)	127	(1)	70	(1)	16	18	4,197	8	2,222	26	6,705
Hong Kong	--	--	(1)	118	(1)	2	(1)	5	1	196	(1)	54	1	375
Italy	(1)	3	(1)	42	4	288	(1)	123	134	15,507	6	379	144	16,342
Japan	3	257	82	9,629	43	3,521	1	320	455	65,315	90	13,462	674	92,504
Korea, Republic of	(1)	33	3	1,456	(1)	6	--	--	67	13,465	3	487	73	15,447
Mexico	118	3,593	3	521	18	1,295	(1)	1	87	9,604	52	8,376	278	23,390
Netherlands	--	--	29	2,219	(1)	65	18	1,160	158	14,376	19	2,418	224	20,238
Peru	--	--	1	88	--	--	--	--	2	577	2	714	5	1,379
Philippines	2	185	2	593	--	--	(1)	60	2	385	1	154	7	1,377
Saudi Arabia	--	--	--	--	--	--	(1)	21	(1)	20	(1)	67	(1)	108
Singapore	--	--	17	1,267	--	--	5	391	1	169	(1)	230	23	2,057
South Africa, Republic of	2	15	(1)	133	(1)	21	(1)	72	20	3,983	1	303	23	4,527
Spain	--	--	(1)	138	(1)	10	--	--	16	2,206	(1)	86	16	2,440
Sweden	(1)	2	(1)	8	4	565	(1)	21	31	4,080	7	1,001	42	5,677
Switzerland	(1)	3	4	220	8	543	--	--	1	336	(1)	15	13	1,117
Taiwan	(1)	12	17	2,007	3	204	--	--	59	8,372	2	584	81	11,179
Thailand	(1)	26	2	320	--	--	--	--	9	1,615	(1)	35	11	1,996
United Arab Emirates	--	--	(1)	20	--	--	2	155	--	--	(1)	120	2	295
United Kingdom	(1)	9	21	1,499	10	719	2	282	3	1,898	11	3,389	47	7,796
Venezuela	(1)	6	14	1,363	1	138	(1)	7	13	2,736	2	1,247	30	5,497
Other	3	271	119	5,852	9	741	8	576	22	5,089	9	2,032	170	14,561
Total	161	[2]6,136	581	44,607	189	15,047	121	9,589	1,583	213,373	278	62,410	2,913	[2]351,161

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

Source: U.S. Department of Commerce.

Table 26.—U.S. imports for consumption of clays in 1986, by kind

Kind	Quantity (short tons)	Value (thousands)
China clay or kaolin:		
Brazil	31	$10
Canada	36	8
France	2	1
Germany, Federal Republic of	40	7
United Kingdom	10,205	1,156
Venezuela	18	2
Total	10,332	1,184
Fuller's earth, not beneficiated:		
France	6	5
Netherlands	4	3
United Kingdom	6	5
Total	16	13
Fuller's earth, beneficiated: United Kingdom	39	9
Bentonite:		
Belgium	10	14
Canada	1,979	274
Germany, Federal Republic of	165	112
Japan	26	12
Mexico	260	9
Philippines	9	1
Singapore	157	23
United Kingdom	160	62
Total	2,766	507
Common blue and other ball clay, not beneficiated:		
Germany, Federal Republic of	664	62
United Kingdom	1,002	77
Total	1,666	139
Common blue and other ball clay, wholly or partly beneficiated: United Kingdom	1,300	170
Total	2,966	309
Other clay, not beneficiated:		
Belgium	132	12
Canada	94	8
Germany, Federal Republic of	111	26
Italy	19	55
Japan	3,119	215
Korea, Republic of	222	39
United Kingdom	186	41
Total	3,883	396
Clay, n.e.c., beneficiated:		
Belgium	2,139	36
Brazil	2	2
Canada	1,074	354
France	157	61
Germany, Federal Republic of	87	36
Japan	66	103
United Kingdom	1,831	579
Total	5,356	1,171
Artificially activated clay:		
Canada	595	174
France	2	21
Germany, Federal Republic of	593	697
Italy	8	21
Japan	19	11
Korea, Republic of	16	4
Mexico	11,679	2,752
South Africa, Republic of	93	165
Switzerland	8	18
Thailand	2	2
United Kingdom	25	47
Total	13,040	3,912
Grand total	38,398	7,501

Source: U.S. Department of Commerce.

WORLD REVIEW

Estimated world production of all grades of kaolin increased slightly, while fuller's earth decreased 7% and bentonite decreased nearly 4%. World kaolin production during the year was about 24.9 million tons, and U.S. output accounted for over 34% of the total. Fuller's earth production was 2.4 million tons, with the United States accounting for over 78% of the total. Bentonite production was 9.2 million tons, and U.S. output was over 30% of the world total.

Australia.—Construction of Comalco Kaolin's 125,000-ton-per-year processing plant at Weipa in the northeast, a Comalco Pty. Ltd. company, was completed in September.[3] The plant, the first of its size in the Pacific Basin region, was designed to produce clays suitable for high-speed, high-solids paper coating. Trial production of the full range of kaolins was started at the pilot plant of Australia China Clays Ltd., at Gulgong, New South Wales.[4] The refined clays are reportedly of the highest quality ceramic and fiber grades. Construction of a 30,000-ton-per-year plant was nearly completed and scheduled to start production at yearend. Progressive expansions were planned to double the plant's initial capacity during the coming years.

Contracts were won by Western Australia's Mallina Holdings Ltd. to supply attapulgite-type herbicide carriers to Japan.[5] An ultramodern brick plant capable of producing upwards of 60 million standard face brick per year was recently completed by Brickworks Ltd., at Rochedale-Brisbane.

Canada.—The Calgary-based Ekaton Industries Inc. (formerly Ekaton Energy Ltd.) concluded that its large sand-kaolin deposit in the Wood Mountain area of southern Saskatchewan would be a viable venture.[6] Ekaton Industries was considering a 160,000-ton-per-year whole fraction filler kaolin plant with eventual upgrading capability to paper-coating grades. Ball clay byproducts also were said to be possible. Ekaton Industries also was planning the acquisition of the Avonlea Mineral Industries Ltd.'s bentonite operation in southern Saskatchewan. Ekaton Industries presently has an absorbent-grade clay operation in Canada. Carlson Mines Ltd. of Toronto was completing a feasibility study on another Canadian sand-kaolin deposit between Kapuskasing and Smooth Rock Falls in northern Ontario.[7] Initial plans called for a 3,000-ton-per-day mill with a stated aim of replacing imports in the Ontario market.

Engelhard of Edison, NJ, announced its intention to construct fluid cracking catalyst (FCC) plants in Canada and the United Kingdom.[8] The manufacturing facilities in Canada were to be in Aurora, Ontario, and based on kaolin-derived zeolite. The demand for FCC has reportedly trebled in Canada and Europe. These calalysts also are produced in Engelhard's Attapulgus, GA, plant.

Swindell Dressler Corp. of Canada Ltd. received a contract from Canada Brick Co. for engineering and construction of a 150-million-brick-per-year face-brick manufacturing facility.[9] On completion, the plant will be Canada Brick's flagship facility, employing the latest state-of-the-art technology and will have the largest brick production capacity in North America.

China.—Government geologists reportedly discovered a 1-million-ton sepiolite deposit in Hunan Province along with 30 other unspecified industrial minerals.[10]

Czechoslovakia.—Three new bentonite deposits, which have estimated reserves of nearly 70 million tons, were discovered in West Bohemia. The new finds were to be used chiefly to fulfill the increasing demand for bentonites, which trebled since 1970 to over 150,000 tons per year, in not only industrial uses but also agricultural and environmental protection applications. Exports for selected high-quality bentonitic clays have also been rising. A geological survey of the Karlovy Vary and Plzen Districts revealed further deposits of kaolin and refractory clays, which may extend the country's reserves for these clays by an additional 200 years.[11]

Egypt.—Testing was recently completed on the first of two brick plants near Cairo, built for the Government by Keller Corp., Federal Republic of Germany. The plant will have an annual production of 60 million bricks of Egyptian standards using the latest in clay preparation technology, cutting and handling equipment, and a nearly 350-foot-long tunnel kiln. Clay for the brickworks was from abundant nearby deposits.

Finland.—The Finnish mining company, Lohja Oy, received permission from the Ministry of the Environment to mine china clay in the Paljakka Nature Park.[12] The permission was granted subject to strict environmental controls and for sales to the Finnish paper industry, displacing British imports.

Indonesia.—The Government-owned P.T. Kaolindo Industry Utama, opened at yearend 1985, was operating at its full plant capacity of 30,000 tons.[13] The plant's main product is 18,000 tons per year of filler-grade kaolin, particularly for cosmetic, paper, and chemical applications offshore. The remaining capacity is for paper-coating applications. Additional clay is anticipated for ceramic uses in Japan and the Republic of Korea.

Iraq.—Bids were being solicited by the Public Enterprise for Glass and Ceramic Industries to both modernize and increase the capacity of its Ramadi ceramic wall tile factory.[14]

Ireland.—Small unnamed Irish-based companies were actively exploring for new commercial sources of kaolin throughout the country. Exports International Ltd. was also examining the Ballymacadam ball clay for possible exploitation.[15]

Kenya.—Athi River Mining Ltd. commenced marketing an indigenous montmorillonite clay suitable for refining edible oils.[16]

Malawi.—Processing of the Linthipe ceramic clays continued to be one of the Malawi Geological Survey Department's main mineral development projects.[17] Reserves of ceramic-grade clays at Linthipe alone were estimated at nearly 20 million tons.

Malaysia.—A joint venture between Laporte Industries Ltd. (a British-based specialty chemicals group), Batu Kawan Berhad, and Felda Mills Corp. was being established to sponsor an $8 million acid-activated bleaching earth plant to come onstream by early 1988.[18] The fully integrated plant will be at Pasir Gudang, which is the main refining center for Malaysian palm oil. Malaysia is the world's largest producer of palm oil and second only to the United States in the production and refining of edible oils.

Mexico.—Fideicomiso de Minerales No Metálicos Mexicanos completed studies and was awaiting approval for a 25,000-ton-per-year paper-grade kaolin plant in Hidalgo.[19]

New Zealand.—English China Clays PLC (ECC) strengthened its white pigments position in the Australian market by acquiring its New Zealand agent, Polychem Group Ltd.[20] Polychem is a major supplier of ECC's clays and calcium carbonates. The acquisition of Polychem was a part of ECC's strategy to look for business opportunities in the whole Pacific Basin area.

Nigeria.—A number of kaolin deposits have been found around the country but have not been thoroughly investigated by the Nigerian Mining Corp. (NMC).[21] NMC holds sizable kaolin reserves in Plateau State. High-quality kaolin in economically viable quantities has been outlined at Major Porter and Nahuta.

Saudi Arabia.—Shallow auger drilling and ground geophysics indicated that reserves of the Khulays bentonite deposit are in excess of 4 million tons with 2 to 3 million tons of overburden.[22] Preliminary tests indicate only a high potential for iron ore pelletization usage because of halite and gypsum contamination.

Senegal.—A major planned expansion of Senegal's attapulgite production capacity was inaugurated in January.[23] Société Sénégalaise des Phosphates de Thiès was co-owned by the Government and Rhône-Poulenc S.A. of France, with a capacity of about 125,000 tons per year. Another enterprise, Compagnie des Produits Chimiques et Materiaux, producing about 100,000 tons per year, was planning to boost production to over 200,000 tons per year. Present and planned attapulgite production was largely targeted for export to Western Europe.

Sri Lanka.—The Geological Survey Department identified a deposit of high-grade kaolin near southern Ambalangoda at Metiyagoda.[24] The refined kaolin content of the deposit was estimated to be in excess of 300,000 tons.

Tanzania.—The present 5,000-ton-per-year Pugu sand-kaolin plant capacity was to be doubled in increments over 2 to 3 years.[25] The major thrust of the project was the production of filler- and extender-grade clays.

U.S.S.R.—A 26-million-brick-per-year-capacity facing-brick plant started production at Tomsk.[26]

United Kingdom.—ECC International opened a $5 million plant for the production of spray-dried granulated ceramic at its 3-year-old Cliff Vale distribution depot in Stoke-on-Trent in July.[27] Additionally, a slurry plant to provide prepared clays and composite bodies in slip form also has been erected in the new facility. Laporte Industrial (Holdings) PLC was working a new line of clay-based coatings for carbonless copying paper used for business forms, continuous stationery, and computer paper at its Widnes plant.[28] The plant was scheduled to reach full production at midyear.

Table 27.—Kaolin: World production, by country[1]

(Thousand short tons)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Algeria	[e]17	[e]19	9	14	[3]16
Argentina	80	160	100	[e]110	110
Australia[4]	168	127	[e]275	[e]140	140
Austria (marketable)	85	92	110	110	95
Bangladesh[5]	6	3	3	5	[3]3
Belgium	58	66	76	41	44
Brazil (beneficiated)	544	463	536	578	610
Bulgaria	261	267	282	283	290
Burundi	[e]2	4	2	5	[3]6
Chile	23	45	54	54	[3]46
Colombia	943	[r]1,114	1,034	1,148	1,100
Costa Rica	1	[e]1	[e]1	([6])	--
Czechoslovakia	581	730	736	720	720
Denmark[e]	[3]6	11	15	[r]14	[3]11
Ecuador	5	1	2	2	2
Egypt	55	110	159	119	[3]141
Ethiopia (including Eritrea)	[e]10	[e]10	NA	NA	NA
France[7]	383	319	338	1,664	[3]1,488
German Democratic Republic (marketable)[e]	230	220	190	190	180
Germany, Federal Republic of (marketable)	500	448	397	452	435
Greece	49	67	101	97	95
Hong Kong	([8])	1	([8])	11	[3]1
Hungary	50	41	43	32	33
India:					
Salable, crude	585	610	555	645	660
Processed	[e]110	[e]110	128	121	110
Indonesia	85	66	92	118	110
Iran[e]	121	110	110	110	110
Israel	13	30	[e]30	[e]30	30
Italy:					
Crude	59	58	58	66	40
Kaolinitic earth	32	28	28	29	[3]23
Japan	218	254	248	245	[3]224
Kenya	1	1	([8])	([8])	[3]2
Korea, Republic of	690	754	795	726	720
Madagascar[e]	[3]3	3	3	3	3
Malaysia	49	63	80	91	[3]94
Mexico	190	179	144	311	220
Mozambique	([8])	([8])	([8])	([8])	([8])
New Zealand	26	26	28	[r] [e]30	30
Nigeria	[e]1	[e]1	([8])	([8])	([8])
Pakistan	49	14	13	7	32
Paraguay	61	50	55	66	66
Peru	[r] [e]2	1	1	([8])	([8])
Poland	51	54	50	53	[3]54
Portugal	[r]69	[r]114	115	88	[3]60
Romania[e]	[r]450	[r]450	[r]450	[r]450	460
South Africa, Republic of	141	143	150	142	[3]138
Spain (marketable)[9]	[r]263	[r]281	352	456	390
Sri Lanka	9	9	12	6	6
Sweden	([8])	([8])	([8])	([8])	([8])
Taiwan	96	113	88	84	[3]70
Tanzania	[e]1	1	2	2	2
Thailand	20	40	65	118	110
Turkey	[e]50	[e]60	61	76	80
U.S.S.R.[e]	2,900	2,900	3,100	3,200	3,300
United Kingdom	2,669	3,000	3,296	3,472	3,400
United States[10]	6,362	7,203	7,953	7,793	[3]8,549
Venezuela	[e]72	12	24	[e]25	24
Vietnam[e]	1	1	1	1	1
Yugoslavia	261	230	[e]230	[e]240	248
Zimbabwe	3	1	1	1	1
Total	[r]19,770	[r]21,289	22,781	24,594	24,933

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.
[1]Table includes data available through July 14, 1987.
[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]Reported figure.
[4]May include ball clay and other clays grouped for statistical purposes as kaolin.
[5]Data for year ending June 30 of that stated.
[6]Revised to not available.
[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]	1982	1983	1984	1985[p]	1986[e]
Algeria[3]	[e]38,600	[e]33,100	27,000	36,376	[4]33,069
Argentina	135,864	149,439	89,876	[e]99,000	110,000
Australia[3]	32,201	33,098	[e]33,000	[e]33,000	33,000
Brazil	180,845	141,857	221,592	245,378	265,000
Burma	1,613	[r]783	799	783	938
Cyprus[5]	14,330	35,300	35,715	57,300	60,600
Egypt[e]	5,700	2,800	[r]4,200	3,300	56,500
France	3,627	3,407	3,831	16,424	11,000
Greece	343,921	759,427	858,400	977,718	992,100
Guatemala[e]	[4]2,750	8,800	9,400	[r]3,300	3,300
Hungary	93,624	87,972	70,722	65,966	66,000
Iran[e]	12,100	11,000	11,000	11,000	11,000
Israel (metabentonite)	13,228	7,538	6,501	[r e]6,600	6,600
Italy	261,200	327,183	335,102	329,600	331,000
Japan	533,993	486,034	452,034	508,749	[4]450,695
Mexico	203,837	249,276	294,700	295,083	276,000
Morocco	4,913	4,515	2,012	3,171	[4]4,226
Mozambique	1,604	276	446	398	440
New Zealand (processed)	6,856	2,158	7,075	[r e]6,600	6,600
Pakistan	1,572	735	1,918	1,776	2,100
Peru	[r e]22,000	[r]16,656	14,298	2,223	5,500
Philippines	5,149	739	42,162	27,526	22,000
Poland[e]	77,000	77,000	77,000	83,000	83,000
Romania[e]	193,000	195,000	198,000	198,000	204,000
South Africa, Republic of	33,981	43,573	46,131	47,910	[4]53,203
Spain	123,800	90,976	80,008	99,471	88,000
Tanzania	55	[e]83	[e]83	83	83
Turkey	[e]34,200	[e]34,200	30,967	51,649	55,000
U.S.S.R.[e]	3,152,600	3,163,600	3,174,700	3,185,700	3,196,700
United States	3,244,800	2,886,870	3,437,940	3,195,280	[4]2,813,043
Zimbabwe	94,236	69,552	[e]77,000	([6])	--
Total	[r]8,873,199	[r]8,922,947	9,643,612	9,592,364	9,240,697

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through July 14, 1987.
[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]Reported figure.
[5]Includes bleaching earths.
[6]Revised to zero.

Table 29.—Fuller's earth: World production, by country[1]

(Short tons)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Algeria[e]	5,600	5,500	[3]3,858	3,900	3,900
Argentina	13,002	7,431	3,980	[e]5,500	6,100
Australia (attapulgite)[e]	16,280	16,500	16,500	16,500	16,500
Italy[e]	[r]7,700	[r]22,000	[r]33,000	[r]33,000	[3]34,171
Mexico	46,835	45,827	50,372	63,934	49,600
Morocco (smectite)	27,121	30,187	36,824	26,924	38,700
Pakistan	15,205	23,298	21,097	11,736	10,900
Senegal (attapulgite)	109,128	110,644	127,315	105,774	[3]90,200
South Africa, Republic of	343	344	--	--	--
Spain (attapulgite)	47,318	49,223	48,399	65,805	56,000
United Kingdom	206,132	211,644	[r]222,666	[r e]220,000	220,000
United States[4]	1,682,655	1,911,634	1,899,145	2,059,281	[3]1,909,978
Total	[r]2,177,319	[r]2,434,232	2,463,156	2,612,354	2,436,049

[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 14, 1987.
[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.

Baggeridge Brick PLC's new Hartlebury brickworks opened during the last quarter of 1986.[29] The new $15 million plant was initially designed to produce 25 million extruded brick annually, but a change in work practices would permit easily doubling the capacity when required. The Nottingham Brick Group announced additional production increases at its Nottingham plant when its fourth kiln comes on-stream in mid-1987.[30] In addition, land adjacent to the plant has been purchased to provide additional clay reserves to support the expansion.

Yugoslavia.—A new kaolin and feldspar operation was being developed at Arandjelovac near Belgrade.[31] The project includes construction of a kaolin-processing plant, scheduled for mid-1987, capable of handling the 20,000-ton-per-year mine output.

TECHNOLOGY

A new edition of a classic work highlights the latest research on clays and ceramic raw materials including structure, geology, occurrence, physical and chemical properties, and applications.[32] Colloidal properties of clay, ion exchange, rheology, plasticity, and identification methods were covered along with other nonclay raw materials and refractories. The book features a discussion of recent advances in clay minerology and instrumentation, together with new information on Mossbauer spectroscopy and chemical separation methods, kaolinites and illites, colloid stability, intercalation, and drying.

A new class of porous, high-surface-area materials of potential interest as catalysts and absorbents was introduced by the synthesis of cross-linked or pillared smectites (CSL).[33] Preparation of these CSL's, also known as montmorillonites, usually involves an exchange of the cations in the interlayer region of the smectite polymeric or oligomeric hydroxy-metal cations. On heating, these inorganic polycations or oligomers form metal oxide pillars that permanently prop open the smectite layers. The cavities so formed are easily accessible for adsorption of gases and vapors. A special large pore size TiO_2-cross-linked montmorillonite was being evaluated for cracking heavy oil fractions and biomass oils. A similar study on the formation of radical cations on Cu (II)-smectite may provide the basis for a new detoxification technology, which can preferentially remove recalcitrant toxins, such as dioxin and dibenzofurans from environmental and industrial wastes.[34] This latter research is particularly attractive because it offers a relatively inexpensive alternate disposal scheme compared with the conventionally practiced high-cost onshore or offshore evaluation schemes.

Comprehensive reports on the production, major operating companies, production flowsheets, mining methods, geology, and marketing of industrial minerals, emphasizing clays, were published for Italy,[35] Morocco,[36] Thailand,[37] and Turkey.[38] The Italian report stressed the individual bentonite mining and chemical processing companies while the Thai paper accented the chemical and physical properties of its kaolin and ball clays along with domestic and foreign markets. The Moroccan and Turkish studies concentrated on the countries' overall, present, and future mining plans for clays. The Moroccan "Ghassoul" clays, an uncommon mixture of bentonite, smectite, and fuller's earth, and its textile applications were singled out for special treatment. The Turkish bentonites and attapulgite-sepiolite clays were highlighted in that report. A unique, detailed, and candid profile of a major domestic air-float kaolin producer also was published.[39] The profile discussed the company's mining, grinding, and quality control problems along with future plans and market strategies. Another similar study reviewed the Pugu sand-kaolin operation in Tanzania with special emphasis on geological, mining, and processing aspects of the operation.[40] The major markets for its kaolin and sand fractions along with chemical and physical specifications for its products also were emphasized.

Another article reviewed the uses of fillers and extenders in the Western United States and Canada.[41] The work included a feature section technically evaluating the market potential for the filler and extender markets by correlating end uses with the physical and chemical properties of conventional fillers, such as kaolin, calcium carbonate, and silica.

The unique flint clays, fine-grained kaolin and/or bauxite mixtures with a conchoidal fracture, were featured in two reports.[42] The first report discusses the major international producers and their geological, mining, processing, and marketing schemes. The main use for these clays has been largely in declining refractory applications. The principal producers with higher bauxite flints were diversifying their mining and processing techniques to enable production of clays also acceptable to the cement and alum manufacturers. Their diversification efforts and the attending modifications were highlighted. The second paper detailed the processing of Israeli flint clays from mine to mill. The work contains a special section on dry magnetic beneficiation, along with conventional processing and selective mining, which is credited with both improving recovery and meeting specifications for higher valued products.

The physical chemistry of the dehydroxyzation of kaolin[43] and thermal sequence in the kaolin-mullite solid-state reaction[44] were thoroughly investigated with the aid of powder X-ray diffractometry, the Rietveld method, spectroscopy, and electron microscopy. The first study from room temperature to 455° C determined that these polymorphic clay minerals dehydroxyzated via an inhomogeneous mechanism that either retained or did not retain the structural details of the unreacted crystalline clays. This unique behavior, if persisting to higher temperatures, could have an influence on the crystallite size and morphology of the mullite formed. The other paper studied the spinel phase formed on the thermal reaction of the kaolin-group minerals. The sophisticated instrumentation revealed a novel precursor spinel phase in the kaolin-mullite reaction mechanism, which was essentially a gamma-Al_2O_3 or much lower in SiO_2 content than previously reported.

This new revelation questions the optimum Al_2O_3-SiO_2 stoichiometry necessary for mullitization to occur. These solid-state mullites, commonly known as refractory grogs or calcines, are widely used in refractory bricks and specialty products. This type of research should allow refractory manufacturers to better control mullite morphology and crystallite size so as to optimize the density and strength of high-performance refractories.

The quality of mineral additives in drilling fluids, such as bentonite, was laboriously correlated with catastrophic and expensive downhole drilling problems and failures.[45] The investigation revealed how polymeric extender additives in bentonites could contribute to unpredictable behavior of a mud in either fluid viscosity, gel strength, or permeability of the filter cake. Another study on standardization of minerals for drilling fluids carefully formulated special muds to perform the following essential functions: (1) lift cuttings to the surface; (2) control well pressure; (3) seal the formation with a filter cake to isolate formation fluids from well-base fluids; and (4) protect and not react with the formation to excessively change the mechanical properties of the rocks being drilled.[46] The state-of-the-art in oil well drilling was technically explored in another related effort.[47] The work, stressing the Continental Shelf and onshore wells, contains a glossary of technical drilling terms, specifications, and flowsheets for typical oil- and water-based mud systems. Tables depicting the principal functions of selected minerals and chemicals also were featured.

In related drilling-mud research, the use of attapulgite, sepiolite, and palygorskite clays in ionically contaminated (salt) drilling fluids to build viscosity and maintain uniform and stable rheological control throughout the life of the fluid is discussed in a major work.[48] The applications of this study toward nondrilling-fluid uses, such as paint, animal feed, and suspension fertilizer stabilization, also were highlighted. A work of this scope and usefulness is rarely found in the clay literature. The organically modified bentonites and hectorite clays were discussed in another brief but similar study.[49] The role of these two modified clays in providing unique drilling muds for use in environmental sensitive areas was cited.

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Cobalt

By William S. Kirk[1]

The cobalt market was characterized by a steep drop in prices in 1986, and domestic cobalt consumption increased slightly during the year. Reported consumption rose to 14.4 million pounds, and apparent consumption increased to 17.4 million pounds. There was no domestic production of cobalt.

Domestic Data Coverage.—The Bureau of Mines began statistical coverage of superalloy recyclers in 1986. Thirteen recyclers processed the vast majority of superalloy scrap. All 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)

	1982	1983	1984	1985	1986
United States:					
Consumption:					
Reported	9,468	11,319	12,944	13,541	14,442
Apparent	11,451	15,712	17,895	15,692	17,373
Imports for consumption	12,870	17,221	25,310	17,708	12,288
Stocks, Dec. 31:					
Consumer	1,327	1,441	1,368	1,131	1,479
Processor	1,161	1,366	1,781	1,557	1,441
Price: Metal, per pound[1]	$8.56	$5.76	$10.40	$11.43	$7.49
World: Production:[2]					
Mine	54,162	52,297	71,759	[p]80,229	[e]79,700
Refinery	42,533	38,769	50,989	[p]57,981	[e]60,645

[e]Estimated. [p]Preliminary.
[1]Based on weighted average of Metals Week prices.
[2]The units for "World: Production" have been 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 General Accounting Office (GAO) issued a report entitled "Adequacy of National Security Council Study for Setting Stockpile Goals." The study refuted some assumptions used by the National Security Council in developing its revised stockpile recommendations as approved by the President during 1985. Despite the GAO report, subsequent legislation designed to transfer management of the stockpile to Congress and to change the method of calculating stockpile goals was defeated. Instead, the Strategic and Critical Materials Stock Piling Amendments Act of 1987, Public Law 99-661, was passed in November. The act required the President to appoint a National Defense Stockpile Manager, kept in place the method of calculating goals, and extended the freeze on reducing stockpile goals below their 1984 quantities until October 1, 1987.

The Deep Seabed Hard Mineral Resources Act of 1980 was reauthorized as Public Law 99-507. The act enabled the National Oceanic and Atmospheric Administration to fund research on and regulate seabed mining. Four consortia have received exploration licenses under the act; no commercial recovery permits can be issued until 1988.

Bureau of Mines and U.S. Geological

Survey personnel continued research on cobalt-rich manganese crusts in the Exclusive Economic Zone in the Pacific Ocean. Nearly 13,000 pounds of crust and rock was collected near Johnson Island for evaluating extraction procedures.

The President signed Public Law 99-499, Superfund Amendments and Reauthorization Act of 1986, on October 17. The act reauthorized Superfund expenditures of $8.5 million to clean hazardous waste sites over a 5-year period. The act called for a tax on chemical feedstock, from which recycled cobalt was exempt.

The Comprehensive Anti-Apartheid Act of 1986, Public Law 99-440, banned imports of iron and steel products from the Republic of South Africa. The act also charged the Administration with preparing a report by yearend on the U.S. reliance on the Republic of South Africa for cobalt and other critical and strategic materials.

Under title III of the Defense Production Act, the U.S. Department of Defense began drafting a request for proposals to stimulate domestic recycling of superalloys that contained cobalt and other strategic metals. The resulting procurement, targeted for chromium, would be processed in two phases. The first would identify sources with acceptable grade and quantity for strategic applications and the second would include negotiations for fixed-price contracts if the sources successfully demonstrated capabilities under the first phase.

DOMESTIC PRODUCTION

After a successful development program, AMAX Nickel Co. began recovering cobalt and other metals from spent petroleum catalysts at its former nickel-copper-cobalt refinery in Braithwaite, LA. Production at the refinery had ceased in 1985. The project was a joint venture between AMAX Nickel and CRI Ventures Inc. CRI was itself a joint venture between Catalyst Recovery Inc. and Shell Chemical Co. The plant began operating in August and was at 70% capacity at yearend. The process, developed and patented by AMAX Nickel, was designed to leave no residue, thereby making it economically and environmentally attractive. The cobalt sulfide residues generated by the process were sent out of the country for refining. Perhaps the most important result of AMAX Nickel's decision to initiate this project was that, because some of the refining equipment at the plant was to be used for treating the catalysts, none of the refining equipment was to be dismantled. Thus, if AMAX Nickel was to find a suitable source of feedstock in the future, it could once again refine cobalt and nickel.

Falconbridge Ltd., of Toronto, Canada, evaluated the former Madison Mine near Fredericktown, MO. Under an agreement with Anschutz Mining Corp., the owner of the Madison Mine, Falconbridge was to perform a study to determine the feasibility of reopening the property. Depending on the outcome of the study, Falconbridge was to have the option to purchase the property, to form a joint venture with Anschutz, or to terminate the project. Falconbridge drilled five test holes and sent core samples to its laboratories in Lakefield, Ontario, Canada, for analysis. Company metallurgists determined that, using Falconbridge's extraction process, it would have been economically feasible to mine the Madison Mine if the mineralization had been extensive enough. Falconbridge conducted an extensive drilling program that confirmed Anschutz's estimates although the company had hoped to find more mineralization. Because of this finding, as well as poor cobalt market conditions and other economic reasons, Falconbridge terminated the project in June. If the project had been successful, Falconbridge had planned to send a concentrate from the Madison Mine to its Kristiansand, Norway, refinery to recover cobalt, nickel and some precious metals. Cobalt was to have been the primary product.

The Minnesota Department of Natural Resources conducted a copper, nickel, and associated minerals lease sale on properties located in the State, with the bid opening on December 11, 1986. Areas offered for lease included tracts in the Duluth Gabbro Complex, which contains the Nation's largest deposit of cobalt, as well as substantial quantities of copper, nickel, and precious metals.

Savanna Resources Ltd., of Calgary, Alberta, Canada, was reported to have acquired 72% of the Turner Albright cobalt deposit in southwestern Oregon.

Table 2.—U.S. cobalt products[1] produced and shipped by refiners and processors

(Thousand pounds)

	1985				1986			
	Production		Shipments		Production		Shipments	
	Gross weight	Cobalt content	Gross weight	Cobalt content	Gross weight	Cobalt content	Gross weight	Cobalt content
Driers (organic compounds)	NA	1,188	NA	1,190	NA	1,563	NA	1,423
Hydrate (hydroxide)	NA	1,149	NA	1,014	NA	109	NA	962
Salts[2] (inorganic compounds)	NA	539	NA	612	NA	748	NA	810
Total	NA	2,876	NA	2,816	NA	2,420	NA	3,195

NA Not available.
[1]Figures on oxide withheld to avoid disclosing company proprietary data.
[2]Various salts combined to avoid disclosing company proprietary data.

CONSUMPTION AND USES

Based on monthly and annual data for 1986, which did not include the new consumption data mentioned in the "Domestic Data Coverage" section, cobalt consumption decreased. However, as a result of the significantly improved statistical coverage, secondary cobalt consumption increased to 2.6 million pounds. This caused an increase in reported cobalt consumption to 14.4 million pounds. Also, apparent consumption, calculated from net imports, secondary production, and changes in industry and Government stocks, increased to 17.4 million pounds. If not for the improved statistical coverage, these figures would have been (in millions of pounds) for reported consumption, 12.9; apparent consumption, 15.8; and secondary consumption, 1.0. Moreover, a significant but undetermined quantity of cobalt contained in scrap was shipped to refiners and then sold as primary metal. This quantity was not reported to avoid double counting.

Table 3.—U.S. consumption of cobalt, by end use

(Thousand pounds of contained cobalt)

End use	1985	1986
Steel:		
Full-alloy	W	W
High-strength, low-alloy	W	W
Stainless and heat-resisting	61	76
Tool	203	256
Superalloys	6,380	[1]6,446
Alloys (excludes alloy steels and superalloys):		
Cutting and wear-resistant materials[2]	1,017	726
Magnetic alloys	1,455	1,791
Nonferrous alloys	W	W
Welding materials (structural and hard-facing)	W	W
Other alloys	122	118
Mill products made from metal powder	W	W
Chemical and ceramic uses:		
Catalysts	1,253	1,445
Drier in paints or related usage	1,139	1,593
Feed or nutritive additive	46	46
Glass decolorizer	42	40
Ground coat frit	724	771
Pigments	401	462
Miscellaneous and unspecified	698	672
Total	13,541	14,442

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."
[1]Data not comparable to those of previous years because of the addition of statistical canvass coverage of the superalloy recycling industry. The 1986 quantity comparable to that of 1985 would be 5.2 million pounds.
[2]Cemented and sintered carbides and cast carbide dies or parts.

Table 4.—U.S. consumption of cobalt, by form

(Thousand pounds of contained cobalt)

Form	1982	1983	1984	1985	1986
Chemical compounds (organic and inorganic) other than oxide	1,643	2,297	2,226	1,850	1,738
Metal	6,055	7,165	8,746	9,463	8,594
Oxide	732	938	915	1,201	1,233
Purchased scrap	871	723	879	897	2,638
Other	167	196	178	130	239
Total	9,468	11,319	12,944	13,541	14,442

PRICES

Seen in terms of 1985 constant dollars, the price for metallic cobalt in 1986 reached its lowest level since 1920. The spot price remained as the standard. The average annual price for electrolytic cobalt was $7.49 per pound.

The price of electrolytic cobalt, which began 1986 at about $11.00 per pound, declined gradually until it bottomed out in August at about $4.00 per pound. The long decline was attributed to Zambia having undercut the price that it and Zaire had agreed on in 1984. Zaire, through its unsuccessful efforts to maintain the producer price, lost a large part of its share of the U.S. market. Otherwise, prices would have fallen much more quickly. When Zaire was forced to discount its cobalt, prices reached their lowest level ever. Then, in September, following Western European prices, the U.S. cobalt price jumped in 1 week from about $3.80 per pound to about $6.30 per pound. The sudden rise was apparently due to reports of low Zairian and Zambian cobalt inventories in Western Europe. Additionally, Zambia was reported to have announced that it would not accept orders from new customers for the balance of the year and that it was cutting production. Western European dealers that had had commitments for deliveries to customers in September were unable to obtain cobalt through normal channels and were forced to look elsewhere and pay higher prices. In November, representatives from Zaire and Zambia met in Kinshasha, Zaire, and agreed to establish a producer price of $7.00 per pound. This appeared to have stabilized the market somewhat, as prices rose slightly to end the year at $6.40 per pound.

Table 5.—Yearend published prices of cobalt materials[1]

(Dollars per pound)

Material	1983	1984	1985	1986
Cobalt:[2]				
Fine powder	10.11	16.63	19.05	15.30
Powder	6.91	13.24	14.87	14.47
Cobalt oxide:				
Ceramic-grade (70% cobalt)	4.90	9.40	9.98	6.08
Ceramic-grade (72% cobalt)	5.04	9.66	10.26	6.24
Metallurgical-grade (76% cobalt)	5.21	9.86	10.61	6.51

[1]Metals Week.
[2]See table 1 for cathode price.

FOREIGN TRADE

As a result of increased coverage of secondary cobalt consumption, import reliance, which had averaged 96% from 1970 through 1985, fell to 85% in 1986. Import reliance is a measure of the extent to which the United States is dependent on foreign sources to satisfy its demand for a commodity.

Falconbridge Trading Associates (FTA), of Dublin, OH, and Harshaw/Filtrol Partnership, of Cleveland, OH, formed a joint venture to process spent catalysts containing cobalt and other metals in Western Europe. Under this arrangement, Harshaw was to provide FTA with the names of companies that needed to have catalysts recycled, primarily Harshaw's chemical customers. FTA was to then recycle catalysts for those companies if they agreed. If the cost of the recovery exceeded the value of the metals recovered, the company was to pay the difference. If, however, the value of the metals recovered exceeded the recovery costs, the company was to receive a rebate from FTA. Although the spent catalysts were to be processed in Western Europe, the majority of them were not to be processed at a Falconbridge-owned facility.

Exports of unwrought cobalt metal and waste and scrap totaled 1.2 million pounds, gross weight, with an estimated 1.0-million-pound cobalt content, valued at $7.0 million. These exports were shipped to 39 countries, with Belgium, Japan, and the United Kingdom, in descending order, receiving the largest quantities.

Exports of wrought metal totaled 600,000 pounds, gross weight, valued at $10.6 million. Of the 24 countries to which cobalt was shipped, the major recipients, in descending order, were Japan, Canada, and Belgium.

Imports of cobalt metal originating in south-central Africa, that is, imports from Belgium-Luxembourg (Zairian origin), Zaire, and Zambia, represented 50% of total cobalt imports compared with 56% from that area in 1985.

Table 6.—U.S. imports for consumption of cobalt, by class

(Thousand pounds and thousand dollars)

Class	1984	1985	1986
Metal:[1]			
Gross weight	23,316	16,613	11,669
Cobalt content[e]	23,316	16,613	11,669
Value	$202,954	$181,379	$83,295
Oxide:			
Gross weight	706	246	511
Cobalt content[e]	522	182	378
Value	$5,285	$2,258	$4,202
Salts and compounds:			
Gross weight	2,284	1,413	805
Cobalt content[e]	685	424	241
Value	$5,371	$4,431	$2,669
Other forms:[2]	787	489	NA
Value	$4,793	$3,356	NA
Total content	25,310	17,708	12,288

[e]Estimated. NA Not available.
[1]Includes unwrought metal and waste and scrap.
[2]Contained cobalt in nickel-copper and nickel matte.

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[4] [5]	
	1985		1986		1985		1986		1985[3]		1986			
	Gross weight	Value	Gross weight	Value	Gross weight	Value	Gross weight	Value	Cobalt content	Value	Cobalt content	Value	1985	1986
Australia	6	26	6	22	--	--	NA	NA	82	[6]559	--	--	87	6
Belgium	845	9,975	512	2,535	162	1,423	325	2,602	62	908	15	136	1,026	768
Botswana	--	--	--	--	--	--	--	--	296	[6]2,027	--	--	296	--
Canada	3,047	33,568	3,324	24,643	36	317	19	161	32	212	17	134	3,105	3,355
Finland	984	11,712	583	6,494	5	126	2	16	10	270	6	172	994	590
France	62	543	84	566	--	--	6	184	(7)	13	--	--	66	88
Germany, Federal Republic of	109	1,280	227	1,507	--	--	35	433	22	252	13	139	131	266
Japan	132	912	620	4,392	--	--	--	--	17	423	34	382	149	654
Netherlands	300	3,738	33	227	--	--	34	147	--	--	--	--	300	58
Norway	1,693	18,601	1,807	18,015	--	--	--	--	--	--	--	--	1,693	1,807
South Africa, Republic of	14	151	22	179	1	5	--	--	275	[6]2,038	23	51	290	45
United Kingdom	192	1,443	138	626	42	387	90	659	75	942	116	1,535	298	321
Zaire	4,801	59,056	694	3,931	--	--	--	--	--	--	9	69	4,801	703
Zambia	4,318	39,958	3,501	19,834	--	--	--	--	--	--	--	--	4,318	3,501
Zimbabwe	(7)	1	--	--	--	--	--	--	--	--	--	--	(7)	--
Other	110	414	118	325	--	--	--	--	44	144	9	50	154	127
Total[5]	16,613	181,379	11,669	83,295	246	2,258	511	4,202	913	7,788	241	2,662	17,708	12,288

NA Not available.
[1]Includes unwrought metal and waste and scrap.
[2]Gross weight figures for cobalt oxide do not indicate cobalt content.
[3]Contained cobalt in nickel-copper and nickel matte from Australia and Botswana. Salts and compounds were imported from the remaining countries.
[4]Estimated contained cobalt.
[5]Data may not add to totals shown because of independent rounding.
[6]Based on weighted average cobalt metal price of $11.43 per pound for 1985, multiplied by 0.6 (estimated factor for matte) for imports from Australia, Botswana, and the Republic of South Africa.
[7]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)		Non-MFN
		Jan. 1, 1986	Jan. 1, 1987	Jan. 1, 1986
Alloys, unwrought	632.86	9% ad valorem	9% ad valorem	45% ad valorem.
Chemical compounds:				
Oxide	418.60	1.2 cents per pound.	1.2 cents per pound.	20 cents per pound.
Sulfate	418.62	1.4% ad valorem	1.4% ad valorem	6.5% ad valorem.
Other	418.68	4.4% ad valorem	4.2% ad valorem	30% ad valorem.
Ore and concentrate	601.18	Free	Free	Free.
Unwrought metal, waste and scrap	632.20	do	do	Do.

WORLD REVIEW

World production of refined cobalt, at 60.6 million pounds, far exceeded world demand, which was estimated to have been approximately 46 million pounds.

Albania.—Construction continued on a nickel-cobalt refinery being built near Elbasan by the West German company Salzgitter Industriebau GmbH using technology supplied by Inco Ltd.

Australia.—Agnew Mining Co. Pty. Ltd. shelved plans to develop an open pit mine near its Agnew Mine while rehabilitating the Agnew Mine after a 1985 rockfall. Instead, the company closed the Agnew Mine indefinitely on August 15, citing the continuing decline in nickel prices.

Queensland Nickel Pty. Ltd. and Nippon Mining Co. Ltd. of Japan terminated the contract under which Queensland supplied nickel-cobalt sulfides to the Japanese refinery for cobalt production. Queensland subsequently contracted to sell all of its byproduct sulfides to Outokumpu Oy for Outokumpu's refinery in Kokkola, Finland. Queensland also began testing ore from Indonesia and New Caledonia at the Yabulu refinery to determine possible future sources of ore after the company's mine reserves are exhausted (expected to be within the next 5 years).

Belgium.—Métallurgie Hoboken-Overpelt S.A., a Belgian cobalt processor, brought on-stream a new facility to supplement its line of cobalt products. Feedstock for the plant consisted of cobalt-containing scrap and complex residues including spent catalysts. The plant was reported to have the capacity to produce powders, oxides, and salts containing 2 million pounds of cobalt per year.

Botswana.—Bamangwato Concessions Ltd. continued to experience financial difficulties despite the new sales contracts negotiated with Falconbridge and others in 1985.

Brazil.—A bill introduced into the Brazilian legislature would require a majority Brazilian ownership in companies developing strategic minerals in the country. Cobalt was included in the list of materials defined as strategic.

Canada.—Mine and refinery production of cobalt was considerably higher than that of 1985.

Falconbridge's mine and mill in Sudbury, Ontario, were shut on May 15 after workers refused to cross picket lines set up by striking office, clerical, and technical workers. The strike was settled 5 days later with workers getting a 3-year contract. By September, the continuing depressed nickel prices prompted the company to consider several means to reduce costs in addition to the drastic cost cuts of recent years. The work force in Sudbury was cut by 200 (approximately 10%), mostly through early retirement. The company also imposed salary cuts on management personnel.

Falconbridge increased its share of Western Platinum Ltd. (Wesplat) from 25% to 49% by purchasing Mobil Corp.'s holdings. Wesplat produced cobalt as a byproduct of its platinum mining operations in the Republic of South Africa.

Inco instituted a number of cost-cutting measures that included halting production at the Clarabelle open pit, Creighton No. 3, Stobie, and Shebandowan Mines. The Sudbury and Manitoba Districts were also closed for a 5-week summer vacation shutdown. A rockfall at the Garson Mine caused the company to suspend mining activities at the mine for the rest of the year.

Inco began producing cobalt from its new Thompson open pit mine in Manitoba. The mine, formally inaugurated in September, required the dredging and draining of Thompson Lake to gain access to the ore body, which remained as a crown pillar above the Thompson underground mine. Estimated production costs at the mine averaged 50% lower than costs at the company's underground mines. The company also committed US$18 million toward rehabilitating the Crean Hill Mine.

China.—The development of a primary cobalt deposit in Hainan Doa, Guangdong Province, was completed early in the year. The Hainan Mine reportedly had an ore output of 100 million pounds per year.

Cuba.—An agreement was reported to have been signed between Cuba and Hungary stating that Hungary was to invest in a new nickel-cobalt processing plant in Cuba.

Finland.—Outokumpu began processing nickel-cobalt sulfide from Queensland's Yabulu refinery in Australia. Outokumpu refined the material, a residue from Queensland's nickel oxide production, at its Kokkola refinery into cobalt and nickel salts.

At the Keretti Mine, Outokumpu opened a nickel-cobalt ore body above the main cobalt-copper-zinc deposit.

Japan.—Although the two Japanese cobalt refiners experienced difficulty in obtaining feedstock, their combined output exceeded that of the previous 2 years. Sumitomo Metal Mining Co. Ltd. was forced to reduce cobalt production at its Niihama refinery because the Nonoc Mining and Industrial Corp. (NMIC) of the Philippines, a major supplier of feedstock to Sumitomo, failed to reopen its operation following a labor dispute. Nikko Nickel Cobalt Refining Co., owned by Nippon Mining Co. Ltd., lost its contract to obtain nickel-cobalt sulfide residues from Queensland's Yabulu refinery in Australia. Consequently, cobalt production at the Hitachi refinery halted at the end of September.

Scientists at Tokai University discovered a large cobalt- and nickel-rich manganese crust off the coast of Minami-Torishima Island. A 1-ton sample was retrieved for testing and analysis. The Japanese Metal Mining Agency was reported to be planning exploration for cobalt-rich deposits in the central and western Pacific.

Norway.—Falconbridge Nikkelverk A/S, the Norwegian subsidiary of Falconbridge, Toronto, Canada, suspended operations for 1 week in early April when it locked out workers at its Kristiansand cobalt and nickel refinery. The labor dispute was between several of the country's unions and the Employers Association of Norway, of which Falconbridge Nikkelverk is a member.

Philippines.—Cobalt production declined precipitously in the wake of financial and labor difficulties that plagued NMIC. At the end of January, the cobalt and nickel mining company asked for an $11 million loan from the Government to upgrade the facilities. In February, the loan was approved by the outgoing Government of the Philippines and, a few days later, by the new Government. On March 20, about 300 workers walked off the job demanding back wages of about $400,000. The company claimed that it could not pay the wages because the Government banks had not released the funds approved under the loan. Although the company and striking workers eventually agreed on terms for settling the strike, the workers refused to return until the company paid all back wages. In August, the company and the Government renegotiated for a $20 million loan so that back wages could be paid and facilities upgraded. Although the Government also approved this loan, it apparently would advance only $10 million. The operation remained closed at yearend while other sources of funding were being sought.

South Africa, Republic of.—The Republic of South Africa announced that it would impose tighter controls on material, such as cobalt, passing through the country for export from Zambia and Zimbabwe, two of the Commonwealth nations that had urged economic sanctions against the Republic of South Africa. The controls included export licenses, special levies, and stricter border control measures.

Wesplat officially opened its new base metal refinery at Marikana near Rustenberg, Transvaal, in December. The refinery had a production capacity of 100,000 pounds of cobalt.

Uganda.—Reports concerning the rehabilitation of the Kilembe Mine in Uganda reappeared. The Government of Uganda was reported to have earmarked $20 million for the rehabilitation of the former copper mines and for a new smelter.

Zaire.—Zaire again mined much more cobalt than it refined.

Reportedly, the European Economic Community (EEC) was to provide a loan of $41 million for the rehabilitation of Zaire's cobalt and copper production facilities. The EEC was apparently concerned about the recent decline in production. The money was to be used to replace obsolete equipment and to rebuild transportation links between plants.

Table 9.—Cobalt: World production, by country[1]

(Thousand pounds)

Country	Mine output, metal content[2]					Metal[3]				
	1982	1983	1984	1985[p]	1986[e]	1982	1983	1984	1985[p]	1986[e]
Albania[e]	900	1,000	1,300	1,300	1,300	--	--	--	--	--
Australia[e 4]	[5]3,262	2,540	2,380	1,830	1,940	--	--	--	--	--
Botswana	559	491	570	489	480	--	--	--	--	--
Brazil	NA	260	[e]220	220	330	--	--	--	--	--
Canada[6]	3,095	3,492	5,125	4,556	5,490	2,295	2,918	4,680	3,919	4,920
Cuba	3,306	3,573	3,079	[e]3,130	3,100	--	--	--	--	--
Finland	2,283	2,281	2,094	[e]2,100	2,100	3,207	3,417	3,203	[e]3,200	3,200
France	--	--	--	--	--	1,252	288	255	[e]240	220
Germany, Federal Republic of[e]	--	--	--	--	--	330	(7)	(7)	(7)	--
Japan	--	--	--	--	--	4,281	3,022	1,995	2,813	[5]2,949
Morocco	1,746	--	--	--	--	--	--	--	--	--
New Caledonia[e 8]	[5]597	880	1,100	1,490	1,540	--	--	--	--	--
Norway	--	--	--	--	--	2,184	1,937	2,625	3,608	3,480
Philippines	1,027	363	141	2,008	200	--	--	--	--	--
U.S.S.R.[e]	5,100	5,300	5,700	6,000	6,200	9,500	9,700	10,400	10,600	10,800
United Kingdom[e 9]	--	--	--	--	--	790	--	--	--	--
United States	--	--	--	--	--	1,016	205	--	--	--
Zaire	[e]24,900	[e]24,900	[e]39,700	[e]44,100	44,100	12,070	11,816	20,006	23,790	25,300
Zambia	7,167	7,052	10,185	12,786	12,700	5,392	5,306	7,654	9,609	[5]9,576
Zimbabwe	[e]220	[e]165	[e]165	[r e]220	220	216	160	171	202	200
Total	54,162	52,297	71,759	80,229	79,700	42,533	38,769	50,989	57,981	60,645

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

[1]Table includes data available through May 19, 1987. The units in this table have been 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, the Republic of South Africa, 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: 1982—7,821; 1983—5,041; 1984—4,700 (estimated); 1985—4,000 (estimated); and 1986—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]Revised to zero.

[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: 1982—4,702; 1983—6,929; 1984—9,025; 1985—11,433; and 1986—11,000.

[9]Estimated recovery of elemental cobalt in refined cobalt oxides and salts from intermediate metallurgical products originating in Canada.

TECHNOLOGY

The potential of spent catalysts as a source of cobalt and other critical metals was determined by Bureau of Mines researchers.[2] Characterization and hydrometallurgical research was conducted to devise procedures for recovery of cobalt and other metals from spent catalysts. The work focused primarily on the recovery of metals from spent hydroprocessing catalysts. Results showed that 99% of the cobalt could be recovered from cobalt-molybdenum catalysts by using a sulfuric acid leach process.

Inco was to reduce its sulfur dioxide emissions from 765,000 short tons per day to 290,000 tons per day by 1994 to meet stiffer Government-imposed regulations. Although some sulfur, as contained in the mineral pyrrhotite (an iron sulfide), was being removed from the ore magnetically, it was not sufficient to meet future standards. The company developed a new technique for separating pyrrhotite from the nickel minerals in the concentrator. Mill operators thus remove most of the sulfide before the concentrate reaches the smelter. The company began constructing a commercial-scale test circuit of the technique at its Copper Cliff mill with partial funding from the

Government of Canada under the Industrial and Regional Development Program.

Two companies were negotiating with the Montana College of Mineral Science and Technology to use their technology for recovering cobalt, nickel, and chromium from electroplating waste. The technique essentially involves precipitating the valuable metals from a waste stream as a phosphate. Beside providing an economic product from the waste, the process helps solve a potential disposal problem.

Developments in cobalt technology during the year were abstracted in Cobalt News, a quarterly publication available through the Cobalt Development Institute, 95 High Street, Slough SL1 1DH, United Kingdom.

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[1]Physical scientist, Division of Ferrous Metals.

[2]Siemens, R. E., B. W. Wong, and J. H. Russell. Potential of Spent Catalysts as a Source of Critical Materials. Conserv. & Recyc., v. 9, No. 2, 1986, pp. 1898-1996.

Columbium and Tantalum

By Larry D. Cunningham[1]

There was no domestic mine production of either columbium or tantalum minerals, and the United States continued to be dependent on imports. Imports for consumption of columbium mineral concentrates mirrored those of 1985, whereas imports for consumption of tantalum mineral concentrates were up significantly. Joint industry and Government panels conducted assessments of the quality and material form of both columbium and tantalum for the National Defense Stockpile (NDS).

Domestic production and value of ferrocolumbium increased modestly from those of 1985. Reported consumption of columbium in the form of ferrocolumbium and nickel columbium declined for the first time in recent years, with consumption in the major steel end-use categories and in superalloys down significantly. Reported shipments of tantalum products were virtually unchanged. However, sales of tantalum capacitors fell to the lowest level since 1982.

Columbium price quotations remained relatively stable, while tantalum concentrate prices continued to fall. World production of tantalum mineral concentrates declined substantially, owing to continued weak tantalum demand and cutbacks in countries where tantalum is produced primarily as a byproduct of tin mining. Net U.S. trade for both columbium and tantalum remained at a deficit.

In June, Thailand's new chemical plant for the processing of columbium- and tantalum-bearing materials was destroyed by fire after protestors demonstrated against the opening of the plant because of environmental concerns.

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 1986 to avoid disclosing company proprietary data.

Table 1.—Salient columbium statistics

(Thousand pounds of columbium content unless otherwise specified)

	1982	1983	1984	1985	1986
United States:					
Mine production of columbium-tantalum concentrates	(1)	--	--	--	--
Releases from Government excesses	--	--	--	--	--
Consumption of raw materials[e]	1,900	1,900	2,600	2,000	W
Production of ferrocolumbium	W	W	W	W	W
Consumption of primary products: Ferrocolumbium and nickel columbium[e]	3,679	4,318	5,399	5,968	5,069
Exports: Columbium metal, compounds, alloys (gross weight)[e]	100	100	100	120	120
Imports for consumption:					
Mineral concentrates[e]	580	730	1,790	1,290	1,320
Columbium metal and columbium-bearing alloys[e]	9	2	10	1	5
Ferrocolumbium[e]	3,128	2,539	4,343	4,699	4,332
Tin slags[e 2]	636	W	W	W	W
World: Production of columbium-tantalum concentrates[e]	r23,333	18,911	r32,831	r35,113	33,147

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]A small unreported quantity was produced.
[2]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)

	1982	1983	1984	1985	1986
United States:					
Mine production of columbium-tantalum concentrates	(1)	--	--	--	--
Releases from Government excesses	--	--	--	--	--
Consumption of raw materials[e]	800	900	1,300	1,100	W
Exports:					
Tantalum ores and concentrates (gross weight)[2]	235	121	156	122	71
Tantalum metal, compounds, alloys (gross weight)	382	211	352	369	392
Tantalum and tantalum alloy powder (gross weight)	115	123	151	143	160
Imports for consumption:					
Mineral concentrates[e]	440	180	680	230	280
Tantalum metal and tantalum-bearing alloys[3]	71	27	47	32	46
Tin slags[e 4]	576	W	W	W	W
World: Production of columbium-tantalum concentrates[e]	[r]626	690	[r]710	[r]697	394

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]A small unreported quantity was produced.
[2]Includes reexports.
[3]Exclusive of waste and scrap.
[4]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, 1986

(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.—The NDS goals and inventories for columbium and tantalum materials did not change during 1986, and there were no sales of stockpile excess materials. Under the offset concept, 57% of the goal for columbium concentrates and 37% of the goal for tantalum minerals were met (table 3). At yearend, the President's proposed modernization of the strategic and critical materials stockpile, announced on July 8, 1985, was still being considered by the Congress.

The American Society for Metals (ASM), with funding provided by the U.S. Department of Commerce and the Federal Emergency Management Agency, issued reports on the asssessment of the quality and material form of both columbium and tantalum for the NDS. The conclusions and recommendations contained in the reports were based on the findings of joint industry and Government panels assembled by ASM. The columbium study recommended that stockpiled columbium-tantalum source materials be classified as suitable for processing to produce columbium of the high quality required by user industries, and that stockpiled ferrocolumbium be retained principally for use as an alloying additive in high-strength low-alloy steels or as feedstock to produce columbium oxide. Stockpiled columbium metal powder was found to be unsuitable for producing aircraft superalloys owing to lack of control of undesirable elements, but the material could be upgraded to aircraft standard by electron beam melting.[2] The tantalum study found that stockpiled tantalum-columbium source materials were suitable for processing to produce the quality and form of tantalum required for capacitor and aircraft superalloy production. Stockpiled tantalum metal powder was acceptable for neither capacitor nor superalloy production, but the metal should be retained for the production of tantalum carbide.[3] In addition, both studies recommended that appropriate action be taken to assure that adequate quantities of columbium and tantalum, of the required purity, be made available in an emergency for the production of superalloys for the manufacture of high-performance turbine engine components.

DOMESTIC PRODUCTION

No domestic mineral concentrate production of either columbium or tantalum was reported in 1986.

Domestic production of ferrocolumbium, expressed as contained columbium, was up over 5% from that of 1985. Value of ferrocolumbium production increased to an estimated $10 million. The regular grade remained 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 down substantially. Consumption of purchased metal scrap was estimated at about 80,000 pounds.

Cabot Corp. completed most of the major restructuring program announced in 1985, which included the planned sale of all of its specialty metals businesses, except columbium and tantalum. In October, as part of the program, Cabot initiated a plan to incorporate the company's largest metals business, High Performance Alloys, as an independent company. Completion of the transaction is expected by midyear 1987, with Cabot retaining a sizable stake in the new entity.[4]

On February 28, International Minerals & Chemical Corp. acquired the Mallinckrodt Div. of Avon Products Inc. for $675 million in cash.[5] However, Mallinckrodt's columbium and tantalum raw material processing activity, which ceased operations at yearend 1985, remained suspended throughout the year.

Advanced Refractory Technology Inc. (ART) entered into a joint venture with Greenbushes Tin Ltd. to produce columbium and tantalum carbide powders, for worldwide sale, from oxides produced by Greenbushes in Australia. Commercial production of the powders was under way at ART's facilities in Buffalo, NY.

Table 4.—Major domestic columbium and tantalum processing and producing companies in 1986

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 Omicron Holdings Inc. and Hermann C. Starck Berlin KG.

CONSUMPTION, USES, AND STOCKS

Overall reported consumption of columbium as ferrocolumbium and nickel columbium was down 16%, a reversal of the upward trend in recent years. Consumption of columbium by the steelmaking industry decreased about 16%, influenced by a 7% decline in raw steel production, with a 9% decrease in the percent of columbium usage per ton of steel produced. Columbium consumption in carbon, stainless and heat-resisting, and high-strength low-alloy steels decreased more than 14% each, in line with production decreases in the major steel end-use categories.

Demand for columbium in superalloys was down about 16%. That portion used in the form of nickel columbium declined 17% to less than 450,000 pounds. Aerospace continues to be a promising major market for superalloys, with markets such as petrochemicals remaining flat.

Overall tantalum shipments were virtually unchanged, as reported by the Tantalum Producers Association. The powder and anodes and the mill products segments, which had experienced declines in 1985, were both up about 5%. Tantalum for cemented carbide was up about 40% after declining significantly in 1985. In contrast, tantalum as an alloy additive was down 21%, compared with a substantial gain in 1985. The demand for tantalum, which is highly resistant to corrosion by most acids, was expected to be stimulated by the chemical industry as more importance was being placed on chemical processing and related corrosion-resistant equipment. Also, tantalum was being investigated as a candidate for use in future armor-penetrating projectiles because of its good ductility, high density, and high-temperature strength properties.

Factory sales of tantalum capacitors declined 7% to the lowest level since 1982, as reported by the Electronic Industries Association. The downturn in the electronics industry, especially the computer and telecommunications sectors, which commenced in 1985, continued into 1986. In addition, industry sources reported that the amount of tantalum powder per capacitor continued to decline, owing to improved quality of powders and a trend toward smaller capacitors. In October, Union Carbide Corp. announced that its electronics components business was being offered for sale. The business manufactures and sells tantalum, ceramic, and film capacitors, with annual sales of about $200 million. Approximately 5,900 workers are employed worldwide, about 3,300 of whom are in the United States. Also, restructuring programs were being initiated and/or implemented at the Mallory Capacitor Co., Mepco/Centralab Inc., and Sprague Electric Co., all major domestic capacitor manufacturers.

Data on aggregate stocks of columbium and tantalum raw materials reported by processors for 1986 were incomplete at the time this chapter was prepared. Estimated aggregate stocks of columbium and tantalum raw materials reported by processors for yearend 1985 were both down from those of yearend 1984, by about 25% for columbium and by about 20% for tantalum.

Table 5.—Reported shipments of columbium and tantalum materials

(Pounds of metal content)

Material	1985	1986
Columbium products:		
Compounds including alloys	1,149,120	846,900
Metal including worked products	404,300	375,000
Other	300	--
Total	1,553,720	1,221,900
Tantalum products:		
Oxides and salts	27,600	19,910
Alloy additive	141,420	111,700
Carbide	90,210	127,000
Powder and anodes	459,800	482,900
Ingot (unworked consolidated metal)	220	8,600
Mill products	249,500	261,200
Scrap	48,300	7,600
Total	1,017,050	1,018,910

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]

	1985	1986
END USE		
Steel:		
Carbon	1,720,554	1,395,792
Stainless and heat-resisting	935,469	801,370
Full alloy	(2)	(2)
High-strength low-alloy	2,056,532	1,715,846
Electric	--	--
Tool	(3)	(3)
Unspecified	29,135	48,607
Total	4,741,690	3,961,615
Superalloys	1,204,249	1,008,364
Alloys (excluding alloy steels and superalloys)	21,716	18,813
Miscellaneous and unspecified	--	6,000
Total consumption	5,967,655	4,994,792
STOCKS		
Dec. 31:		
Consumer	W	W
Producer[4]	W	W
Total stocks[e]	720,000	780,000

[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

Published prices remained stable for pyrochlore concentrates and for columbium products based on them. Unchanged since April 1980, the price for pyrochlore concentrates produced in Canada continued to be quoted at $3.25 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 was unchanged, as in 1985, at $5.66 per pound of contained columbium, f.o.b. shipping point.

In mid-September, the quoted price for high-purity ferrocolumbium containing 62% to 68% columbium was lowered from $17.70 to a range of $17.00 to $17.50 per pound of contained columbium, f.o.b. shipping point. At the same time, the spot price for columbite concentrates fell from a range of $3.50 to $5.00 per pound of combined Cb_2O_5 and tantalum pentoxide (Ta_2O_5), c.i.f. U.S. ports, to a range of $2.00 to $2.50. Nickel columbium was reported to be selling throughout the year for about $17.00 per pound of contained columbium, and the selling price for columbium oxide remained at about $6.50 per pound of oxide.

The overall price for tantalite remained down. 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, started the year at $21.00 to $24.50, fell to $16.00 to $18.00 in late May, and then rose in the fourth quarter to finish the year at $18.50 to $25.00. The contract price for tantalite both from the Canadian tantalum producer, Tantalum Mining Corp. of Canada Ltd. (TANCO), and from Greenbushes of Australia remained suspended. Published price quotations for tantalum mill products and powders were unchanged, in the range of $100 to $160 per pound. The published price for tantalum carbide was being quoted at $52 to $54 per pound at yearend.

FOREIGN TRADE

Net trade remained at a deficit for both columbium and tantalum, but was at the lowest level since 1983. Trade volume was relatively unchanged for export items, with total value down by more than 10%. For imports, trade volume and value were down by more than 20%. Exports and reexports of tantalum ore and concentrates declined by 40% to 71,000 pounds valued at $360,000. The Federal Republic of Germany was the sole recipient.

The value of imports of raw materials and intermediates, such as ferrocolumbium and columbium oxide, exceeded the value of reported columbium and tantalum exports by more than 50%. Imports for consumption from Brazil included about 5.3 million pounds of ferrocolumbium with a value of $16.4 million, compared with 7.2 million pounds valued at $22.2 million in 1985. Imports for consumption of columbium oxide from Brazil increased substantially to 1.3 million pounds valued at $7.6 million, compared with 725,000 pounds valued at $4.7 million in 1985. Contained in the columbium oxide imports were an estimated 28,000 pounds of tantalum oxide valued at over $800,000, compared with an estimated

Table 7.—U.S. foreign trade in columbium and tantalum metal and alloys, by class

(Thousand pounds, gross weight, and thousand dollars)

Class	1985 Quantity	1985 Value	1986 Quantity	1986 Value	Principal destinations and sources, 1986
EXPORTS[1]					
Tantalum:					
Powder	143	15,188	160	14,172	France 45, $3,699; West Germany 34, $3,224; Japan 31, $2,893; Spain 16, $1,731.
Unwrought and waste and scrap	305	8,304	318	5,041	West Germany 260, $2,671; Japan 14, $1,114; Belgium-Luxembourg 31, $792; France 3, $173.
Wrought	64	9,339	74	10,391	Japan 25, $3,831; United Kingdom 17, $2,417; West Germany 11, $1,761; France 6, $925.
Total	XX	32,831	XX	29,604	Japan $7,800; West Germany $7,700; France $4,800; United Kingdom $4,100.[2]
IMPORTS FOR CONSUMPTION					
Columbium:					
Ferrocolumbium[e]	7,229	22,207	5,280	16,443	All from Brazil.
Unwrought metal and waste and scrap	8	31	8	56	Austria 5, $36; Japan 2, $10; United Kingdom 1, $7; West Germany ([3]), $3.
Unwrought alloys	([3])	2	4	87	Japan 1, $43; West Germany 3, $39; Canada ([3]), $5.
Wrought	([3])	8	1	31	All from West Germany.
Tantalum:					
Waste and scrap	134	5,518	119	3,764	West Germany 64, $2,496; Venezuela 21, $586; Belgium-Luxembourg 6, $278; Mexico 14, $187.
Unwrought metal	22	2,282	45	3,225	West Germany 36, $2,589; Belgium-Luxembourg 8, $501; United Kingdom ([3]), $77; Japan 1, $44.
Unwrought alloys	--	--	([3])	2	All from West Germany.
Wrought	9	254	1	7	Switzerland ([3]), $4; Canada 1, $3.
Total	XX	30,302	XX	23,615	Brazil $16,400; West Germany $5,200; Belgium-Luxembourg $800.[2]

[e]Estimated. 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	1985		1986	
	Gross weight	Value	Gross weight	Value
Canada	2,821	4,496	2,850	4,534
Netherlands[1]	--	--	2	4
Nigeria	77	177	2	2
Total[2]	2,899	4,673	2,854	4,541

[1]Presumably country of transshipment rather than original source.
[2]Data may not add to totals 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	1985		1986	
	Gross weight	Value	Gross weight	Value
Australia	150	2,032	--	--
Belgium-Luxembourg[1]	--	--	2	37
Brazil	231	2,262	146	994
Canada	233	2,553	186	2,119
French Guiana[1]	5	70	1	12
Netherlands[1]	--	--	256	1,846
Taiwan[1]	--	--	([2])	1
Thailand	60	502	--	--
United Kingdom[1]	--	--	202	1,330
Venezuela[1]	1	20	--	--
Zaire	57	748	111	1,374
Total	737	8,187	[3]905	7,713

[1]Presumably country of transshipment rather than original source.
[2]Less than 1/2 unit.
[3]Data do not add to total shown because of independent rounding.

Sources: Bureau of the Census and Bureau of Mines.

14,000 pounds valued at about $500,000 in 1985. 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 were virtually unchanged from those of 1985. Canada remained the leading supplier, providing almost all of both total quantity and total value. Imports were estimated to contain 1.17 million pounds of columbium and a negligible quantity 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 increased by more than 20%. However, average unit value for overall imports was down by more than 20%, owing to the continued depressed prices for tantalum ore. Imports from the Netherlands and the United Kingdom, nonproducing countries together providing about 50% of total quantity and 40% of total value, may have come from ore mined in Africa and/or Asia. Imports were estimated to contain 280,000 pounds of tantalum and 150,000 pounds of columbium at an average grade of approximately 37% Ta_2O_5 and 24% Cb_2O_5.

Data on receipts of raw materials other than mineral concentrates were incomplete.

Imports for consumption of columbium-tantalum synthetic concentrates were down substantially: 927,000 pounds valued at $3.5 million, compared with 2.75 million pounds valued at $18.4 million in 1985. These figures are not included in the salient statistics data.

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 1982, 1983, 1984, 1985, and 1986 was, in thousand pounds, 991, 1,049, 828, 877, and 622, 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 rose to 55 short tons from 22 tons shipped in 1985. Data were not available as to the disposition of the shipments.

Most tantalum is associated with tin, and developments in that industry will influence tantalum production. On April 1, the International Tin Council (ITC) officially ended all export and production controls for its 22 members. The ITC had already discontinued its tin price support operation in October 1985. The controls had been in effect since 1982 as a device to alleviate excess world tin supply. Accordingly, the end of the controls further depressed already low tin prices and caused significant cutbacks in tin production and/or mine closures in most African tin-producing countries, Malaysia, and Thailand, where tantalum is produced as a coproduct and/or byproduct of tin mining.

Australia.—For the fiscal year (FY) 1986, ending June 30, 1986, Greenbushes reported on a year of adjustment to the effects of the collapse in the tin price support scheme operated by the ITC and a continued weak tantalite market. The company reacted to these difficulties with a 40% cut in its mine work force and by switching to a higher tin grade in the ore mined and treated. Ore treated was 1.7 million tons in FY 1986, compared with 2.1 million tons in FY 1985. Tantalum oxide produced in concentrates was down to 95,700 pounds from 136,800 pounds in FY 1985. The chemical plant produced 20,400 pounds of Ta_2O_5 and 5,100 pounds of Cb_2O_5, compared with the 1985 totals of 40,100 pounds and 4,400 pounds, respectively. Tantalum oxide contained in tantalum glass production was down to 64,000 pounds from 74,100 pounds in FY 1985.

The joint venture between Greenbushes and Barbara Mining Corp. Ltd., a subsidiary of Bayer AG of the Federal Republic of Germany, reportedly is poised to develop the Bynoe tin-tantalum project located near Darwin. A pilot plant has operated on-site to confirm grades and metallurgical recoveries. Also, sufficient reserves have been delineated to support commercial production, which could commence with the improvement of tantalum prices.

West Coast Holdings Ltd. reportedly plans to conduct a full feasibility study on the construction of a plant at its Brockman multiminerals deposit in the Kimberleys, Western Australia. West Coast holds a 50% interest in Brockman. The remaining 50% interest is held by Greater Pacific Investments Ltd. West Coast expects the study to be completed by midyear 1987. Depending on a favorable outcome of the study, development of Brockman could commence in 1988. A throughput of 370,000 tons per year of ore could yield about 1,600 tons of Cb_2O_5, 100 tons of Ta_2O_5, and 460 tons of yttrium oxide. An estimated $46 million would be required to bring the project into production.

Promin Holdings Ltd. and Laser-Tech Australia Ltd. reportedly plan to invest $1.3 million to construct a tin smelter in Cairns, North Queensland. The venture, Queensland's first-ever regional smelter, will also produce byproduct columbium- and tantalum-bearing tin slags.

Brazil.—A bill before the Brazilian legislature would require at least a 51% Brazilian equity in all joint ventures with foreign firms involving minerals in the strategic category. The bill, said to be favored by the President of Brazil, covers development of columbium, tantalum, and other mineral deposits that are abundant in Brazil and considered vital to that country's industries and national security.

Late in the year, Brazil's Industrial Development Council approved a project by Cia. Brasileira de Metalurgia e Mineração (CBMM) to produce about 40 tons of columbium metal per year. CBMM reportedly plans to invest up to $6 million in equipment at its plant in Araxá, with production envisioned by 1990.

Brazil's total production and exports of all columbium products were 19,200 tons and 13,500 tons, respectively, compared with 19,500 tons and 16,000 tons, respectively, in 1985.

Canada.—The Niobec Mine at St. Honoré, Quebec, celebrated its 10th anniversary of commercial operation. The mine was explored and developed as a joint venture between Teck Corp. and the Société Québécoise d'Exploration Minière (SOQUEM), producing its first columbium concentrate in 1976. In early 1986, the government of the Province of Quebec transferred a substantial portion of the mining assets of SOQUEM to Cambior Inc., a new company based in Montreal. In August, Cambior negotiated acquisition of the SOQUEM assets, including the Niobec Mine, and the company was taken public. Hence, the Niobec Mine is now a 50-50 joint venture between Cambior and Teck.

Teck operates the mine through a subsidiary company, and Cambior is responsible for marketing and sales of Niobec's production. The mining and marketing operations are managed by a committee, with both parties equally represented.[6]

As reported by Teck for the FY ending September 30, production of columbium oxide at the Niobec Mine was up 17% to 7.5 million pounds, compared with 6.4 million pounds in 1985, with the mine operating at full capacity. Ore milled was up 13% to 846,389 tons from 745,724 tons in 1985; the mill operated on the average at 2,384 tons per day, virtually unchanged from the 2,382 tons per day in 1985. Recovery was 62.3%, slightly higher than the 61.7% in 1985, with the Cb_2O_5 grade of ore increasing to 0.72% from 0.70% in 1985. Ore reserves increased at the end of the FY to 12.2 million tons assaying 0.66% Cb_2O_5, compared with about 12.1 million tons assaying 0.66% Cb_2O_5 in FY 1985.[7]

The Hudson Bay Mining and Smelting Co. Ltd. continued to report that tantalum mining operations at the Bernic Lake, Manitoba, operation of TANCO remained suspended. Sales of tantalum concentrates by TANCO in 1986, as in 1985, were made from existing stockpiles. Although TANCO's tantalum operation remained closed, the company's ceramic-grade spodumene plant was brought on-line at the Bernic Lake site.

Highwood Resources Ltd. and Hecla Mining Co. of Canada Ltd. signed a joint venture agreement for the development of Highwood's Thor Lake beryllium, columbium, tantalum, and rare-earths deposit near Yellowknife, Northwest Territories. Under terms of the agreement, Hecla will earn a 50% interest in the project by reimbursing Highwood 50% of its prior expenditures, estimated at $6 million. Hecla also will provide financing necessary to bring the mine and related infrastructure into operation, estimated at $30 million. Contingent on favorable feasibility and marketing studies, production is expected to begin in 1988.

China.—First-phase development of the Yichu Mine in Jiangxi Province, which is slated to be China's largest producer of columbium and tantalum, was completed. The mine produced and dressed about 1,650 tons per day of ore. Columbite, tantalite, mica, and powdered feldspar from the mine were marketed domestically and exported. China could become a major world producer of tantalum ore. The Yichu deposits also have large resources of associated values of lithium, cesium, and rubidium.

China and Japan reportedly reached a 5-year joint minerals exploration agreement whereby the Ministry of International Trade and Industry's Metal Mining Agency of Japan (MMAJ) will assist China in exploration for rare metals beginning in early 1987. Exploration will take place in the Heilongjiang and Guangdong Provinces. MMAJ's requested budget for FY 1987 for the initial phase of the project was about $2 million.

Germany, Federal Republic of.—Bayer, an international chemical producer based in Leverkusen, acquired a 90% interest in Hermann C. Starck Berlin KG. Starck, a chemical and metallurgical company, manufactures and markets columbium, tantalum, and other specialty metals. Starck's activities include plants at Goslar and Laufenburg and a joint venture in NRC Inc., Newton, MA, a major U.S. producer of tantalum products.

Greenland.—Early in the year, the Geological Survey of Greenland announced that the assessment of geological data received during a 1980 survey of southern Greenland had led to the identification of a large columbium-tantalum occurrence. The occurrence was found during a reconnaissance exploration program involving airborne gamma-spectrometer and stream sediment sampling surveys. The mineralization, occurring as pyrochlore and columbite, is found within the Motzfeldt Centre, a major alkaline intrusive complex. The Centre is located about 9 miles from coastal areas and about 15 miles from the Narsarsuaq Airport, the main entrance to southern Greenland, and thus has access to infrastructure not available in most parts of Greenland. A conservative estimate of ore reserves was given at about 110 million tons grading a minimum of 0.3% Cb_2O_5 and 0.5% Ta_2O_5. Greenex A/S, Greenland's lead-zinc producer and newly acquired by Sweden's Boliden AB, was granted a license to explore the area further.

Japan.—Production of ferrocolumbium was 950 tons, down significantly from the 1,182 tons produced in 1985. Columbium ore imported for ferrocolumbium production declined to 1,820 tons, with Canada providing about 90%, compared with 2,176 tons in 1985. Ferrocolumbium imports fell by more than 30% to 2,122 tons compared with 3,163 tons in 1985. The bulk of imports continued to come from Brazil. Tantalum ore imports totaled 73 tons, compared with 244 tons in 1985; imports were distributed almost evenly among Brazil, Malaysia, and Rwanda.

The V Tech-Fansteel Inc. joint venture, formed in late 1985, started pilot production of columbium and tantalum products, with full production planned in 1987. The venture reportedly will initially serve the Far Eastern markets, and is intended to offset the depressed U.S. tantalum market caused by the growing import of finished components utilizing tantalum capacitors.[8]

Mozambique.—Mozambique's Mineral Resources Ministry reportedly was seeking financing for a detailed evaluation of the Inchope pegmatite in central Mozambique at yearend. A combined columbium and tantalum content of 0.02 to 0.04 pound per cubic foot was indicated. The prospect is located near the rail link from Beira to Zimbabwe, but the area is subject to anti-Government terrorism.[9]

South Africa, Republic of.—Late in the year, the Utah Mining Co., U.S.-based and Australian-owned, sold its controlling interests in the Southern Sphere Holdings and Tantalite Valley minerals prospecting companies in the Republic of South Africa. Severin Mining and Development Co., a South African firm, acquired the entire share capital of both Utah subsidiaries, and the company envisions the development of a tantalite deposit located in both the Republic of South Africa and Namibia, along the Orange River. To raise funds for the development of its newly acquired mineral deposits, Severin plans to seek listing on the Johannesburg Stock Exchange by midyear 1987. Utah's sale of the subsidiaries reportedly was not sanctions-related.

Thailand.—In the first part of the year, the Thailand Smelting and Refining Co. Ltd. (Thaisarco) tin smelter had been able to cope with the tin crisis and operate at a high rate by storing tin concentrates, paying advances to miners, and toll smelting. However, by yearend, Thaisarco reportedly was operating at about 50% of annual production capacity. Tin concentrate feed to the smelter had dwindled owing to continued low world tin prices and the closure of about one-half of Thailand's tin mines. The Thaisarco smelter has an annual capacity to produce about 700,000 pounds of tantalum contained in tin slags.

On June 23, a fire destroyed the newly constructed columbium and tantalum extraction plant on Phuket Island. The fire occurred after protestors demonstrated against the opening of the chemical plant because of environmental concerns over the plant's waste treatment facilities and acid storage areas. The facility, Asia's first, was owned by the Thailand Tantalum Industry Corp. Ltd. (TTIC). The plant's planned annual capacity was about 300 tons each of Cb_2O_5 and Ta_2O_5 and over 500 tons of potassium tantalum fluoride. This capacity would have represented a shift in the location of processing facilities to Thailand from Europe or the United States rather than an increase in world production. The facility was financed by the International Finance Corp., an affiliate of the International Bank for Reconstruction and Development (World Bank). Thai officials were concerned that the destruction of the plant could affect financing of other World Bank projects in the country. By yearend, the Thai Government had approved equity participation of about $7 million in the reconstruction of TTIC's plant. The equity interest represented about 20% of the plant's total project capital. The remaining capital would come from a 20-year soft loan and from existing TTIC shareholders. The Government would also participate in choosing a new site for the facility.

The MMAJ plans to build a test plant in Thailand, at the request of the Thai Government, to separate and extract columbium, tantalum, and other rare metals contained in waste derived from milling tin ores. The plant, planned for completion in the first half of 1987 at a site to be determined, will have capacity to treat 2 tons of waste per day. If tests are successful, Japan and Thailand will enter into a joint venture to construct a commercial plant, probably in 1989. Also, Thailand's Department of Mineral Resources and the MMAJ reportedly signed an agreement covering the second phase of exploration for columbium and

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]				
	1982	1983	1984	1985[p]	1986[e]	1982	1983	1984	1985	1986	1982	1983	1984	1985	1986
Australia: Columbite-tantalite	256	258	[r] [e]340	[r] [e]350	195	45	45	70	70	40	90	90	120	120	70
Brazil:															
Columbite-tantalite	443	582	375	400	400	97	134	86	90	90	130	170	110	116	116
Pyrochlore	43,195	37,099	66,330	70,550	65,920	18,142	15,582	27,860	29,630	27,690	--	--	--	--	--
Canada:[e]															
Pyrochlore	10,500	6,700	9,700	10,900	11,500	4,730	2,770	4,380	4,900	5,160	--	--	--	--	--
Tantalite	590	--	--	--	--	18	--	--	--	--	170	--	--	--	--
Malaysia: Columbite-tantalite	[r]15	148	99	176	165	2	22	15	26	25	1	10	7	12	12
Mozambique:															
Microlite	65	51	22	14	13	NA	NA	NA	NA	NA	33	25	8	7	7
Tantalite	48	31	15	9	9	NA	NA	NA	NA	NA	15	10	5	3	3
Namibia: Tantalite	20	6	15	10	11	5	2	4	3	3	6	2	4	3	3
Nigeria:															
Columbite	397	192	[e]265	[e]220	30	180	85	120	90	12	24	11	16	13	2
Tantalite	2	[e]2	[e]2	[e]2	--	(5)	(5)	(5)	(5)	--	1	1	1	1	--
Portugal: Tantalite	13	7	7	4	--	4	2	2	1	--	4	2	2	1	--
Rwanda: Columbite-tantalite	137	111	115	61	--	40	33	34	18	--	30	24	25	13	--
South Africa, Republic of:															
Columbite-tantalite	22	1	1	(5)	--	7	(5)	(5)	(5)	--	6	(5)	(5)	(5)	--
Spain: Tantalite	118	104	70	40	26	NA	NA	NA	NA	NA	[6]31	[6]33	[6]21	[6]10	7
Thailand: Columbite-tantalite	86	1,210	1,052	952	[6]269	15	205	180	162	46	20	278	284	257	73
United States: Columbite-tantalite	(7)	--	--	--	--	(7)	--	--	--	--	(7)	--	--	--	--
Zaire: Columbite-tantalite	132	112	220	408	265	36	30	60	110	70	37	32	62	110	75
Zimbabwe: Columbite-tantalite	79	5	130	88	[6]73	12	1	20	13	11	28	2	45	31	26
Total	[r]56,118	46,619	78,758	84,184	78,876	23,333	18,911	32,831	35,113	33,147	626	690	710	697	394

[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 31, 1987.

[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.

[7]A small unreported quantity was produced.

tantalum. The 3-year undertaking will cover about a 600-mile-square area in Chiangmai Province, northern Thailand, where traces of both minerals were found during the first phase of the project.

Zimbabwe.—Late in the year, the Zimbabwe Mining Development Corp. (ZMDC) acquired about a 91% interest in the Kamativi Tin Mines from the Industrial Development Corp. Kamativi had been experiencing serious financial difficulties since the collapse of ITC's tin price support operations. ZMDC's purchase of Kamativi, its only tin undertaking, added about 1,600 new employees to the company's work force.

TECHNOLOGY

The Bureau of Mines studied the availability of columbium from market economy countries. The study analyzed 19 deposits, 3 producers, and 16 nonproducers, in 7 countries.[10] The United States is a major world consumer of columbium products and is totally dependent upon foreign sources for all its columbium raw material supply. An economic evaluation was performed on each deposit to assess the production costs of recovering ferrocolumbium, the principal form in which columbium is consumed.

The Bureau investigated a columbium-bearing regolith on upper Idaho Gulch, near Tofty, in the Hot Springs mining district of Alaska.[11] The study was conducted as part of a Bureau project to assess columbium and certain other critical and strategic mineral occurrences in Alaska. The investigation indicated the presence of low-grade concentrations and minor resources of columbium, but no tantalum. The regolith contains approximately 340,000 pounds of columbium resources, 30,000 pounds indicated and 310,000 pounds inferred.

Greenbushes joined with Australia's Commonwealth Scientific and Industrial Research Organization in a prototype facility to test the feasibility of recovering small amounts of tantalum from normally unusable materials.[12] The facility consists of a superconducting magnet encased in a cryogenic container and a slurry-handling system. The operation filters tantalite particles from a fine slurry by exerting a magnetic force on the particles, causing them to cling to a mass of steel wires while the rest of the slurry passes on.

Leybold-Heraeus GmbH, Federal Republic of Germany, designed an electron beam (EB) melting furnace intended for commercial production of superalloys in volumes up to 4 million pounds annually.[13] The new design employs three EB guns with a power supply rated at 600 to 800 kilowatts. Based on company calculations EB melting is the most cost-efficient superalloy production method, at 16.17 cents per pound compared with 17.70 cents per pound for vacuum arc remelting.

In a short study, the properties and service requirements for implant materials were reviewed and several advantages of columbium as a metallic implant were considered.[14] The review concluded that dispersion-hardened columbium is biocompatible, strong, ductile, and favorable in cost relative to tantalum and other commonly used implant materials.

In an overview of the microalloying industry, the importance of columbium, vanadium, and titanium as alloying elements was discussed.[15] The sources of the elements were identified, along with an appraisal of the ability of producers to supply consumer needs. Historical consumption trends, supply-demand relationships, and recent technological developments in microalloyed steels were analyzed.

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Copper

By Janice L. W. Jolly[1] and Daniel Edelstein[2]

Benefiting from the cost-cutting efforts of the past several years, generally favorable labor settlements, and an improving market, several major U.S. copper-producing firms made a profit or were at a break-even point during 1986. Compliance with environmental regulations was still a problem for some companies, but in general, the mood of the industry was positive. Management and labor were conciliatory in their

Table 1.—Salient copper statistics

(Metric tons unless otherwise specified)

	1982	1983	1984	1985	1986
United States:					
Ore produced ---- thousand metric tons--	181,826	177,930	171,814	162,210	169,238
Average yield of copper -----percent--	0.55	0.51	0.58	0.62	0.62
Primary (new) copper produced:					
From domestic ores, as reported by:					
Mines	1,146,975	1,038,098	1,102,613	1,105,758	1,147,277
Value ---------- thousands--	$1,840,856	$1,751,476	$1,625,116	$1,632,483	$1,670,660
Smelters	940,547	888,130	989,924	[r]939,257	[1]908,087
Percent of world total	12	11	12	11	11
Refineries	1,050,445	1,028,423	1,089,584	1,003,636	[2]1,073,210
From foreign ores, matte, etc., as reported by refineries	176,333	153,667	75,016	53,529	W
Total new refined, domestic and foreign	1,226,778	1,182,090	1,164,600	1,057,165	1,073,210
Refined copper from scrap (new and old)	467,549	401,668	324,949	[r]377,457	406,222
Secondary copper recovered from old scrap only	517,726	449,478	460,695	[r]503,407	478,730
Exports:					
Refined	30,558	81,397	91,414	37,937	12,452
Unmanufactured[3]	344,669	239,190	317,167	435,069	442,441
Imports for consumption:					
Refined	258,439	459,568	444,699	377,725	501,984
Unmanufactured[3]	524,830	675,343	551,802	443,932	597,523
Stocks, Dec. 31: Total industry and COMEX:					
Refined	[r]695,000	[r]692,000	[r]564,000	[r]320,000	225,000
Blister and materials in solution	233,000	174,000	245,000	146,000	135,000
Consumption:					
Refined copper (reported)	1,658,142	1,803,931	2,122,732	[r]1,976,038	2,101,542
Apparent consumption, primary and old copper (old scrap only)	[r]1,762,385	[r]2,012,739	2,106,580	[r]2,144,360	2,136,472
Price: Weighted average, cathode, cents per pound, producers	72.80	76.53	66.85	66.97	66.05
World:					
Production:					
Mine ------- thousand metric tons--	[r]7,622	[r]7,662	7,974	[p]8,088	[e]8,156
Smelter ---------------do----	[r]7,951	[r]8,135	8,404	[p]8,584	[e]8,554
Refineries---------------do----	[r]9,002	[r]9,249	9,141	[p]9,405	[e]9,550
Price: London, high-grade, average cents per pound	67.14	72.13	62.45	64.27	62.28

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

effort to remain competitive with low-cost foreign producers in an international market subject to depressed prices; labor issues were solved without a strike for the first time since World War II. Despite the closure of several operations, mine production was moderately higher than in 1985 as the result of new lower cost electrowinning capacity, renewed production from mines in Michigan and Montana, and increased capacity at several operating mines. Restructuring of, and changes in, copper mine and plant ownership continued as several major companies moved to gain financial strength.

The competitiveness of the U.S. copper industry continued to be adversely impacted by the strengthening of U.S. and European currencies relative to currencies of the major copper-producing and exporting countries. The average copper price for 1986 in current U.S. dollar terms was the lowest since 1975.

U.S. apparent consumption of copper remained relatively high, while refined stocks decreased during the year. U.S. imports of refined copper reached a record-high level, nearly one-third higher than that of 1985. Exports of concentrates increased by 50%, and exports of unalloyed and alloyed scrap were also slightly higher. U.S. net import reliance[3] was virtually unchanged at 27% of apparent consumption. The domestic brass industry won several significant countervailing duty and antidumping suits during the year, forestalling increased erosion of its domestic market share.

Domestic Data Coverage.—Domestic production data for copper were developed by the Bureau of Mines from seven separate, voluntary surveys of U.S. operations. Typical of these surveys is the mine production survey. Of 73 operations to which a survey request was sent in 1986, 84% responded, representing an estimated 97.3% of the recoverable copper content in the total mine production shown in tables 6, 8, 9, and 31. Production for the remaining 12 copper companies was estimated using data from other surveys.

Legislation and Government Programs.—On October 17, Public Law 99-499, the Superfund Amendments and Reauthorization Act of 1986 (SARA), an act to extend and amend the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund), was signed into law. As provided by SARA, $2.75 billion for the 5-year Superfund funding was to come from petroleum taxes, $2.5 billion from a broad-based corporate tax, $1.25 billion from general revenue, $600 million from interest on the fund and from recovery of cleanup costs from polluters, and $500 million from a 0.1-cent-per-gallon tax on retail sales of motor fuel; the last was to be used specifically for cleaning up leaking pollution from underground fuel tanks. The 100 most hazardous substances found in Superfund sites, out of 717 previously identified by the Environmental Protection Agency (EPA), were to be ranked in 4 priority groups on the basis of chemical toxicity, frequency of occurrence at Superfund sites, and potential for human exposure. Copper and silver were included in the third group. Under section 110 of SARA, EPA and the Toxic Substances and Disease Registry Agency were to develop toxicologic profiles for all substances on the priority list. Toxicologic profiles for the first priority group were expected to be completed by October 1987. Under section 121, which addressed the cleanup standards for Superfund remedial actions, some new requirements were added by SARA; most significant of these was the emphasis toward risk reduction through destruction or detoxification of the hazardous waste, rather than through prevention of exposure achieved by various methods of containment.

In August, EPA issued its final rules on arsenic emissions from copper smelters under the Clean Air Act of 1970. It was anticipated that only ASARCO Incorporated's El Paso, TX, smelter would have to install new equipment to meet the standards. EPA prepared a document entitled "Summary Review of the Health Effects Associated With Copper: Health Issue Assessment" during the year, which discussed health effects associated with exposure to copper and some copper-related compounds in the ambient air.[4] A General Accounting Office report to the House of Representatives on sulfur dioxide emissions from nonferrous smelters was published in April.[5]

EPA submitted its report to Congress on wastes generated from the extraction and beneficiation of metallic ores on December 31, 1985. On the basis of this report, EPA published its regulatory determination as required on June 30, 1986; it determined that most mine waste is not hazardous and thus not regulated under the terms of subtitle C of the Resource Conservation and Recovery Act (RCRA). However, the agency stated that it would develop a program for regulating solid wastes generated by the mining industry under subtitle D, which deals with solid wastes; only if it appeared that a subtitle D approach was not applicable would a subtitle C regulation for mining wastes be developed. At yearend, EPA was proceeding with studies addressing the processing of certain ores and minerals and planned to submit a report to Congress on its findings by yearend 1987. Copper acid plant sludges were among six waste streams placed on a "fast track" study schedule. After these studies were complete and commented upon, EPA was to make regulatory determination within 6 months. EPA also issued land-disposal restrictions in late November for metal compounds contained in hazardous liquid wastes. The restrictions, mandated by the 1984 amendments to RCRA, were to become effective in July 1987.

At the request of the Congressional Copper Caucus, the Congressional Office of Technology Assessment (OTA) began a study of the competitiveness of the domestic copper industry. OTA was to identify technical and economic factors and to develop alternatives to help revitalize the copper industry.

U.S. Government efforts to establish an intergovernmental Producer-Consumer Forum (PCF) or study group for copper continued. A United Nations Ad Hoc meeting was held in December in Geneva, Switzerland, to discuss formation of such a study group.

Several copper industry mergers were allowed to proceed during the year under what appeared to some industry analysts to be a key change at both the Federal Trade Commission and the U.S. Department of Justice in the interpretation of the antimerger statute—section 10 of the Clayton Act, which was previously considered a deterrent to any combination that held a threat of significantly reducing competition. In assessing the legality of a merger in 1986, it was said, these agencies placed more emphasis on overseas competition. The rationale for the apparent change in interpretation was based on the supposition that if foreign producers were not a significant factor in the domestic market, but could be expected to move in if U.S. producers raised prices by about 5%, and if there were no significant additional problems, such as transportation or product acceptance, preventing domestic buyers from turning to foreign suppliers, there would be no antitrust problem. In addition, if one of the companies in the merger was faltering and no buyer could be found, a merger that formerly might have been considered unlawful, might now be allowed.[6]

The Department of Defense Authorization Act, 1987, Public Law 99-661, which included policy changes affecting the National Defense Stockpile (NDS), was signed into law by the President in November. Among the law's mandates was the requirement that a new position of National Defense Stockpile Manager be created in early 1987. NDS disposals were to be contingent on purchases, requiring incoming and outgoing transactions to balance. 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.

According to some analysts, the new income tax law passed in late 1986 was expected to be especially detrimental to the mining companies such as copper mining companies. Although the percentage depletion allowance for hard minerals was preserved, mining was expected to be adversely affected by cutbacks in deductions for research, exploration, and development costs and by additions to the preferences subject to the alternative minimum tax. The new tax law was said to sharply discourage capital expenditures for plant and equipment as a result of the elimination of investment tax credits and short-term depreciation deductions. Credits for research and development expenditures were reduced to 20% and were now applicable within a sharply narrowed definition. New tax rules for inventory and for taxation of credit for nonpaid bills also were expected to have substantial adverse impact on some producers. A minimum corporate tax of 20% was also set. One study indicated that as a group, mining firms will see their collective tax rate jump by about 29%.[7]

Beginning on December 1, as a provision of a budget reconciliation bill, Public Law 99509, which was signed into law in October, a 0.22% user fee was imposed on the customs value of all imports. This fee, set to remain in effect through fiscal year 1989, was designed to cover the U.S. Custom Service's operating costs. Imposition of the fee was not expected to impact the volume of imports, though industry representatives had mixed opinions as to whether the importer or consumer would bear the ultimate cost of the tariff.

DOMESTIC PRODUCTION

Mine and Plant Labor.—Productivity, in terms of metric tons of copper produced and average hour worked at copper mines and mills, was 17.7 hours per ton in 1986, up slightly from 17.0 hours per ton in 1985. The average number of copper mine and mill workers, including office workers, for 1986 was 10,154. A total of 20,326,091 hours were worked. U.S. Department of Labor statistics indicated the average number of employees at copper smelters and refineries was 5,400 workers in 1986; this compared with an average of 6,100 smelter and refinery employees in 1985.

Most copper mining labor contracts expired in June or July 1986, and for the first year since World War II, there was no strike coincidental with negotiations. Cooperation was the dominant mood. With bad times behind and uncertain times ahead, unions, workers, and companies made the necessary concessions to keep the mines operating. At Copper Range Co.'s White Pine Mine in Michigan, labor givebacks helped to keep copper production costs down. Wages at White Pine averaged $8.50 per hour plus profit sharing and productivity pay.

Newmont Mining Corp. was the first domestic producer to make a formal contract offer, seeking concessions averaging 20% overall. About 3,850 persons worked for Newmont's Magma Copper Co. at the San Manuel and Pinto Valley mining divisions. Newmont's new 3-year contract reduced the total labor costs at the two units to about $15.48 per hour, or $9.91 per hour plus benefits. The cost-of-living allowance (COLA) was also eliminated. Workers were to be entitled to a quarterly bonus pegged to the price of copper on a sliding scale and given as much advance notice as possible of plant closures. The trigger for the bonus scheme was to be 1-cent-per-pound rises in the Commodity Exchange Inc. (COMEX) spot prices over 70 cents. A major modification of work rules also was to reduce personnel requirements, cut labor costs, and improve productivity.

Kennecott workers voted to accept a new 4-year union contract that reduced wages and benefits by more than 23% but which was expected to create 2,000 jobs through the reopening of the Bingham Canyon Mine. The new contract included elimination of the COLA, a $1,000 bonus, and a commitment by the company to reopen the Bingham Canyon Mine in Utah unless the COMEX spot price for copper dipped below 55 cents per pound. Agreements were reached on local issues at Kennecott's Ray Mines Div. where about 725 workers were employed. Under the new contract, which runs through June 30, 1990, the average Kennecott worker will earn $10.52 per hour, compared with $13.74 per hour under the previous pact.

Asarco and Phelps Dodge Corp., when taking over Kennecott's Ray Mines Div. and Chino Mines Co., respectively, agreed to abide by the new 4-year labor contracts accepted by unionized workers at these mines in July, which called for an average cut in wages and benefits of $5.45 per hour. Except for the Chino and Tyrone Mines, where the labor contract was to expire in 1987, Phelps Dodge's operations were union free. The average wage for Phelps Dodge was reported as $12.50 per hour.[8] Assuming benefits were about 60% of wages, Phelps Dodge's average cost per worker would be about $20 per hour.

Asarco negotiated a 3-year contract with wage cuts that lowered the average to $10.06 per hour. Included were a first-year wage reduction of $3.50 per hour, suspension of COLA adjustments, and minor reductions in benefits. The contract also provided for a wage restoration of $0.75 per hour on July 1, 1987, and an additional restoration of $1.00 per hour on July 1, 1988. The United Mine Workers of America Union (UMWA) lost its bid to represent workers at Asarco's mine near Troy, MT. Workers at the Troy silver-copper mine voted 190 to 90 against joining the UMWA in July.

Unionized workers at Inspiration Mine's Globe-Miami, AZ, copper operation ratified a new 3-year contract, effective July 17, which reduced average hourly wages by 23%, or by $3.10 per hour; it also eliminated the COLA provision and provided for important adjustments in local work rules. The new pact also eliminated the old supplemental unemployment benefit and cut medical benefits. The pact included a wage restoration scheme tied to COMEX copper quotes.

Montana Resources Inc. (MRI), a subsidiary of Washington Corp. of Missoula, MT, indicated salaries at the Continental Mine, Silver Bow, MT, would average about $20,000 per year, or about $9.60 per hour plus a basic benefit package that included partially paid health insurance and paid vacations. Four local labor unions attempted to organize MRI workers following opening of the mine but were unsuccessful. MRI would not prenegotiate labor contracts, preferring that the unions organize according to National Labor Relations Board rules after the mine reopened and the workers were hired. Anaconda Minerals Co., the previous owner, held contracts with 13 unions, which were voided when its property was transferred to MRI in December.

Cost of Production.—The 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 56 cents per pound in 1986. When recovery of capital was included, the average production cost was 67 cents per pound. A number of major operating companies reported profits in 1986 despite an average producer's refined copper price of 66 cents per pound, which was the lowest average annual price reported in the past 10 years. By comparison, the average international copper production cost was estimated to be 65 cents per pound for 117 operating mines.

Mine Production.—Copper was mined in 12 States during 1986, with Arizona yielding 69% of the total, and New Mexico and Michigan in second and third places, respectively. The number of copper-producing mines was 87, up from the total of 68 mines in 1985. Of these, 61 were producing copper mines, and 26 were mines from which copper was produced as a byproduct of gold, lead, silver, or zinc. Total U.S. operating mine capacity, in terms of recoverable copper per year, was estimated to be 1.43 million metric tons, with 21 major producers accounting for more than 1.37 million tons. The Continental (East Berkeley) Pit reopened during the year; some new capacity was added at the Tyrone and San Manuel Mines; and some capacity was reduced at Inspiration, Sierrita, and several byproduct mines. Except for leaching, the Bingham Pit was closed until late in the year. Capacity utilization at operating mines was 81%.

Following the closure of the Twin Buttes Mine in late 1985, Anamax Mining Co. proceeded with the sale of its land holdings, buildings, and equipment. Anamax assets included thousands of acres along the Santa Cruz River, mining claims, and at least two large copper ore bodies with millions of tons of proven resources. Park Corp. planned to buy the Twin Buttes property from Anamax, after a tailings stabilization effort was completed, with the object of developing the site into an industrial park. Industrial Constructors Co., a subsidiary of Washington Corp. of Montana, was to stabilize a 1,100-acre tailings area at Twin Buttes; the project began in late March and was to continue through the spring of 1987.

In February, Atlantic Richfield Co., Anaconda's parent company, settled out of court its long-running dispute over mining taxes by agreeing to pay $14 million to the State and local governments during the next 7 years. The Montana State Revenue Department indicated that the review of Anaconda's books for the years 1972-82 was one of the largest audits in the State's history. The audit began in October 1983, 3 months after Anaconda halted mining operations at Butte. The State claimed Anaconda undervalued ore production and overstated expenses on reports filed with the State during the 10 years. However, the State was unable to prove that the company had willfully falsified tax returns.[9]

Andover Resources Corp. of Denver, CO, acquired rights to the Ferris-Haggarty copper mine near Encampment, CO. The mine had been closed since 1909. The company planned to put the mine back in operation within 3 to 4 years, creating about 200 to 300 jobs. Initial examination reportedly had determined sufficient reserves to make the mine profitable.[10]

Asarco reported that 1986 was its first profitable year since 1983. Earnings during the last half of the year counterbalanced substantial losses incurred during the first half. The company experienced an operating loss of $16.2 million, but after eliminating the accounting effects of foreign currency translation gains and nonoperating income from inventory sales and other transactions, net earnings for the year totaled $9.1 million. In addition to new 3-year labor contracts, which resulted in significant wage reductions, the company also sought and received substantial reductions in charges for transportation services and energy. In addition, a new sales organization was formed to market sulfuric acid, which was produced in substantial quantities as a byproduct of the environmental control systems at the company's smelters.[11]

Asarco had substantial interests in three of the world's largest mining companies: MIM Holdings Ltd. in Australia, Southern

Peru Copper Corp. (SPCC), and México Desarrollo Industrial Minero S.A. (MEDIMSA). Asarco and its associated companies together in 1986 accounted for about 8% of copper production in market economy countries.

In late 1986, Asarco purchased the Ray copper mine, electrowinning plant, and smelter from Kennecott, doubling Asarco's domestic copper mining capacity. These efficient mining properties represented an important strategic step for Asarco in assuring secure sources of material for the company's smelting and refining plants. With the purchase of Ray, Asarco expected to provide 60% of the copper concentrates required by its operating smelters. Asarco planned to increase mine capacity at Ray to 110,000 tons per year by yearend 1987. The Ray copper smelter had not operated since 1982, but the electrowinning plant was reactivated in late 1985. The Ray Mine concentrates had been processed at Asarco's Hayden, AZ, smelter since late 1983. Asarco paid Kennecott $72 million in cash plus participation by Kennecott in future revenues of the Ray unit resulting from copper price increases in excess of a COMEX price of 68 cents per pound. This participation was to be in effect for a 10-year period beginning in November 1988 and was limited to aggregate payments of $65 million.[12] Asarco expected to acquire the balance of the general partnership interest of Anamax in the Eisenhower property, as a result of Anamax's exercise of an option to terminate the partnership.

Reserves reported for Asarco's operating properties in 1986 were as follows:

State and property	Reserves (million metric tons)	Copper content (percent)	Silver content (troy ounce per ton)
Arizona:			
Mission Complex[1]	250	0.62	0.12
Ray	630	.71	--
Silver Bell	19	.68	.6
Idaho:			
Coeur	.6	.90	18.0
Galena[2]	941	.58	14.0
Montana: Troy	36	.75	1.4

[1]Includes only ASARCO Incorporated's share of reserves.
[2]Contains 10.04% lead and 0.11% zinc.

The Mission Complex comprised the Mission, Eisenhower, Pima, and San Xavier Mines, the ores from which were processed through the Mission mill. Eisenhower was a general partnership operated by Asarco.

The White Pine Mine of Copper Range went into production in June. Although most of the surface operations presented little problem, there was considerable preparatory work before underground operations began. Progress was made in improvement of mine efficiencies and production, so that by December, mine and mill tonnage had tripled, with mill recovery increasing by about 7.5% and concentrate grade improving by almost 3% since the mine started. Anode and cathode production was up to over 10 million pounds per month, and payments on the refinery lease were started. By December, production at the mine was about 13,600 tons per day. The goal for 1987 was to get the mine into full production. Production costs were 1% lower than they had been projected to be, and about 60% of the costs when the mine last operated in 1982. The startup agreement was predicated on a price for copper of 59 cents per pound.

At yearend, an annual distribution of about $5,500 per worker, including about 140,000 shares of stock in Copper Range valued at $24.40 per share, was made in the first payout under employee ownership. A similar distribution was to be made in each of the next 4 years. In addition to the stock, about $1 million in incentive pay to workers was to be paid at a rate of 50 cents per hour worked since January 1, 1986. In 1986, this amounted to about $1,250 for a worker who had worked the full year. The White Pine Mine had closed in 1982 during a strike, at a direct cost of about 3,000 jobs in Ontonagon County, MI, and the surrounding region. The unemployment rate in the county reached 30% in 1983. At yearend 1986, employment at the mine had reached 912 workers.

In a company report released at yearend,[13] Copper Range reported that the White Pine Mine, Michigan, was expected to have contributed $20 million to the economy of Ontonagon County, $12 million to Gogebic County, and $6 million to Houghton County during its first year. White Pine's impact was interpreted as going far beyond those figures; the 900 jobs created by the mine added almost $18 million to personal income, creating the need for 63 new retail establishments and 576 new nonmanufacturing jobs. About $13 million was spent on retail sales, according to economic impact formulas developed by the U.S. Chamber of Commerce. The report indicated that the mine paid $32.3 million directly to vendors in its first year of operation.

Cyprus Minerals Co.'s metals operating segment reported profits of $15.8 million in 1986, contrasted with 1985 losses of $33.3

million. The company's Bagdad copper-molybdenum mine was profitable for the second consecutive year. Costs at the Sierrita Mine, Arizona, which Cyprus acquired from Duval Corp. on March 31, while below 60 cents per pound, including byproduct credits, were somewhat higher than at Bagdad. Cyprus was profitable at all of its operations during the second quarter while molybdenum prices were up. By October, however, the molybdenum price had decreased, and the company reported a $9.5 million loss for the third quarter. Bagdad had a small operating profit, but Sierrita was operating at a slight loss. The company needed higher molybdenum prices to return to previous levels of profitability.

Significantly lower cost smelter tolling contracts had been renegotiated at both Bagdad and Sierrita with Inspiration Consolidated Copper Co. (ICC). Cyprus' tolling agreement with Newmont was also to continue in 1987, and additional tonnage had been added. A contract to sell concentrates to Nippon Mining Co. Ltd. of Japan in 1987 was canceled. Another contract, between Cyprus Bagdad Copper Co. and Mitsui Mining & Smelting Co. Ltd., had 2 years to run. Cyprus was marketing 20% to 25% of its concentrates overseas. The copper content of concentrates was 30% to 33% at Bagdad and 26% at Sierrita. Cyprus' molybdenum roasting contracts were also to expire in 1987.

Cyprus closed the Sierrita Mine on March 31 for an inspection-and-maintenance period, but rehired 200 workers by April 2. Increased stripping was not planned for 3 to 4 years at Sierrita. Cyprus' mining plan at Sierrita initially called for a 65% reduction in its 100,000-ton-per-year contained copper capacity. Later, however, Cyprus increased output from 50,000 to 63,500 tons per day, and recovery rose by about 10% to 15%.[14]

Cyprus was planning to produce 4,500 to 5,400 tons per year of cathode by solvent extraction at Sierrita. A leaching plant using Duval's CLEAR process that had produced a precipitate of nearly 70% copper at a cost of about 45 cents per pound was closed.[15] The company's solvent extraction-electrowinning (SX-EW) plant at Cyprus' Johnson Mine also was closed permanently at yearend. The current cathode production costs at the Bagdad SX-EW plant were estimated to be about 29 cents per pound without mining costs, and roughly 45 cents per pound when mining costs were included. Ore stockpiles from the Esperanza Mine were being leached at Sierrita.

Cyprus planned to reopen the Esperanza Mine in 1988. When operating, the mine had the capacity to produce 25,000 tons of copper annually, in addition to molybdenum concentrate. With the addition of Sierrita, Cyprus became one of the four largest copper producers in the United States and ranked among the three largest producers of molybdenum in the world.

The Exxon Minerals Co. announced at yearend it was shelving its permitting process for the Crandon Mine project in Wisconsin for an indefinite period of time.[16] The reason given was the long-range depressed forecast for the metal markets. The Crandon project team was to close its Rhinelander office early in 1987, although a small crew would remain to monitor ground water and wells and to maintain the Crandon office. The Wisconsin Department of Natural Resources Final Environmental Impact Statement was completed at yearend. Hearings on the report were to be held in March 1987.

In 1986, Inspiration Resources Corp. (IRC) made further progress in reducing operating costs and reported a profit of $37.8 million for the year. Cash costs for producing copper at the corporation's North American mines were reduced to below 60 cents per pound, according to the company annual report.[17] In the second quarter of the year, IRC's U.S. subsidiary, ICC, and its precious metals subsidiary, Inspiration Mines Inc., together reported an operating income of $3.3 million, against a loss of $4 million for the same period in 1985. The shutdown of the Inspiration, AZ, concentrator and switch to an all-leach copper production in January, and a credit of $3 million on the capitalization of exploration expenses and reduced depreciation charges due to restructuring provisions taken at yearend 1985 were credited with the positive income results. At mid-1986, the successful negotiation of labor contracts, which reduced average wages and benefits by about 23%, also contributed to a positive cash flow.

ICC produced 47,000 tons of copper, including 41,700 tons by the leach extraction method, according to the company annual report. Mine production at ICC's mine in Miami, AZ, was given as 9,513,000 tons of ore containing 0.574% copper. Large low-grade reserves at Inspiration of mixed chalcocite-chrysocolla ores prompted the company to develop the modified dump leach treatment used in 1986, known as the ferric cure process. This leach treatment included controlled leach pad construction of mine-run ore, followed by saturation and curing of leach pad heaps with sulfuric acid solution containing 2.5 grams of ferric iron per liter. The leach pads were then rinsed for 120 days to remove the copper values. About 60% of the copper was not acid soluble, but a 15-day treatment with the ferric solution prior to acid leaching resulted in 72% recovery.

Reserves at ICC's Inspiration Mine, a surface mine in Miami, AZ, were reported to be 111.3 million tons of leachable ore, averaging 0.57% copper; 117.2 million tons of sulfide ore, averaging 0.53% copper, was reclassified as inactive by the company. These reserves compared with 218 million tons of 0.53% copper ore reported in 1985. In addition, reserves in the underground mine, which had been closed since 1983, were given as 19 million tons of 1.84% copper.

In recent years, ICC discharged its electrowinning effluent into Webster Lake and was ordered by EPA to clean the lake, situated near the company's milling operations. EPA ordered the company to completely drain the lake and pump wastewater from the underlying aquifer, a task that the company considered uneconomical. Webster Lake contains about 1 billion gallons of acidic water, but the ground water volume in the aquifer under the lake was said to be enormous. The cleanup was to be finished by September 1986.[18]

ICC was the primary user of the 134-mile Southern Pacific Transportation Co.'s branch rail line that had been proposed for abandonment. ICC accounted for 98% of the traffic currently using the line. Joining ICC in protesting the railroad's application for abandonment of the line were the Arizona Department of Transportation, the cities of Globe and Miami, and the San Carlos Apache Tribe. Southern Pacific declared the primary reason for abandonment was that traffic on this line could no longer support the costs of operation and maintenance, and claimed the line needed about $40 million of track rehabilitation. The Interstate Commerce Commission issued a decision in June 1986 that Southern Pacific should not be permitted to abandon the Globe-Miami rail spur. The Commission found that the line posted an operating profit of $2 million in the succeeding 12 months. Southern Pacific appealed, but the judgment was upheld in September.[19]

Iron Mountain Mines Inc. planned to recover a wide variety of salts directly from a small copper-producing property near Redding, CA, using an in situ leaching and a hydrometallurgical processing plant designed by Davy McKee Corp. Cathode copper and copper sulfate, among the products indicated, were to be produced at the rates of 6 tons and 24 tons per day, respectively. Iron Mountain was currently recovering a small amount of copper from rainfall-induced seepage from old mine workings, but EPA was concerned about cadmium, zinc, and other metals left in the solution that Iron Mountain reportedly planned to recover.[20] At yearend, Iron Mountain was still seeking approval from EPA and State agencies for its plan, the Iron Mountain property having been listed on State and Federal Superfund toxic-waste-site lists.

British Petroleum Co. Ltd. (BP), which acquired a 25% interest in Standard Oil Co. in the late 1960's, held 55% of Standard Oil in 1986, and announced a plan to take 100% control of Standard Oil early in 1987. Standard Oil acquired Kennecott in 1981. Standard Oil reported an operating loss of $342 million for its metals mining segment (including foreign activities) in 1986; this compared with a loss (including unusual charges) of $851 million in 1985.[21] Results improved mainly owing to the decrease in losses and shutdown costs from Kennecott's Bingham Canyon Mine, Utah, most of which had been written down in 1985. The losses incurred in the disposal of the Ray and Chino copper mines were written down in 1986. Standard Oil's metal mining losses from Kennecott's operations had risen from $91 million in 1983 to $160 million in 1984 and $165 million in 1985. According to Standard Oil reports, $53 million was spent on the Bingham Canyon Mine modernization project in 1986, with another $171 million committed for equipment and supplies.

Kennecott began a 3-year, $400 million modernization program at its Utah Copper Div. that was expected to result in an annual copper production capacity of 168,000 tons, plus 260,000 troy ounces of gold, 2 million troy ounces of silver, and 8 million pounds of molybdenum per year. The decision to reopen the property depended upon successful completion of labor negotiations; these were completed at midyear. The modernization project was to provide in-pit crushing equipment and construction of new grinding facilities near the mine. Transportation improvements included a belt ore conveying system, and installation of pipelines between the new Copperton grinding and concentrating facilities and existing Arthur concentrator and Garfield smelter. The project was to use some of the largest crushing, conveying, and grinding equipment available and be capable of processing 68,850 tons of ore per day. Kennecott planned to include construction of a new concentrator east of the Copperton grinding mill. Under the original plans, the company was to improve existing flotation facilities at its Magna plant, which would receive ground ore from the new Copperton crusher via a pipeline. Instead, in the revised plans, concentrates would be transported from a new flotation mill at Copperton via pipeline to the smelter at Garfield, 13 miles north of Copperton. Rail ore haulage would cease.

Kennecott recalled workers in late August and September and started mining in October at Bingham Canyon. Initially, work involved extensive rehabilitation of equipment in preparation for startup. Bingham's concentrator was expected to start up in January 1987, and smelter and refinery operations were to resume later in the year. A production goal for mid-1987 was set at about 54,000 tons of ore per day. The modernization program was expected to be completed in 1988. By yearend 1986, 1,330 employees were back at work. At full capacity, the Utah Copper Div. was expected to employ 2,100 hourly and salaried employees.

Kennecott was to sell thousands of acres of land in the Lares-Utuado-Adjuntas area of Puerto Rico. Kennecott and AMAX Inc. purchased the land in the 1960's where known copper ore deposits were situated. Environmental and local political opposition reportedly delayed efforts by the company to develop these deposits.

Kennecott's problem with dust at its tailings pond north of Magna continued during 1986. The company was ordered by the Utah Air Conservation Committee (UACC) to prepare interim plans for controlling the dust until the startup of mine production in January 1987. The UACC gave Kennecott until May 1, 1987, to submit a revised plan for controlling dust during any future temporary shutdowns such as labor strikes or adverse economic conditions. A third plan, which had to be submitted to the UACC by January 1, 1988, was required for the anticipated permanent closure of the mine.

A loss of $20.2 million was attributed to Newmont's equity in Magma in 1986, down from $36.7 million for 1985, and $22 million for 1984.[22] In September, Newmont announced its intention to distribute as a dividend to its shareholders 80% of its equity in Magma, a wholly owned subsidiary. The dividend was to be declared on March 10, 1987. The corporation was to retain 15% of Magma's common stock, with 5% of the stock to be placed in an incentive plan for Magma's management team. The distribution was contingent upon Magma's having financed working capital and needed capital projects, including a new smelter and an expansion of its copper refinery. In October, the capital stock of Pinto Valley Copper Corp. was also transferred to Magma, becoming the Pinto Valley Div. of Magma. Magma's total indebtedness to Newmont, which was $346.1 million as of September 30, 1986, was canceled as part of the restructuring. Expenditures for the year included $37.8 million for development of the oxide mining and leaching projects, $34.3 million for purchasing copper and equipment from Pinto Valley, and $7.03 million for other capital expenditures. Revenues were $205.2 million and costs were $242.7 million, resulting in a net loss of $6.9 million.

Mining and leach production began during the year from the company's oxide ore body lying over the mined-out portion of the San Manuel underground mine. Magma planned expansion into in situ leaching of oxides in the caved subsidence area by 1988. Production of sulfide ore from the Kalamazoo ore body was scheduled to begin in 1989. Magma's current mine plan for the San Manuel-Kalamazoo underground mine is based on 141 million tons of sulfide ore reserves grading 0.77% copper. This tonnage was scheduled to last until late 1997. After 1997, it was expected that 257 million tons of sulfide ore containing 0.70% copper would remain, which could become economically feasible to mine with moderately higher copper prices than at present. Underground mine life could then be extended by up to 20 years. Magma planned to undertake a $200,000 study of the feasibility of leaching tailings at the old Miami open pit and underground mines. Previous work indicated a potential for recovery of 115 million pounds of copper over an 8-year period.

MRI purchased Anaconda's properties in Montana. Included were the 5,000-ton Butte underground mine, shuttered in 1975, and the 90,000-ton-per-year Berkeley open pit, closed in 1983. The Butte smelter and refinery were closed in 1980, and Anaconda shipped its copper concentrates to Japan. Mining started in mid-July 1986 from the East Berkeley Pit, or the Continental Mine, as the new owner called the property. Full production of 36,000 tons of ore per day was attained in September with a staff of 315 employees. At full capacity, MRI hoped to produce 180 tons of copper concentrates and 10 to 15 tons of molybdenum concentrates per day for shipment overseas. The copper concentrates were to go to Japan, the Republic of Korea, and Taiwan, and the molybdenum concentrates to the United Kingdom and Europe.

Six Japanese copper smelters concluded an agreement in June to import 100,000 tons of copper concentrates per year from the Continental Mine with a foreign exchange clause that protects them from a rise in the yen against the dollar. The contract was initially for 1-1/2 years, to the end of 1987. Shipment began in October. The smelters were Nippon Mining, Mitsubishi Metal Corp., Mitsui Mining, Sumitomo Metal Mining Co. Ltd. (SMM), Dowa Mining Co. Ltd., and Nittetsu Mining Co. Ltd. The Republic of Korea and Taiwan were also mentioned as possible recipients of the mine's concentrates. Molybdenum concentrates were to be recovered and sold in Chile, Europe, and North America.

The Montana State Board of Investments approved a $12 million loan package for MRI to finance resumption of mining operations in Butte. The board was to provide $8 million in coal severance tax trust funds, $3 million was to come from Midwest Federal Savings in Minneapolis, MN, and Northwest Bank of Butte, MT, was to supply another $1 million for the 5-year loan.[23] The State Department of Revenue approved MRI's application for a "new industrial" rate that was expected to drastically cut taxes on the Butte mining complex. Under this classification, the State taxed local mining properties at about one-third the normal rate. The tax was to be at 3% of the market value, reducing MRI's tax to about $1.1 million for 1986. The tax incentive was to remain in effect for 3 years.

Reserves at the Berkeley open pit totaled 328 million tons of ore averaging 0.59% copper. Reserves at the Butte underground mine totaled 75 million tons of ore containing greater than 1% copper. Gold and silver byproducts represented 15% of the total revenues derived from the mine. Molybdenum was an important byproduct from the Continental Mine.

A cost breakdown provided by the company prior to reopening estimated 7% for taxes, 15% for employee wages and benefits, 12% for energy, and 27% for freight and smelting. The company based its budget on a copper price of 65 cents per pound. The copper price was lower than this at yearend, but the price of molybdenum was well above the mine's break-even price of $2.00 per pound.

Phelps Dodge reported net earnings of $61.4 million, a little more than double the company's earnings in 1985. This was achieved despite the failure of copper prices to rise significantly during the year. This success underscored the success of the productivity improvement programs implemented by the company since 1984. As a result, earnings from the primary metals business improved to $68.8 million, compared with $62.0 million in 1985 and an operating loss of $211.1 million in 1984. The company reported that in 1986, the unit production costs per pound of copper were one-third lower, without adjustment for inflation. Adjusted for inflation, production costs were roughly 44% lower than in 1981.[24] Miscellaneous income for 1986 included $7 million from the sale of one-half the Cayeli Bakir Isletmeleri AS zinc-copper deposit in Turkey to Metallgesellschaft AG and also reflects an $8.2 million writeoff of the corporation's Douglas, AZ, copper smelter, which was to be closed in January 1987. About $5.7 million was received in dividends from the company's share in SPCC of Peru. The company's long-term debt was down to $419.7 million, the lowest level since 1974. Phelps Dodge announced in November that it would move its headquarters to Phoenix, AZ, by May 1987. A 20-member sales staff was to remain in New York City.

The U.S. Department of Justice ruled that Phelps Dodge must pay a $1 million penalty for water pollution violations and spend more than $8 million to construct a water-control system at its Morenci, AZ, mine. The decision was a result of an EPA complaint filed in May 1985. EPA alleged that mine tailings and low-grade sulfide ores dumped on the Morenci property had infiltrated Chase Creek and the San Francisco and Gila Rivers, contaminating the area with cadmium, copper, lead, magnesium, and zinc. Phelps Dodge also paid a $50,000 fine to the State of Arizona. In addition, the company agreed to build a $9 million flood control system consisting of a dam and three reservoirs on Chase Creek and a dam and reservoir on Gold Gulch, which flows into the Gila River. If not completed within 15 months, the company was to pay penalties of up to $3,000 per day.

In early February 1986, an agreement was signed between SMM of Japan and Phelps Dodge for joint operation of the Morenci copper mine in Arizona. According to the agreement, SMM and Sumitomo Corp. (SC) were to invest a total of 15% in equity, or $75 million, in the Morenci copper operations, with $50 million provided by SMM and $25 million by SC. To oversee their 15% management participation, Sumitomo Metal Mining Arizona Inc. (SMMA) was established, with 75% owned by SMM and 25% by SC. In return for 15% equity participation, SMM will take 15% of copper output from Morenci over a 20-year period. The first shipment left for Japan in April 1986.

In December, Phelps Dodge purchased Kennecott's two-thirds interest in Chino Mines. With the expected cessation of conventionally produced copper at the Tyrone Mine in the early 1990's, the company's balance between mining, smelting, and refining capacity was underscored. Acquisition of Chino Mines provided additional smelting and mining capacity. Chino had reserves for at least 20 years at current production levels and considerable capital has been expended to make it a modern state-of-the-art mining and smelting complex. Phelps Dodge paid $88 million cash; in addition, the company expected to invest about $20 million at the mine to continue modernization. Mitsubishi Metal retained a one-third interest in the mine.

According to its annual report to stockholders, Phelps Dodge's domestic mines and related facilities produced a record high 401,000 tons of copper in 1986, 367,000 tons on the company's own account, and the balance for SMMA, representing its share of Morenci production, down slightly from that of 1985, but nearly double that produced in 1983.[25] Precipitate production at Bisbee, Morenci, and Tyrone amounted to about 36,500 tons. Electrowon production at Tyrone increased from about 10,300 tons in 1984 to about 32,000 tons in 1986 with expansion of the plant operated by Burro Chief Copper Co., Phelps Dodge's subsidiary. The average grade of ore mined at Morenci was 0.84% copper and the average at Tyrone was 0.86% copper. Byproducts included gold, molybdenum, silver, other metals, and sulfuric acid. The copper production reported above did not reflect Phelps Dodge's interest in the Chino Mines.

Phelps Dodge expected to modify the Chino operations to increase production and productivity. Some notable improvements had already been made by Kennecott and Mitsubishi Metal, such as the new concentrator near the Santa Rita Mine (1983) that produces 40,000 tons of ore per day; the old one, situated near the smelter and served by train, was no longer in use. A pilot plant operation at Chino indicated that the amount of ore handled at the new concentrator could be increased by 1,800 to 3,600 tons per day by adding a small grinding plant to operate along with the two big semiautogenous grinding mills. The mill was to treat as much as 43,600 tons per day with the modification. This expansion was expected to cost about $3 million. The stripping ratio between waste and ore at Chino's Santa Rita Pit was about 2-1/2 to 1. Phelps Dodge planned to install a new in-pit crusher to be used to process the chalcocite ore (0.20% to 0.45% copper) for leaching. This type of leach material was to be segregated for use in a new SX-EW plant, which was in the late planning stages. The ore was to be transported from the in-pit crusher through a pass at one end of the pit by use of a belt conveyor system. The average cost to produce cathode copper was expected to be about 63 cents per pound, but was expected to be reduced with the introduction of minor improvements, such as increased truck loading, and some major ones, such as the solvent extraction circuit described above.

At Morenci, AZ, mining was being done at only the Morenci Mine, but both the Morenci and the Metcalf concentrators were being used. Mine capacity was limited by the two mills, which were fed from the mine by train. Two used ball mills were installed at one of the Morenci concentrators in 1986, increasing throughput at a modest cost per ton. Plans were to install an in-pit crusher and construct a conveyor system from the mine that will bypass the primary crusher associated with the Morenci mill and greatly increase the mill throughput. Molybdenum-bearing concentrates from the mine were treated only at the Metcalf mill. The company was planning to mine the Western Copper deposit, which lies between the Morenci and Metcalf properties; stripping was to start in 1990.

Phelps Dodge purchased twenty-nine 170-ton trucks and converted the Morenci Mine from rail mining to truck mining, giving the mine more operating flexibility, eliminating the substantial expense of building and maintaining temporary track, and lowering unit costs. Costs were also lowered by reducing staff by 45%, saving overhead costs of roughly $10 million annually. Haulage trucks at Chino, Morenci, and Tyrone were controlled by computerized dispatching systems, pioneered at Tyrone, which substantially improved haulage efficiencies.

Copper ore reserves at each of Phelps Dodge's mines and at its Safford and Western Copper deposits at yearend 1986 were estimated by the company as follows: Morenci (85% basis), 612 million tons with an average grade of 0.77% copper; Safford, 210 million tons with an average grade of 0.89% copper; Ajo, 190 million tons with an average grade of 0.50% copper; Western Copper property, 142 million tons averaging 0.64% copper; Chino (66% basis), 221 million tons with an average grade of 0.72% copper; and Tyrone, 125 million tons with an average grade of 0.79% copper. In addition, the company owned the Copper Basin property southwest of Prescott, AZ, which was estimated to contain 159 million tons averaging 0.55% copper and 0.021% molybdenum. Reserve figures for Morenci and Tyrone include copper estimated to be recoverable through leaching.[26] Reserves at Morenci and Chino do not include the 15% and one-third interests in the mines owned by SMMA and Mitsubishi Metal, respectively.

Tennessee Chemical Co. operated one underground mine (Cherokee Mine), an ore beneficiation plant, and a metallurgical-chemical complex. The underground Boyd Mine was closed in 1981, the Cherokee open pit mine was shut in January 1982, and the Calloway Mine was closed in 1985. The company planned to cease all mining in the summer of 1987. The sulfur content of the ore is more than 20%; from this ore, Tennessee Chemical extracts pyrite and copper concentrate, which are roasted to produce sulfur dioxide, iron oxide, and crude copper oxide.

Smelter Production.—Primary and scrap smelter production decreased in 1986 compared with that of 1985. Nine primary smelters with a combined capacity of 1.1 million tons operated during the year. In addition, seven secondary smelters with a combined capacity of 208,000 tons operated. One primary smelter began operation during the year, and one was scheduled to close in January 1987. One secondary smelter operated only intermittently as cleanup efforts in preparation for permanent closure proceeded.

U.S. Metals Refining Co., Carteret, NJ, a wholly owned subsidiary of AMAX, announced that it would begin in January 1987 to demolish most of its plant facilities in Carteret, NJ, in order to make way for a proposed $150 million real estate development project, which called for construction of a deepwater port, warehouse space, and a marina. Most of the smelter operations at the site were halted in 1986 after extensive legal battles with New Jersey and New York environmental authorities. A representative for AMAX Specialty Metals Corp. indicated that production of oxygen-free, high-conductivity (OFHC) copper from purchased cathode would be continued there. Accused of polluting the air with benzene, dioxin, and lead, the company paid a fine of $215,300 to the New Jersey Department of Environmental Protection and made a separate payment of $75,000 to New York State for lead pollution cleanup in Staten Island.

EPA charged Atlantic Richfield Co. (ARCO) and Cleveland Wrecking Co. in September with violating the Clean Air Act and national standards for asbestos emissions at the Anaconda smelter. The complaint, filed in September, sought civil penalties that could amount to more than $10 million. Cleveland began demolishing the smelter under contract with ARCO in 1982 and finished the job in June 1986. The complaint claimed that the two companies had repeatedly violated the National Emission Standard for Hazardous Air Pollutants (NESHAP) since 1983. Demolition of the smelter involved removal and stripping of friable asbestos, subject to NESHAP regulations. EPA charged the company did not remove the asbestos materials before dismantling the flue, failed to "carefully lower" the components covered with asbestos to the ground, and the material was not kept wet until disposal. The same violations reportedly were committed in dismantling the mill.[27]

Asarco reported blister copper capacity at its three smelters to be 363,000 tons per year, with 104,000 tons at El Paso, 159,000 tons at Hayden, and 100,000 tons at the Ray smelter. About 260,000 tons of blister was reported as produced in 1986 at the two operating smelters.[28] In addition to mining and treating ore from its own mines, Asarco was a custom smelter and refiner of nonferrous metal ores mined by others. Ores and concentrates purchased from others or processed for them on toll accounted for about 86% of the silver, 88% of the copper, and 81% of the lead produced by Asarco's primary plants.

About 88 workers were employed at the Asarco smelter in El Paso, TX, down from 172 previously employed. The smelter could process copper concentrate containing an average of 27% copper at the rate of 27,000 tons per month. There were two acid plants at the smelter, and the smelter was in compliance with air standards. Environmental controls and measures had reduced its effective capacity. Smelter slag was sold to companies for use as ballast, rock wool manufacture, decorative material, and as a cinder for a racetrack. Asarco's purchase of the Ray Mines Div. from Kennecott also included the Ray smelter, which was closed in 1982 and was adjacent to Asarco's own smelter at Hayden, AZ. Should conditions in the markets for concentrates and copper metal warrant, the Ray smelter was capable of treating up to 363,000 tons of copper concentrates per year. The Ray smelter was modern and cost-efficient and complied with environmental regulations when it last operated in 1982, according to the Asarco 1986 annual report.

Production at Asarco's modernized Inco flash copper smelter at Hayden was 66% greater than in 1982, the last full year of operation prior to installation of the new oxygen flash furnace, despite a 3-week shutdown in February to repair furnace brickwork. The furnace was to be shut again late in the first quarter of 1987 for modifications expected to cost $1.5 million, but which were expected to extend furnace refractory life, increase throughput, and lengthen the periods between maintenance shutdowns. Hayden's 1986 output of copper anodes was shipped to the company's Amarillo, TX, copper refinery.

The No. 2 reverberatory furnace at the White Pine Mine, Michigan, was lit in April; anode casting began on May 15; and processing of the first anodes in the tankhouse began on May 27. The White Pine smelter reportedly was in full EPA compliance, but utilized gas scrubbers and did not have an acid plant.

ICC continued to operate its smelter at full capacity, treating purchased and tolled concentrates, although it planned to keep its sulfide mill and concentrator at Globe, AZ, closed indefinitely. Contracts signed in 1986 were expected to ensure ICC sufficient concentrates to meet its smelter requirements over the next several years. The plant processed about 345,000 tons of concentrate in 1986 and arranged for enough feed to meet requirements for the next 3 years; ICC's major concentrate contracts were with Cyprus and Phelps Dodge. ICC planned to install a new anode casting facility and air-to-gas coolers on the smelter's converters next year, which along with labor-cost cuts was expected to raise profitability. Unlike many of its competitors, ICC had not had to make substantial capital expenditures to upgrade its smelter to meet regulatory requirements. The smelter already complied with the Clean Air Act standards that took effect in January 1986.[29] Even so, ICC was charged with failing to comply with State emissions regulations by not conducting a sulfur dioxide fugitive emissions study of its copper smelter.

Magma's plans for reducing the company's average net operating costs from 70 cents per pound in 1986 to 45 cents per pound by 1989 included retrofitting the San Manuel, AZ, smelter to comply with EPA air quality regulations. About $30 million was to be spent on a new oxygen plant, mill modernization, and expansion of the refining capacity. The new flash smelter, from Outokumpu Oy of Finland, was to cost $127 million and have an increased input capacity of 2,700 tons of concentrates per day. One-third of this capacity was to be used to toll smelt 300,000 tons of Cyprus' concentrates per year, under a 10-year contract. The EPA and the State agreed to permit Magma to smelt at current levels until November 1, 1988, the expected completion time of the retrofit.

Outokumpu signed a $20.4 million contract to sell licensing rights, equipment, and machinery to Magma for modernization of the San Manuel copper smelter. Magma was to use Outokumpu flash smelter technology, the second plant in the United States to use it, the other being the Phelps Dodge smelter at Hidalgo, NM. Outokumpu was to supply flash furnaces, gas cleaning equipment, and electrical filters for the plant, which would produce 270,000 to 300,000 tons of blister per year.

Production at Phelps Dodge's smelters was reported to be 266,440 tons, lower than the 280,800 tons reported as produced in 1985. The corporation's Ajo, AZ, smelter had been shut since April 1985. The Douglas, AZ, smelter was expected to be shut permanently in January 1987 as a result of a four-way agreement signed in July by Phelps Dodge, the U.S. Department of Justice, the State of Arizona, and EPA to limit sulfur dioxide emissions at Phelps Dodge's Douglas smelter.[30] Regulatory agencies considered the Douglas smelter a major source of air pollution in the area. The shutdown agreement, which allowed the smelter to reopen following a 3-week shutdown, required the company to pay $400,000 for past violations of Federal sulfur dioxide emission standards and provided for additional fines of $100,000 for each succeeding violation to date of closure. All the concentrates that had been going to the Douglas plant were to be tolled or sold in the free market. Most of the feed had come from the Morenci Mine. Some of the concentrates were to be diverted to the newly acquired Chino Mines smelter. The company planned to transfer compatible equipment to other operations but would sell the rest.

Phelps Dodge invested $37 million at its Hidalgo smelter for an overhaul and for installation of oxygen-enrichment facilities for the Outokumpu flash furnace. A 3-year-old oxygen plant was removed from Morenci and reinstalled at Hidalgo. The Hidalgo smelter uses an Outokumpu flash furnace that enables the plant to meet air quality standards. Most of the Outokumpu furnaces include an oxygen enrichment plant, but one had not been installed with the Hidalgo plant when first built. Capacity at Hidalgo was expected to be increased by about 21%, from the present 700,000 tons to about 850,000 tons of concentrate per year. Anode production was expected to be about 30,000 to 35,000 tons per year. The company planned to also increase the capacity of its newly acquired Chino Mines Inco flash furnace by use of additional oxygen. The results were expected to reduce energy usage, increase efficiencies and reliability, and lower unit costs.

In early February, Chino began shipments of its first anodes from the new anode refining-casting plant. By eliminating the old fire refinery and replacing fire-refined metal with anode copper, Chino hoped to take advantage of larger markets for anode. Chino acquired the anode wheel, anode refining furnace, and controls from the dismantled Anaconda smelter in Montana.

Refinery Production.—Refinery production remained at about the same level as that of 1985, even though new capacity had been added, owing to the continued shutdown of Kennecott's refineries, and to the permanent shutdown of AMAX Copper Inc.'s facilities in Carteret, NJ. New production was added from renewed activity at the White Pine plant and from several electrowinning plants. During 1986, 24 refineries operated, including 8 electrolytic, 10 electrowinning, and 9 fire-refining facilities. Several companies did more than one type of refining and processed both primary and secondary materials. An analysis of trends in composition of refinery production feed materials indicated a distinct change in the amount of foreign and scrap materials being processed by U.S. refining plants over the period 1940-86. Since 1940, the proportion of scrap being refined has increased significantly, while the foreign component (as estimated at smelter level) has decreased in near equal magnitude. In 1941, 28% of refined cathode was derived from foreign materials, while about 8% was from scrap. In 1986, less than 4% was from foreign material and 31% was from scrap. The changeover occurred in 1964, the last year in which foreign materials exceeded the tonnage consumed in scrap at refineries.

Most secondary refining in 1986 was being done at three large electrolytic plants by Cerro Copper Products in Illinois, Nassau Recycling Corp. in South Carolina, and Southwire Co. in Georgia. In addition, fire refining of scrap was being done by Cerro Copper in Illinois, Warrenton Refining Co. in Missouri, Essex Group in Indiana, Phelps Dodge in Texas, Reading Metals Inc. in Pennsylvania, and several smaller plants. Secondary refining ceased at Chemetco Metals Corp. in 1984, and at AMAX's New Jersey plant in early 1986. Increased refining of scrap since the late 1960's was necessitated by the requirement for high-purity copper by the wire and tube industry. A general shortage of foreign concentrates, blister, and anode for processing in the United States also resulted because of new processing capacity constructed in Far East countries, and in Chile, Mexico, and Peru, which were principal sources of U.S. imports of mine and smelter products for further processing.

Asarco planned to spend about $1.1 million to modernize the SX-EW plant at the Ray Mine, Arizona, which it had recently acquired. This was expected to increase the plant's capacity from 29,000 to 36,300 tons of electrowon cathode per year, eliminate the existing precipitation plant, and further reduce the already low production costs. At yearend, refined copper capacity was estimated to total 443,000 tons at Asarco's Amarillo, TX, (414,000 tons) and Ray's SX-EW (29,000 tons) refineries. A record high of 400,000 tons of refined copper was produced at the Amarillo refinery, according to the company annual report. In 1986, 12% of the copper refined was from Asarco's own mines, 67% was custom refined, and 21% was toll refined.

The first cathode shipment from the White Pine, MI, refinery took place on June 27. Copper Range leased the refinery from The Louisiana Land and Exploration Co. (LL&E) with an option to buy through 1988. Since its construction in 1982, the 54,000-ton-per-year refinery had been operated principally with scrap as a raw material in anticipation of the mine reopening.

According to IRC's annual report for 1986, the corporation produced 73,870 tons of refined copper at its refinery in Miami, AZ, down from 76,255 tons reported for 1985. Kennecott sold its Baltimore, MD, copper refinery and rod mill at yearend to Cox Creek Refining Co. The 197,000-ton-per-year rod plant was closed in May 1985, and the 200,000-ton-per-year refinery was shut in June 1983. Startup of the facilities by Cox Creek was anticipated for late 1987.

Magma began production from its new 22,000-ton-per-year electrowinning plant at San Manuel, AZ, at midyear. Following a successful 1986 test program and armed with 20 years' experience of in situ leaching of the old Miami, AZ, underground mine, Magma planned expansion of electrowinning by in situ leaching of oxides in the San Manuel, AZ, caved subsidence area in 1988. The initial production rate was to be 25,400 tons of copper per year, increasing to 51,000 tons per year by 1990. Costs were expected to be lower than pad leaching costs, which in 1986 were only one-half the underground mining costs.

Noranda Lakeshore Inc. was well under way with its innovative in situ mining development. Production from its electrowinning plant continued during the year.

Production at Phelps Dodge's refinery in Texas, including toll production, was reported in the company annual report to be 330,000 tons, down slightly from that of 1985. Most of Phelps Dodge's refined copper, and additional copper purchased by the company, was cast into rod. Rod sales to outside wire and cable manufacturers constituted 66% of the company's primary metals sales in 1986. Phelps Dodge also sold a small portion of its refined copper as refinery shapes and as oxygen-free copper.[31] OFHC was also produced. In addition, a small fire-refining line was operated irregularly for processing No. 1 runaround scrap from the wire mill and some purchased scrap into electrolytic-grade ingot and wirebar. Fire refining for wirebar was not expected to continue after March 1987 owing to the anticipated closure of the Phelps Dodge wire mill at Fort Wayne, IN, which was the only company plant still using this material. Two 380-ton reverberatory furnaces were being used for wirebar and ingot production. In addition to the refined copper processing lines, the plant also produced copper and nickel sulfates from the spent electrolyte circuit and selenium, and doré from the tankhouse slimes.

Construction of three solvent extraction plants and one electrowinning plant at the Morenci Mine, Arizona, was started. The project was expected to be completed by yearend 1987 at a cost of about $90 million. Sulfur concrete, a material developed by the Bureau of Mines, was to be used in construction of the plants. The electrowinning plant, receiving feed from the three solvent extraction plants, was expected to produce at the rate of 45,000 tons of cathode per year. SC, of Japan, was to share in 15% of the project's costs and production. Unit costs were projected to be below 30 cents per pound with the costs of mining the ore to be leached borne by conventionally produced copper.

A 20% capacity increase in the SX-EW plant at Tyrone, NM, was also planned, so that within the next several years, the company was to produce more than 72,600 tons annually from this type of low-cost copper at its mines. Construction was started in mid-August 1986. Burro Chief, a 100%-owned subsidiary of Phelps Dodge, invested a total of $47.6 million to finance construction and expansion of the SX-EW plant at Tyrone. The plant was currently producing about 32,000 tons of cathode copper per year at a total unit cost, including interest and depreciation, of less than 30 cents per pound.

Copper Sulfate.—Copper sulfate was produced from copper scrap, blister copper, copper precipitates, electrolytic refinery solutions, and spent electroplating solutions by at least six companies. Imports, primarily from Peru and Mexico, accounted for nearly 8% of domestic consumption during the year. The estimated end-use distribution of shipments from domestic producers was 65% for agricultural uses, such as fungicides and fertilizers; 28% for industrial uses, such as metal finishing, mineral froth flotation, and wood preservatives; and 7% for water treatment.

Kocide Chemical Corp., a major producer of copper sulfate, was proceeding with plans to develop an in situ leaching and precipitation operation at the old underground Van Dyke Mine in Miami, AZ, and was seeking the necessary permits. Startup was scheduled for early 1988. Kocide was purchasing cement copper for copper sulfate production. Tennessee Chemical, which had announced that it would cease mining and blister copper production during 1987 at its Copper Hill, TN, operations, was planning to continue copper sulfate production from purchased raw materials. Copper sulfate was produced from blister shot, formed by pouring molten blister into water.

Table 2.—Copper sulfate producers in the United States in 1986

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 production as a byproduct of copper smelting in the United States was valued at $36.4 million in 1986, an increase over the value estimated for 1985. Three copper smelters in Arizona produced 1 million tons, and four copper smelters in New Mexico, Tennessee, and Texas produced 1.3 million tons, in terms of 100% sulfuric acid. Increased sulfuric acid production at copper smelters despite the closure of several plants resulted from improved sulfur capture at all facilities. Total byproduct sulfuric acid from copper, lead, and zinc production amounted to 2.8 million tons in 1986, valued at $53.7 million.

CONSUMPTION AND USES

Apparent consumption of refined copper declined from that of 1985, yet remained well above recessionary levels experienced in 1982 and 1983. Apparent consumption was calculated as the domestic primary refined production, plus net imports of refined copper, plus copper recovered from old scrap in alloyed or unalloyed form, plus an adjustment for stock changes. In 1986, the domestic supply of copper produced from primary materials and old scrap was at about the same level as that of the previous year, accounting for about 72% of apparent demand. The shortfall in production was met by imports of refined copper, which increased 33% to reach a record-high level, and by a 30% decline in domestic stocks of refined copper. According to Bureau of Mines estimates, the end-use distribution for copper was 70% in electrical, 15% in construction, 6% in machinery, 4% in transportation, 2% in ordnance, and 3% in other. Electrical and electronic uses in all industrial sectors except ordnance were included under electrical. Over the past two decades, there has been a significant increase in copper consumption in the electrical-electronics end-use sector relative to other sectors. Although this sector accounted for an average 50% of the market during the 1960's, it accounted for almost 70% during the 1980's.

Refined copper and copper-based scrap was directly consumed in the manufacture of semifabricated or fabricated shapes and chemicals at approximately 20 wire-rod mills, 35 brass mills, and 1,000 foundries, chemical plants, and miscellaneous manufacturers. Wire-rod mills, the producers of wire-rod, a semifabricated shape that is drawn into wire, was the largest consuming group of refined copper, accounting for 70% of domestic consumption of refined copper. The end-use distribution of copper and copper-alloy mill products by industrial sector in 1986, as estimated by the Copper Development Association (CDA) from the gross weight of copper and copper-alloy shipments from brass mills, wire mills, foundries, and powder plants was construction, 41%; electrical, 23%; machinery, 14%; transportation, 12%; and other (including ordnance), 10%. CDA estimates for copper use in construction, machinery, transportation, and other end-use sectors include electrical uses in those sectors. The total shipped increased from that of 1985, with building construction and electrical being the main growth sectors, reflecting a 5% growth in the constant dollar value of total new construction as calculated by the U.S. Department of Commerce.[32] Transportation uses declined slightly owing to a decline in domestic automobile production.

Telecommunications uses, which were included in the electrical end-use sector and comprised only about 8% of the total market, declined slightly owing to the increased use of long-distance fiber-optic cable. According to CDA, the top 10 markets for copper and copper-alloy products in the United States during 1986 were, in order of importance, plumbing, building wire, telecommunications, power utilities, in-plant equipment, air conditioning, automotive electrical, automotive nonelectrical, business electronics, and industrial valves and fittings.

A significant growth area for copper has been in electronic connectors and wire, where miniaturization, high-temperature fabrication, and high-performance requirements have led to a shift from pure copper to specialty alloys such as beryllium copper as the choice of materials. Copper alloy consumption in electronic uses has grown to over 100 million pounds in 1986, reflecting a fivefold increase since 1975 in domestic sales by the electronics industry. The growth in electronics was particularly evident for the automotive market, where the value of the electronic component of a typical domestic automobile was estimated to be $23 in 1970 and $550 in 1985.[33] Despite the downsizing in automobiles, which occurred following the 1973 energy crisis, and the one-third market share currently enjoyed by aluminum radiators, a recent CDA study indicated that increasing electric and electronic applications in automobiles had reversed the downward unit-usage trend for copper and copper alloys, with 1986 usage estimated at about 48 pounds per passenger car, compared with 36 pounds in 1980, and 41 pounds in 1975. The unit usage was forecast to continue to increase through 1990.[34]

Consumption of copper-base scrap at brass mills declined by 8% during 1986, as domestic consumers reported shortages of scrap as a result of high exports of copper scrap and narrow profit margins for scrap dealers. At times during the year, No. 1 scrap was reportedly selling at a premium to refined copper. As a result of the scrap shortage, consumption of refined copper at brass mills increased by 26%. Domestic brass mills continued to face strong foreign competition, and imports of brass mill products, according to the Copper and Brass Fabricators Council Inc., increased slightly, yet remained below the record-high level set in 1984.[35]

In an effort to maintain profitability as a result of strong import penetration, companies continued to sell off unprofitable operations, and the trend toward specialization of product at both the brass mill and service center levels continued. Buffalo Brass Co. Inc., formed by a group of investors to purchase Anaconda's American Brass Div. plants, sold the two Connecticut plants to another investor group, Valley Brass Corp., while retaining ownership of its other plants in Buffalo, NY; Kenosha, WI; and Franklin, KY. An agreement was reached in May for the purchase of Revere Copper and Brass Inc. by Vasiliou Management Co., an investment group headed by a former Revere director. Weiner Metals Co., the brass-ingotmaking division of Weiner Steel Corp., in Paramount, CA, was acquired by the Cookson American Group, Providence, RI. Weiner Metals' 8-year-old facility had a capacity of 4 million pounds of brass ingot per month and had about 50 employees.

Chase Brass & Copper Co., Cleveland, OH, which was once a full line producer of brass sheet, strip, rod, wire, and tube, reorganized into three separate divisions that were to specialize in free-cutting brass rod, strip, and narrow strip, and invested $40 million in a new plant using a low-cost process for the continuous casting and rolling of narrow strip. In June, SCM Metal Products Co., Cleveland, OH, closed its Hammond, IN, copper powder plant. However, the company planned to continue supplying copper powder from three other plants.[36]

STOCKS

As a result of a domestic supply deficit, stocks of refined copper held by consumers, producers, and in COMEX warehouses continued to decline for the third consecutive year. Industry stocks of refined copper fell to their lowest level since 1973 and, at the prevailing rate of consumption, constituted only about a 5-week supply. This compared with the peak yearend inventory levels experienced in 1982, which corresponded to about a 20-week supply.

The first 6 months of 1986 witnessed an almost steady decline in stocks held at producers, consumers, and COMEX warehouses. However, in July, there was a dramatic 35% increase in stocks held by wirerod mills. This increase was attributed to a shift in stocks and preshipments of copper by merchants and producers to ensure adequate availability in the advent of anticipated strikes at the primary producers. This reportedly represented only a physical relocation of stocks with the merchants and producers maintaining control of the stocks and consumers buying on consignment. When labor strikes failed to materialize, stocks temporarily accumulated at refineries while the accumulated excess stocks at consumers were worked off. The perception of copper being readily available, the relative low level and stability of copper prices, and the cost-cutting trend of reducing inventory carrying charges led to the overall decline of consumer-held stocks.

The drawdown in stocks at COMEX warehouses reflected a strong demand for lower grade cathode, wirebar, etc., by the domestic brass mill industry, while the inventory of high-grade material was actually increasing. Declining domestic fire-refined production resulted in demand for lower grade material being met by offtake from COMEX warehouses.

In an effort to boost its volume of trade, on March 24, the Midamerica Commodity Exchange became affiliated with the Chicago Board of Trade, the largest domestic futures exchange. The association was expected to add liquidity to Midamerica's contracts. In a move to specifically boost its failing copper contract, establish a closer link to the London Metal Exchange (LME), and to enhance its role in arbitrage transactions, Midamerica introduced a new 55,000-pound high-grade copper contract on June 19, double the size of its previous futures contract. The new contract terms accepted delivery of only high-grade copper cathodes, specifying brands deliverable against the LME higher grade contract, listing both West European and U.S. warehouses as points of delivery, and accepting LME warrants as deliverable against it.

COMEX won approval from the Commodities Futures Trading Commission (CFTC) and began trading copper options contracts in April. The new contract was an option on one 25,000-pound COMEX copper futures contract.

In what some viewed as a response to added pressure from the new Midamerica contract and in order to become more in step with market demands for physical high-grade copper cathode suitable for the dominant continuous cast rod market, COMEX filed two concurrent proposals with the CFTC. One proposal, geared toward drawing more high-grade cathode under the current standard contract, sought to raise the premium for high-grade cathode, in effect since December 1985, from 0.5 to 1.5 cents per pound, while the second proposal sought to institute a separate high-grade contract alongside the standard contract. In June, COMEX won approval to institute the new premium beginning in January 1987, and in October 1986, the new high-grade contract was approved. Actual use of the high-grade contract reportedly would depend on whether or not the additional premium alone was sufficent to draw more high-grade cathode into COMEX warehouses. Institution of the high-grade contract would make COMEX more suitable as a physical market, allowing producers and consumers to more readily use the exchange for hedging their sales and purchases.

In a similar move aimed at making its contracts more representative of the physical metal market, where high-grade cathode dominated over wirebar, the LME instituted a new standard-grade and grade-A contract in April. Only 4 brands of high-quality wirebar, as opposed to the prevailing 12 brands, were expected to be deliverable against the new grade-A contract.

Table 3.—U.S. refined copper inventories,[1] December 31

(Thousand metric tons)

Year	Consumers			Producers[3]	COMEX[4]	Total industry[5]	U.S. Government[6]	Total U.S.[5]
	Brass mills	Wire mills	Other[2]					
1955	39	20	4	31	([7])	93	802	895
1956	46	36	9	71	1	163	845	1,009
1957	46	48	3	99	1	196	918	1,113
1958	47	34	8	44	10	142	1,031	1,172
1959	30	16	11	16	12	85	1,035	1,120
1960	29	32	4	89	2	157	1,040	1,197
1961	34	26	8	44	8	120	1,036	1,156
1962	31	34	6	64	4	139	1,029	1,168
1963	30	15	4	47	1	97	1,018	1,115
1964	31	19	2	31	3	86	994	1,079
1965	35	20	5	32	9	101	814	915
1966	61	41	4	39	4	148	410	559
1967	35	20	4	24	12	96	250	346
1968	36	24	4	44	11	118	242	361
1969	36	34	4	35	4	112	230	342
1970	38	95	4	118	16	271	230	501
1971	37	84	5	68	18	213	228	441
1972	25	45	5	52	52	179	228	407
1973	27	39	5	34	5	110	226	335
1974	33	98	6	92	39	268	32	300
1975	28	108	6	188	91	420	24	444
1976	33	103	6	172	182	497	44	541
1977	31	105	6	212	167	522	21	543
1978	28	63	7	153	163	414	21	435
1979	25	44	9	64	90	232	20	252
1980	22	50	10	49	163	294	20	314
1981	26	109	9	151	170	465	20	485
1982	25	125	9	268	248	675	20	695
1983	26	116	5	154	371	672	20	692
1984	27	134	7	125	251	544	20	564
1985	20	100	5	66	109	300	20	320
1986	14	66	5	36	84	205	20	225

[1]Revised series. Semifabricated forms at consumers are not included. Data source was various issues of the Bureau of Mines "Mineral Industry Surveys" and unpublished Bureau of Mines data for 1955-70. Data for 1971-85 have been published in the "Copper" chapter of the "Minerals Yearbook."
[2]Stocks held by ingot makers, miscellaneous manufacturers, foundries, and chemical plants. Data for 1955-64 are estimated based on partial data.
[3]Inventories held by primary and secondary refineries.
[4]Data from Commodity Exchange Inc., New York; series issued June 1987.
[5]Data may not add to totals shown because of independent rounding.
[6]General Services Administration inventory in the National Defense Stockpile.
[7]Less than 1/2 unit.

PRICES

Despite changing market conditions, such as declining producer and exchange stocks, potential producer strikes, and a dramatic decline in the value of the dollar, the domestic prices for refined copper remained relatively stable throughout the year, the producer price spread between the high and low values being only about 10 cents per pound. The average annual producer price for 1986 of 66.05 cents per pound remained within the low 66 to 67 cents per pound average price range that has prevailed for the past 3 years. For the second year in a row, there was no producer premium for wirebar over cathode, reflecting its declining importance in light of continuous cast technology. Although the average COMEX first position prices rose by 0.7 cent per pound, the average producer cathode price declined by 0.9 cent per pound, reflecting the increased pricing competition between producers and merchants and the producer trend toward COMEX-based pricing systems.

Producer and exchange prices peaked in March as a result of strong seasonal demand, with domestic brass mills reportedly operating at, or near, capacity. The potential for strikes by mine workers at the end of June, when their contracts expired, was balanced by industry perceptions of an adequate metal supply. Consequently, consumers continued to draw down their stocks and there was little or no upward pressure on the price of copper. When strikes failed to materialize with the expiration of labor contracts, and a month-long strike at Noranda Mines Ltd.'s CCR Div. in Montreal, Canada, was settled, the potential for supply disruption was lessened. This, coupled with the seasonal summer slowdown, as reflected in a 25% decline in consumption in July, resulted in copper prices taking a sharp drop, the COMEX price for copper dropping below 59 cents per pound, the lowest level since December 1984. Prices remained depressed throughout the remainder of the year, although, at yearend, the potential for supply disruption owing to a strike at Noranda Mine's Horne smelter and a strike at SPCC's Cuajone Mine was putting upward pressure on prices.

Strong competition within the copper market led to continued alteration of pricing terms, with foreign producers reducing premiums and domestic producers further embracing COMEX-based pricing and offering other alternative pricing schemes apart from the traditional producer price. By March, Corporación Nacional del Cobre de Chile (CODELCO-Chile) had lowered its price for cathode sold in the United States by 1.5 cents per pound to 1.0 cent per pound over COMEX spot copper prices. The premium had been at 2.5 cents per pound since CODELCO-Chile began quarterly revisions in January 1985. Effective the beginning of 1986, Newmont began offering a maximum premium cap over COMEX settlement prices and extended its pricing 2 months forward rather than 1 month. Phelps Dodge, which sold the majority of its copper as wire-rod and adopted a quarterly adjusted COMEX-based system for wire-rod beginning January 1984, switched its premium changes to a monthly basis in April. The first adjustment under the new scheme was downward, from 8.25 cents to 7.75 cents per pound over COMEX for May. Pricing competition intensified through the year, with only Inspiration committed to maintaining its producer-based pricing.

In August, Phelps Dodge increased its wirebar premium from 0.625 cent per pound to 1.5 cents per pound, marking the first change in its wirebar premium in 20 years. Phelps Dodge was the major consumer of its wirebar at its Fort Wayne, IN, plant.

Of particular economic significance during the year was the precipitous decline in the value of the U.S. dollar, which declined by about 25% against both the Japanese yen and the West German deutsche mark. However, during the same period, the dollar rose against the currencies of the major suppliers of copper to the U.S. market, including Canada, Chile, Mexico, and Peru. This, coupled with the fact that most of the swing or marginal capacity is within the United States and is thus dollar denominated, served to cushion the impact of fluctuations in the dollar on domestic prices.[37]

Domestic dealer buying prices for copper scrap remained relatively stable throughout the year, with average New York prices varying between 45 and 49 cents per pound. However, in the face of a strong market and relatively tight supply for No. 1 scrap, some east coast dealers were reportedly offering as much as 52 cents per pound for good lots of No. 1 copper. Consumers were reportedly paying prices at or near the COMEX spot price for the same material. Wholesale prices for No. 2 scrap averaged 8 to 9 cents per pound below No. 1 scrap prices. Red brass scrap buying prices were in a narrow 34- to 37-cent-per-pound range, with a wholesale selling price about 6 to 8 cents above that. The falloff in tin prices reportedly depressed red brass scrap values.

FOREIGN TRADE

In the face of increased foreign investment in domestic mining operations, closure of domestic smelters, and favorable treatment and refining charges being offered by foreign smelters and refiners, exports of copper concentrates reached a record-high level, accounting for about 15% of domestic mine production. Exports of copper and copper-bearing scrap, which reached record-high levels, were reportedly a major reason for the shortage of scrap on the domestic market. The large volume of copper scrap exports was reportedly due to favorable terms offered by foreign buyers and, as a result of a large U.S. trade deficit, low ocean freight costs for bulk shipments out of the United States. Taiwan was the major recipient of exported scrap.

The U.S. net import reliance for copper, measured as a percent of apparent consumption, was 27%, the third successive year with a rate in excess of 20%. Imports for consumption of refined copper reached a record-high level, up 33% from that of 1985. Canada and Chile were the principal sources of imported refined copper. Increased imports from Canada accounted for almost one-half of the increase in total refined imports.

Imports of copper and brass mill products continued at the high level experienced during the past 4 years, increasing slightly from those of 1985, reportedly remaining 16% below the peak experienced in 1984.[38] In March, a coalition of domestic brass mills, copper fabricators, and unions filed antidumping petitions with the U.S. Department of Commerce, International Trade Administration (ITA), against suppliers of brass sheet and strip from Brazil, Canada, France, the Federal Republic of Germany, Italy, the Republic of Korea, and Sweden. In addition to antidumping petitions, which claimed that the imported brass sheet and strip were being sold at lower prices in the United States than in their country of origin, the petitioners filed countervailing duty petitions against producers in Brazil and France, claiming that these producers were receiving government subsidies. In May, the International Trade Commission (ITC) made a preliminary determination that imports from these countries were in fact injuring domestic producers and, in August, the ITA, in a preliminary determination, found that dumping from these countries had occurred and imposed a cash deposit, or bond, on such imports equal to the dumping margins. The margins ranged from a low of 1.5% for Canada's Arrowhead Metals Ltd. to over 40% for Brazilian and French suppliers. In addition, a 7.19% countervailing duty was imposed on French material. Although similar charges against Brazil were initially dismissed, in November, the ITA reversed its findings and imposed a 3.5% ad valorem countervailing duty against Brazilian suppliers. According to the ITA, imports of brass sheet and strip from the seven countries in 1985 amounted to $217 million, representing 8% of U.S. consumption of these articles.

In November and December, the ITA issued final determinations regarding Brazil, Canada, and the Republic of Korea, which supported its preliminary findings and set margins for Brazil at 40.6%, Canada at an average 8%, and the Republic of Korea at 7.2%. In December, the ITC cleared the way for imposition of duties when it issued a final determination that brass imports from Brazil, Canada, and the Republic of Korea had injured the U.S. industry.

WORLD REVIEW

World mine production of copper increased slightly from that of 1985. All of the major North and South American copper-producing countries had increases in production while Australia, the Republic of South Africa, and Zambia experienced significant declines. Western European production declined owing to depletion of ore at Outokumpu's Vuonos Mine in Sweden and the temporary shutdown in July of Rio Tinto Minera S.A.'s (RTM) three copper mines in Spain. The RTM mines, with a combined capacity of 47,000 tons per year, experienced significant production losses but were reopened owing to pressure from labor unions and the Government. In Japan, restructuring and streamlining of operations by Dowa Mining resulted in lower copper output.

Although several world class copper mines were being developed, nearing completion, or being readied for reopening, and several smaller mines opened or reopened, major new production capacity contributed little to mine output in 1986. A final development decision on the Escondida project in Chile was still forthcoming; the Olympic Dam project in Australia was given the final go-ahead; copper production at the Ok Tedi Mine in Papua New Guinea was poised for startup; work continued on the Neves-Corvo project in Portugal, which was expected on-stream by 1989; and development of the Salobo copper-gold deposit in Brazil was being planned.

Although expansions at major copper mines occurred or were planned, much of the expansion, such as that at Cananea in Mexico and Chuquicamata in Chile, was geared toward maintaining production levels in the face of declining ore grades. Major restructuring moves occurred in Canada, Japan, Scandinavia, and the United States as copper-producing companies sought to gain or maintain profitability as low copper prices persisted.

Consumption of refined copper by market economy countries increased over 1985 levels yet remained below the peak experienced in 1984, according to preliminary data from the World Bureau of Metal Statistics. Demand in Western Europe increased slightly, with consumption declines in Belgium and the United Kingdom being more than compensated for by increases in France, the Federal Republic of Germany, and Italy. French exports of semifabricated alloy and unalloyed products increased by almost 6%. In Asia, strong demand by the Republic of Korea and Taiwan, where consumption reportedly increased by 18% and 60%, respectively, overshadowed the consumption decline in Japan.[39] Japan's semimanufacturers, which operated under a disadvantage owing to a tariff on imported refined copper aimed at protecting its small mining industry, were particularly hard hit by the appreciation in the value of the yen and manufacturing competition from the Republic of Korea and Taiwan. In South America, consumption in Brazil reportedly increased by 26% in response to increased domestic demand. Both Mexico and Peru experienced significant declines in consumption.

Demand for refined copper by market economy countries continued to exceed production for the third consecutive year with the result that world stocks of refined copper continued the downward trend of recent years, declining by an estimated 150,000 to 200,000 tons. Most of the decline in stocks occurred at producers and consumers, commodity exchange stocks having declined by only 41,000 tons. By yearend, the downward trend in stock levels had slowed, if not reversed, with stock levels rising slightly in December. Whereas net exports to centrally planned economy countries, particularly China, contributed significantly to the supply deficit in the market economy countries in the past several years, they were not a major factor in 1986.

The tight supply of custom concentrates in the international marketplace, which had existed since 1983, and which had driven down custom treatment and refining charges, eased significantly during 1986, reportedly moving into a slight surplus situation. By yearend, treatment and refining charges on the spot market, denominated in U.S. dollars, had increased by about 50%.[40] Spot tolling and refining charges, which averaged about 9 cents per pound, c.i.f. Japan, at yearend 1985, rose to 17 cents per pound by yearend 1986.[41] Factors contributing to the surplus included increased exports of concentrates from North American producers and a cutback in purchases by Japanese smelters. Appreciation of currencies in Japan and the Federal Republic of Germany, two major customers in the custom concentrate market, significantly hurt their competitive positions in the world market by increasing costs in terms of U.S. dollars.

Australia.—Copper mine production decreased by about 8%, as production increases at Cobar Mines Pty. Ltd.'s CSA Mine and Conzinc Rio Tinto of Australia Holding Pty.'s (CRA) Woodlawn Mine were more than offset by declines at EMAC-Gunson Partnership's Mount Gunson Mine, which closed at midyear owing to reserve depletion, and at Peko-Wallsend Ltd.'s Warrego Mine. Production at Mount Isa Mines Ltd.'s Mount Isa Mine (Australia's largest producer, accounting for about 75% of output) and Renison Goldfields Consolidated Ltd.'s Lyell Mine (the second largest producer, accounting for about 10% of production) remained at about the 1985 levels. The Mount Isa Mine, situated in Northern Queensland, was one of the world's largest base metal deposits, producing copper and lead-zinc-silver ores by underground methods with copper mill-head grades averaging 3.6% copper. A new crushing-conveying system, scheduled for commissioning during early 1987, was being installed to service the deeper levels being developed in the "1100" ore body.

Plans to close the Lyell underground mine in 1989 following depletion of the "40 series" ore block, which came into production in early 1986, were reversed. A State aid package, which included 3 years of free access to local hydropower, was said to be the reason for the reversal. The mine was to be high-graded and was expected to produce 24,000 tons of copper in concentrates per year through 1994.

CRA announced plans to proceed with the development of an underground mine to supersede open pit operations at its Woodlawn copper-lead-zinc-silver mine. Underground production would extend the life of the mine for about 4 years at the rate of 500,000 to 600,000 tons of ore per year.

The final go-ahead to develop a major mine and treatment facility was given by the Western Mining Corp. Ltd. and BP Australia Ltd. partnership for the Olympic Dam underground uranium-copper project at Roxby Downs in South Australia. The project, which was estimated to cost about $575 million, was to consist of a mine, mill, smelter, and refinery with an annual capacity of 55,000 tons of copper, 2,000 tons of uranium oxide, and 90,000 ounces of gold. Construction on the project began early in the year, and startup of mining was scheduled for mid-1988.

Canada.—Despite continued financial difficulties, mine production of copper increased for the fourth consecutive year. Canada's competitive position as a copper producer was impacted by low coproduct and byproduct metal prices, appreciation of Canadian currency relative to the currencies of producers in Asia, Africa, and South America, and unmatched wage reductions to those achieved by U.S. producers. Mine production was regionally divided, principally between the western Province of British Columbia, which accounted for 40% of production and for most of the increase in production, and the central and eastern Provinces of Manitoba, 9%; Ontario, 38%; and Quebec, 9%. Although concentrates from the central and eastern Provinces were treated at Canada's six copper smelters, much of British Columbia's production was exported as concentrate, principally to Asian smelters. Although mine production increased, Canadian smelter and refinery production declined, principally owing to a 3-week strike during June at Noranda Mines' CCR Div. copper refinery in Quebec, one of the world's largest refineries, and at yearend at its Horne smelter. The strike at the 213,000-ton-per-year Horne smelter, which began in early November following 6 weeks of operating at reduced capacity, continued through yearend. As a result, both Noranda Mines and Corporation Falconbridge Copper (CFC), which had about one-third of its copper tolled at the Horne smelter, declared limited force majeures on cathode shipments for January 1987. Owing to refined production losses, Canadian exports of refined copper, principally to the United States, declined by about 10%.

In July, Lornex Mining Corp. Ltd. and Cominco Ltd. merged their Highland Valley, British Columbia, copper operations to form the Highland Valley Copper Partnership. The joint venture combined operations of the Lornex and Bethlehem concentrators and the mine operations in the Valley ore body. Plans called for expansion of Cominco's higher grade Valley Mine, with estimated reserves of 800 million tons grading 0.48% copper and a total expanded output of 180,000 tons of contained copper per year by yearend 1987.

A mine-deepening project at Sherritt Gordon Mines Ltd.'s Ruttan Mine, in Manitoba, which allowed for a 50% expansion in production to 9,000 tons of ore per day or about 30,000 tons of copper per year, was completed. The higher production rate reportedly reduced cash costs to below 55 cents per pound from levels in excess of 70 cents per pound. However, owing to a large accumulated debt, the mine reportedly needed a price of 65 cents per pound to break even.

Newmont reversed its decision to close its 25,000-ton-per-year Similkameen Mine in British Columbia when it reached agreements for labor and hydroelectric power cost reductions. The mine was expected to remain operational until mid-1990.

Falconbridge Ltd. completed the purchase of Kidd Creek operations, in Timmons, Ontario. Subsequently, Falconbridge sold its 50% interest in CFC to Kerr Addison Mines Ltd., 51% owned by Noranda Mines, for about $87 million. In 1985, CFC produced about 20,000 tons of copper. The proceeds of the sale reportedly were to be used to reduce Falconbridge's large debt.

Other selected copper industry events included exhaustion of ore reserves at the Corbet Mine of the Lac Dufault Div. of CFC; initiation of construction at Noranda Mines' CCR refinery of a slimes treatment plant; a decision by Noranda Mines to extend operations at the Bell Mine through 1989 and consideration given to reopening the Granisle Mine; opening of a new 4,500-ton-per-year SX-EW plant by Gibraltar Mines Ltd.; and a decision to accelerate the mining rate at Afton Mines Ltd.

Chile.—Copper production continued a decade-long increase, growing by 2.2% to a new record high of 1.39 million tons. State-owned CODELCO-Chile, the world's largest copper-producing company, accounted for about 1.1 million tons of production from its four divisions: the Chuquicamata Div. accounted for 515,800 tons; El Teniente, 365,300 tons; El Salvador, 102,800 tons; and Andina, 118,100 tons. Production increases were reported at all the divisions, with the exception of Chuquicamata, where production declined for the second consecutive year owing to declining ore grades. CODELCO-Chile reported proven reserves of 113 million tons of copper ore, having an average ore grade of 0.9% copper. Copper sales by CODELCO-Chile exceeded production and rose by 6% to 1.39 million tons, with 1.07 million tons coming from CODELCO-Chile's own resources, and the rest from purchases from third parties and exchanges. Western Europe was CODELCO-Chile's largest market, accounting for 47% of sales, followed by Asia, 21%; South America, 18%; North America, 12%; and Eastern Europe, 2%. Of the copper sold during 1986, 47% was cathode; 6%, wirebar; 15%, fire-refined ingot; 16%, blister; and 16%, concentrate. This reflected a major shift in consumption trends and CODELCO-

Chile's production over the past 10 years. Wirebar sales accounted for 331,000 tons, about 37% of 1976 sales.[42]

Despite the increase in sales and production, earnings and profits declined slightly from those of 1985, owing to lower average prices for copper. Copper remained Chile's principal source of export earnings, and despite the Government's efforts at diversifying exports, mining accounted for over 60% of export revenues. In 1986, CODELCO-Chile contributed $455.1 million to the Chilean Treasury Department, $44 million more than in 1985. This increase, despite lower profits, reflected changes in the taxation law, effective January 1986.

During 1986, CODELCO-Chile reported spending $377.6 million on fixed asset investments in plants and equipment. CODELCO-Chile reportedly spent $2.4 billion in capital investments over the past decade. Production costs reportedly fell from 84 cents per pound of refined copper in 1974 to 41 cents per pound in 1985.[43] However, as average ore grades at CODELCO-Chile's mines fell from 1.46% in 1985 to 1.35% in 1986, average production costs reportedly rose to 42 cents per pound in 1986.[44]

At Chuquicamata, an expansion program was under way to double the capacity of the concentrator to 153,000 tons of ore per day by 1987. However, owing to budget constraints announced during 1986, completion of the project was postponed for 2 years. Copper production, which had been scheduled to rise to 650,000 tons in 1986, was revised to 545,000 tons.[45] Meanwhile, ore grades at the pit were expected to continue to decline to about 1.0% copper over the next 2 years but were expected to begin rising again in 1988 as the pit is expanded.

Plans were continuing for the expansion of Chuquicamata's electrowinning capacity to 80,000 tons per year by 1990, with the addition of a 40,000-ton-per-year SX-EW plant to treat ore and waste dumps from Chuquicamata and from the Mina Sur open pit oxide mine. Current electrowon production was from Mina Sur, which processed about 10,000 tons of ore per day via vat leaching.

In January, CODELCO-Chile let a $78 million contract to the Japanese company Mitsubishi Heavy Industries Ltd. to construct a 600,000-ton-per-year sulfuric acid plant to treat exhaust gases from the Chuquicamata smelter. The acid plant, to be completed by August 1988, was being built in conjunction with a new 200,000-ton-per-year Outokumpu-type flash smelter, which will replace the existing reverberatory furnace. Despite this announcement, unionized workers, concerned with severe air pollution from sulfur and arsenic emissions, threatened to disrupt production at the mine. The air pollution problem had been increasing owing to greater smelter throughput, as concentrate grades declined, as well as to a steady increase in the arsenic content of the ore. Construction of a roasting plant to remove arsenic reportedly was planned. Construction of coal handling and pier facilities for the Tocopilla powerplant and expansion of the No. 2 electrolytic refinery continued. The refinery expansion was to increase capacity by 32%, to 475,000 tons per year.

At the El Teniente Div., startup problems at the new fire-refining furnace reportedly led to production losses in excess of 10,000 tons of fire-refined material. In June, storms temporarily disrupted power to both the El Teniente Div. and the Andina Div., resulting in a production loss in excess of 30,000 tons of concentrate. Investments in production continued to be made to enable exploitation of the Sur and Norte Mines, and to increase capacity at the smelter by installing larger converters.

A 4-year $90 million investment program at the Andina Div. was completed by midyear. The expansion, which boosted capacity to 118,000 tons from 60,000 tons per year in 1983, included an expanded concentrator and the opening of the open pit south-mine section. Production at Andina took a large jump in 1984 owing to mining of high-grade "Sur-Sur" ore and the first incremental addition to the concentrator. Total mining costs, including depreciation and byproduct credits, reportedly dropped to below 37.5 cents per pound.

In December, the state-owned custom smelting and refining company, Empresa Nacional de Minería (ENAMI), sharply curtailed its credit or price-support system, which had been in place since 1983, offered to the small- and medium-sized mining sector. Under the modified system, price supports for the mines were to be limited to a maximum of 100 tons of contained copper per month per producer, with a 65-cent-per-pound ceiling. This was expected to reduce the annual quantity subsidized from 120,000 tons to only about 36,000 tons. The program, which was conceived originally as a cyclical credit system, with mining companies expected to make repayments when the price for copper rose above the price support value, 70 cents in 1983, had become essentially a subsidy as the price of copper remained depressed. Meanwhile, ENAMI completed expansion work at its Las Ventanas electrolytic refinery, increasing its capacity by 30,000 to 205,000 tons per year. Plans were under way for expanding its 70,000-ton-per-year Videla Lira smelter by 20,000 to 30,000 tons through addition of a new modified converter by 1988. Feasibility studies were under way for a further smelter expansion.

Principals in the Escondida copper project, 60% owned by The Broken Hill Pty. Co. Ltd. of Australia, 30% by Rio Tinto Zinc Corp. Ltd., and 10% by Mitsubishi Corp., were seeking to finalize a financing package that would allow construction to begin by mid-1987. The Escondida deposit is one of the world's major copper properties, with resources estimated to be at least 1.25 billion tons grading 1.68% copper. The development plan called for an open pit mining operation coming on-stream by 1990, which during its first 10 years of operation, would produce over 300,000 tons of copper per year, at a development cost of $1.2 billion.

Exxon's Cía. Minera Disputada de las Condes S.A. had plans to nearly double its total mine production from the El Soldado and Los Bronces Mines from 73,000 to 140,000 tons per year by 1990. Combined production was expected to rise to 95,000 tons and 114,000 tons, respectively, for 1987 and 1988. Exxon had reportedly already spent $160 million to boost production at those mines since assuming control of Disputada in the 1970's when annual production was 29,000 tons of copper.[46]

Mexico.—Two major copper mines, Mexicana de Cobre S.A.'s La Caridad Mine (44% state owned) and Cía. Minera de Cananea S.A.'s Cananea Mine (92% state owned), accounted for more than 97% of Mexico's copper mine production. Remaining production was derived as a byproduct of other nonferrous mining. In June, Mexicana de Cobre dedicated its new $337 million Outokumpu flash smelter. The smelter, with a capacity of 2,250 tons of concentrate per day, or 180,000 tons of anode per year, was reportedly operating at 60% of capacity by yearend and was able to process all of La Caridad's 1,000 tons of concentrate production per day. With startup of the new smelter, Mexicana de Cobre began shifting from being an exporter of copper concentrates to being an exporter of blister copper. Mexicana de Cobre expected to supplement its mine production with Cananea concentrates. At the same time, it was expending $18 million to expand mining and milling facilities at La Caridad by about 25% during 1987 to 90,000 tons of ore per day. The increased ore production capacity was expected to compensate for a drop in ore grade from 0.77% copper to 0.65% over the next 10 years.[47]

During the June dedication, the cornerstone for a proposed $50 million acid plant was laid. However, the smelter, which may yield as much as 1,275 tons of sulfur dioxide per day when operating at capacity, will operate without the acid plant until its completion, scheduled for March 1988. The smelter was originally designed to use a high stack to disperse sulfur dioxide, but, as part of an agreement negotiated with the United States in 1985 to limit emissions from the two Mexican smelters and Phelps Dodge's Douglas smelter, Mexico agreed to add the acid plant. Mexicana de Cobre signed a loan agreement with the Canadian Economic Development Corp. to finance the plant and had awarded the construction contract to a Canadian firm.

At the Cananea Mine, an expansion program, begun in 1981, was completed, and as a supplement to existing capacity, a new concentrator with a capacity of 60,000 tons of ore per day was reportedly 90% complete and in partial operation. In 1986, Cananea processed 7.6 million tons of ore to produce 34,200 tons of copper in concentrate. In 1985, only 5.2 million tons of ore was processed to yield 26,100 tons of copper in concentrate. However, ore grade declined from 0.76% copper in 1985 to 0.68% in 1986. With expansion of the concentrator, Cananea exported concentrates for the first time. Total copper output by Minera de Cananea increased by about 4%, to 47,200 tons of copper: 34,300 tons was in the form of blister; 8,000 tons, in the form of electrowon cathode; and 4,900 tons, in the form of concentrate. The electrowon copper came from leaching of low-grade ore dumps (0.15% to 0.45% copper). A new SX-EW plant with a capacity of 20,000 tons of cathode per year was under construction and expected on-stream by yearend 1988. It was expected that when the expansion program is completed, Cananea will have a total capacity of 170,000 tons of copper per year.[48]

Papua New Guinea.—In February, the Government of Papua New Guinea and foreign investors reached a revised agreement concerning the future of the Ok Tedi Mining Ltd. (OTML) gold-copper project. The Government temporarily withdrew its mining permit early in 1985 when it feared that its partners would not proceed with plans to develop the copper ore body underlying the gold ore capping. The March 1985 agreement, which allowed for resumption of mining, called for a commitment to construct a 30,000-ton-per-day copper concentrator, a feasibility study to consider the viability of a second 30,000-ton-per-day concentrator, and a firm commitment to construct a permanent tailings pond.

Under the revised agreement reached in February 1986, about $285 million of OTML debt would be transferred to shareholders, the Government would pay about $9 million to OTML to restore its share in the company to 20% (the Government reduced its share to 16.5%), the construction of a permanent tailings pond would be deferred by up to 4 years, a 40-megawatt hydroelectric station would be constructed, and copper production would begin by yearend. Initial production of copper ore would be at a rate of 8,000 tons per day, increasing in stages to reach a peak of 60,000 to 70,000 tons per day by mid-1988. Implementation of the agreement would require almost $400 million in investments in addition to the $1.1 billion original capitalization. At a rate of 70,000 tons of ore per day, OTML would be producing almost 200,000 tons of contained copper per year at a cost projected to be as low as 42 cents per pound of copper.[49] However, startup of copper production late in 1986 was delayed as the company emphasized gold mining to take advantage of high gold prices. At yearend, consideration was being given to construction of a smelter to treat as much as 1 million tons of concentrate per year, including toll material.

Production of copper at Bougainville Copper Ltd.'s open pit at Panguna, on the Island of Bougainville, increased from 175,000 tons in 1985 to almost 179,000 tons in 1986. Bougainville was seeking to alter its 15-year startup concentrate sales contracts with the Federal Republic of Germany, Japan, and Spain, which were to expire in 1987. Bougainville was reportedly seeking to market the bulk of its concentrates in the Asian Pacific region.

Peru.—In 1986, three state-owned mining companies, Empresa Minera del Centro del Perú (Centromín Perú), Empresa Minera del Perú (Minero Perú), and Empresa Minera Especial Tintaya S.A. (Tintaya), and privately owned SPCC accounted for about 96% of Peru's copper production. SPCC, jointly owned by Asarco, Phelps Dodge, Newmont, and the Marmon Group Inc., operated the Toquepala and Cuajone Mines and the Ilo smelter to produce 242,000 tons of copper, accounting for 61% of Peru's copper production. Strike activities at the SPCC mines and smelter in January, March, June, and November resulted in a 10% decline in production from that of 1985. Production by SPCC has fluctuated significantly over the past 10 years from a high of 276,000 tons in 1978 to a low of 219,000 tons in 1983.

At the Cuajone Mine, by far the largest of the two SPCC copper mines, a slow decline in ore grades has been compensated for by increased concentrator capacity. Although ore grades fell from 1.15% copper in 1980 to 0.95% in 1986, ore capacity was increased from the design capacity of 41,000 tons to 50,000 tons per day. Concentrates from the Cuajone and Toquepala Mines were treated at the Ilo smelter. Blister from Ilo was sold on long-term contracts to Western Europe and Asia.

Production by Centromín Perú, which operated seven mines in the Central Sierra region, the La Oroya smelter and refinery, and the Cerro de Pasco electrowinning plant, declined by about 9% to 242,000 tons, also owing to strike activity. Centromín Perú's profits steadily declined over a 4-year period, from profits of $50 million in 1983 to a loss in excess of $150 million in 1986. The loss was attributed to a Government freeze on the exchange rate, to low metal prices, and to a 49-day strike.

Tintaya completed its first full year of operation with production of about 53,000 tons of copper contained in concentrates, a threefold increase over that of 1985, when technical problems resulted in reduced production. Concentrates from Tintaya were being tested for processing at SPCC's Ilo smelter as a partial substitute for Toquepala Mine's concentrates. Toquepala's output was expected to decline unless substantial investments were made.

Production from Minero Perú's Cerro Verde Mine increased slightly to about 20,000 tons as it reportedly began treating the copper sulfide ore underlying the nearly depleted oxide ore, using an acid leach process. Forty percent of the electrowon production reportedly came from the sulfide ore. Several alternative plans to build concentrators of various sizes ranging from 5,000 to 20,000 tons of ore per day were reportedly frozen owing to financial constraints. In August, following default on an overdue loan payment, the International Monetary Fund declared Peru "ineligible" for future lending.

Philippines.—Mine production in the Philippines increased slightly from that of 1985 but was down by about 27% from its 1980 peak. Seven companies accounted for 99% of Philippine production. Copper was the country's second most important mineral product and source of foreign exchange earnings, having been displaced from the lead position by gold in 1985. Because of relatively high production costs and the continued depressed copper prices, copper producers, with the exception of Philex Mining Corp., continued to operate at a loss. Production by Atlas Consolidated Mining and Development Corp., the country's largest copper producer, declined by 24% to about 70,000 tons, owing to a work slowdown in February and a strike in March, as well as to the closing of two of its surface mines and concentrators during 1985.

Atlas' losses, though down from that of 1985, amounted to $34.9 million for the first 9 months of 1986. Production cutbacks by Atlas were partially offset by increased production from Maricalum Mining Corp.'s Sipalay Mine. Maricalum assumed ownership of the Sipalay Mine from Marinduque Mining and Industrial Corp. and reopened the mine in mid-1985 with the aid of an almost $16 million advance by Japan's Marubeni Corp. against future copper deliveries. Sipalay, on average, operated at about 75% of capacity, producing 42,000 tons in 1986, but at yearend was operating at a higher rate.

Philex, the only profitable copper producer in the Philippines, reportedly was undertaking a $14.8 million expansion program to raise its mining and milling capacity by 14% to 32,000 tons of ore per day at the Santo Tomas Mine in Tuba, Benguet.

The Philippines Associated Smelting and Refining Corp. (PASAR) smelter and refinery at Isabel in South Leyte, 34% state owned through the National Development Corp., was operating at or near capacity for most of the year and produced 135,000 tons of refined copper. However, owing to cuts in its treatment charges, it was reportedly experiencing cash flow problems, and early in the year, the new Philippine administration established a committee to examine ways of restructuring PASAR, including possible sale of the Government's 42% interest. In August, the company broke with past policy and began soliciting toll smelting and refining contracts for up to 210,000 tons of foreign concentrates. By yearend, no agreements had been reached.

Construction of ASEAN Copper Products Inc.'s 100,000-ton-per-year copper semifabrication plant suffered a setback owing to a lack of support from the member countries of the Association of Southeast Asian Nations that were joint owners of the project. The Philippine Government, being the majority owner (60%), was considering a scaled-down, 30,000-ton-per-year alternative plant.

Zambia.—The state-controlled (60.3% Government owned) Zambia Consolidated Copper Mines Ltd. (ZCCM) accounted for all of Zambia's copper mine, smelter, and refinery production. Though mine production declined for the fourth consecutive year and for the 9 months ending December 31, the company's losses increased compared with the same year-ago period, restructuring was reportedly having a positive impact, with production increasing during the third quarter by 3,500 tons over the corresponding period in 1985.

As part of a rehabilitation program begun in 1984 to reverse deterioration of its copper operations, ZCCM announced in January a 5-year reorganization plan, which included the near-term closure of 50,000 annual tons of mine capacity as soon as developed ore reserves were exhausted. By midyear, ZCCM had closed the Kansanshi and Chambishi Mines and the No. 3 shaft of the Konkola Mine, and by August, one tankhouse at the Ndola refinery and concentrators at Nkana and Chambishi had been closed. At the end of May, the Luanshya smelter was closed for a 6-month overhaul, after which it was to be placed on a care-and-maintenance basis. Closure of the refinery and smelter were viewed as rationalization moves, given the excess smelter and refinery capacities relative to mine production and ZCCM's intention of increasing SX-EW production. The 5-year plan also included a one-third reduction in the 60,000 copper workers, including a reduction of 3,000 in 1986.

By the end of March, the $250 million tailings leach plant Stage III expansion project at Nchanga was nearing completion, reclamation of tailings having begun in December. By yearend, Zambia had stopped shipping its copper through the Republic of South Africa and began exporting all its copper through Dar es Salaam, Tanzania. Port congestion and a shortage of locomotives was reportedly delaying shipments of copper.

Zaire.—Mine and processing facilities of the state-owned La Générale des Carrières et des Mines du Zaire (Gécamines), which accounted for more than 90% of production, were grouped into three geographic areas along the copper belt; Kolwesi (west), Likasi (central), and Lubumbashi (south). The majority of production came from the eight open pit and one underground mine in the stratiform deposits of the western region, where ore grades averaged 4.4% copper. The rest of production came primarily from the Kambone and Kipushi underground mines in the central and southern sectors, respectively. Copper oxide, sulfide, and mixed sulfide ores were treated at seven concentrators, situated close to the mines. Although most of the sulfide concentrates were treated at the Lubumbashi smelter, oxide concentrates were treated at electrowinning facilities at Shituru (central) and Luilu (west). About one-half of the electrowon production was fire refined at Shituru.

Gécamines was proceeding with its 5-year, $870 million investment program, announced in 1985, to rehabilitate its ailing copper industry. The program, aimed at maintaining existing mine production capacity while raising productivity and reducing production costs, included management training, recruitment, and decentralization programs; improvement of equipment maintenance and introduction of new mine vehicles; optimization of mining operations, including revised mine plans; improvements to rail haulage and telecommunications systems; overhaul of the accounting system; completion of the electrolytic refinery and construction of a 100,000-ton-per-year flash smelter at Luilu; development planning for the Tenke deposit in the central region; and purchase of a mobile in-pit crusher and conveyor system for the Kolwezi open pits. Although $500 million of the investment was to come from retained earnings, Gécamines had reached agreements in principle to finance the rest through international lending organizations.

A baghouse collector at the Lubumbashi smelter experienced startup problems. It was expected that when operational, the baghouse would not only improve air quality but would permit recovery of an additional 3,000 tons of copper per year. In January, a filtration plant came on-stream at Luili for dewatering concentrates from the Dima concentrator in order to facilitate rail transport.

Table 4.—Estimated production costs at producing copper mines[1]

(January 1986 U.S. dollars per pound of refined copper)

Country	Number of mines	Mine operating cost	Mill operating cost	Smelter-refinery cost[2]	(Less) byproduct credit	Net operating cost[3]	Taxes[4]	Total cash costs[3]	Recovery of capital	Total production cost[3]
Australia	3	$0.20	$0.11	$0.33	$0.06	$0.58	$0.01	$0.58	$0.07	$0.66
Canada	15	.26	.35	.42	.25	.78	.01	.79	.12	.91
Chile	9	.29	.16	.10	.06	.49	.01	.50	.06	.56
India	5	.34	.21	.41	.04	.92	.05	.96	.11	1.07
Peru	6	.17	.18	.25	.05	.55	.01	.56	.12	.68
Philippines	9	.36	.27	.22	.24	.62	.06	.67	.08	.76
South Africa, Republic of	3	.32	.24	.27	.11	.72	--	.72	.13	.85
United States[5]	16	.23	.21	.19	.09	.54	.02	.56	.11	.67
Zaire	6	.37	.18	.22	.40	.37	.08	.45	.07	.51
Zambia	8	.31	.14	.05	.09	.42	.07	.48	.12	.61
Other	37	.25	.28	.28	.29	.53	.05	.58	.10	.68
Total or average	117	.28	.21	.21	.17	.53	.03	.56	.09	.65

[1]Based on life-of-mine operating parameters regarding production rates and ore grades.
[2]Includes cost of transportation.
[3]Data may not add to totals shown because of independent rounding.
[4]Taxes and production cost are at a zero percent rate of return.
[5]Includes Bingham Canyon, which was temporarily shut down in January but was reopening by yearend. Does not reflect reduced labor rates of new contracts negotiated in June that significantly lowered mine and mill operating costs at affected mines.

Source: Bureau of Mines, Minerals Availability System (MAS) cost analysis. Prepared by Kenneth Porter.

TECHNOLOGY

Technical innovations of interest to the copper industry during the year included advancements in leaching and hydrometallurgy, powder metallurgy, and smelting. Summary reports on leaching and SX-EW progress were especially prevalent.

In constructing its new electrowinning plant in Morenci, AZ, Phelps Dodge was pouring a 50,000-square-foot sulfur concrete floor in the tankhouse. In other installations, sulfur concrete, developed by the Bureau of Mines, demonstrated excellent mechanical properties, acid resistance, and durability compared with conventional portland cement. The material was awarded the IR 100 Award by the publishers of Research and Development magazine as 1 of the 100 significant technical advancements in the United States for 1986. Bureau scientists were providing technical advice during the plant construction.

The Canada Centre for Mineral and Energy Technology (CANMET) of Ottawa, Canada, was making an economic evaluation of its ferric chloride leach process for sulfide concentrates and planned to construct a pilot plant. In this process, all metals are dissolved, instead of selectively leached. A complex zinc-lead-copper-iron sulfide bulk concentrate from New Brunswick was treated at 108° C and atmospheric pressure. Lead powder added to the resulting metal-bearing solution at about 90° C, precipitated copper and silver, along with antimony, arsenic, and bismuth. In succeeding leaching and precipitation steps, about 97% of the copper and more than 95% of the silver were recovered. The French firm Minemet Recherche Inc. piloted a leach process for complex ores of copper, lead, and zinc. The metal values were dissolved in a sodium/copper chloride solution at 90° C. Copper was recovered by solvent extraction followed by electrowinning. Plans for further work were stalled because of ownership changes affecting the company. In Spain, Técnicas Reunidas S.A. (Madrid) was developing a pressure leaching method called Comprex, for use on the sulfide deposits of Spain. With Comprex, the sulfides are converted to sulfates and then oxidized. Copper is dissolved by the excess sulfuric acid produced; liquids and solids are then separated. Both copper and zinc are recovered by solvent extraction and electrowinning. Pilot plant tests produced a 97% recovery from concentrates for copper.

The U.S. Bureau of Mines Reno Research Center completed laboratory-scale tests of a calcium chloride/oxygen leach process to obtain cobalt and copper from a sulfide ore from the Blackbird Mine near Cobalt, ID. Noranda Mines had owned the mine since 1977, but the high cost of mining and processing made it uneconomical. Noranda Mines was seeking an economical hydrometallurgical route because of the high arsenic content. The Bureau of Mines process was applicable to other arsenical materials. An apparent disadvantage was that it used calcium chloride, which had to be washed out and recovered, because, as a soluble salt, it could be leached from the tailings.[50]

Nerco Minerals Co. of the United States, International Copper Institute (ICI) of the United Kingdom, and Técnicas Reunidas announced a joint venture to test the commercial potential of the "Cuprex Process," a hydrometallurgical technology to produce copper and other metals from sulfide concentrates. The process combines chloride leaching and electrowinning developed by Técnicas Reunidas and a solvent extraction procedure using a chemical reagent patented by ICI. The reagent, a pyridene dicarboxylic acid ester, extracts copper selectively from other metal ions in solution. Advantages claimed were lower capital costs, lower energy costs, and an absence of environmental problems. If the commercial feasibility could be demonstrated, it was claimed that this would be the first commercial process for extracting pure copper from sulfide ores by a hydrometallurgical route without prior roasting or smelting. The plant was to be built near Madrid and to begin production within the next 2 years.[51]

Powder metallurgy has emerged as a source of new and viable manufacturing processes with compelling economic and technical advantages over conventional ingot metallurgy practice. Modern approaches to powder production and consolidation were reviewed in a recent article from both the scientific and technological viewpoints. Historical milestones and some relationships between powder processing, microstructure, and mechanical properties were discussed, with particular emphasis on the specialty alloys. Rapid solidification processing has resulted in the production of high-conductivity copper alloys that exhibit microstructural stability up to about 1,000° C.[52]

A new process developed by Gorham International, Maine, was expected to produce fully dense powder metallurgy parts at lower cost than either sintering or sintering combined with hot isostatic pressing. Advantages claimed for the pressure-assisted sintering (PAS) process are equipment costs that were considerably lower than those incurred with other processes; shorter cycle times than other processes; a very narrow density scatter band; and better dimensional control than with conventional sintering. Conventional sintering gases, or inert gases such as argon, can be used. Gorham was beginning a 2-year research program to reduce the cost of producing fully dense powder metallurgical parts by the PAS process. Copper-based alloys were to be the subject of one of eight separate laboratory studies.[53]

The KHD-CONTOP (continuous top-blowing) process for copper recovery at smelters was described in a recent article.[54] In 1983, KHD Humboldt Wedag AG built a 1-metric-ton-per-hour pilot plant near Cologne, Federal Republic of Germany, to develop a variation of the cyclone smelting process. The KHD-CONTOP process was designed to treat relatively dirty concentrates and separate the volatile impurities in the smelting and particularly in the slag cleaning step. The process offered substantial economical and process technological advantages over other smelting techniques as a result of a combination of the cyclone smelting process and a continuous process flow with a supersonic jet top-blowing technique. Capital and operating costs were reported to be considerably lower than those of conventional processes. The process was described as a very-high-energy, high-temperature smelting process using a water-cooled cyclone chamber as the reaction zone. The equipment can be installed either as a separate smelting unit, or added to an existing reverberatory unit. Small trial units were to be installed in the reverberatory furnaces at Chuquicamata, Chile (500-ton-per-day capacity); Palabora Mining Co. Ltd., Republic of South Africa (150-ton-per-day capacity); and at Hindustan Copper Ltd., India (60-ton-per-day capacity). The process can be used to treat low-sulfur concentrates and mercury and arsenic-laden materials.

The energy-efficient regenerative burner has not been successfully applied to smelting and refining of copper because of problems associated with contaminated waste offgases. Even so, BNF Metals Technology Centre in the United Kingdom believed that, in copper, an energy reduction of about 30% would result through the use of regenerative burners. BNF was preparing a multiclient project to study the deleterious effects of offtake gases; investigate the possibility of self-cleaning regenerators that would reduce or eliminate fouling problems; and consider the potential for regenerators on oil fuel burners. In addition, researchers were to determine the most favorable siting within the furnace and the changes in furnace contour necessary to achieve optimum operation of the burners.[55]

MIM Holdings was to invest about $6 million in a trial Isasmelt plant at its Mount Isa copper smelter in Queensland, Australia, with a view to expanding the plant's smelter capacity. If developed, the new technology would allow Mount Isa to make full use of its copper concentrator. The Isasmelt unit, which was based on Sirosmelt submerged combustion technology that was developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) of Australia, can produce copper matte of a higher grade than previously achieved with the existing reverberatory furnace. The Isasmelt process can be used for both lead and copper smelting. Mount Isa was already using one such demonstration plant at its lead smelter.[56]

The CSIRO-Sirosmelt system, which had been made available to other Australian companies for smelting tin and lead, was based on the submerged combustion technique, where air and fuel are injected through a lance into a molten bath of slag and metal-rich product. Combustion and smelting of the concentrate or ore then take place below the surface of the bath, thus delivering the heat where it is needed and promoting turbulence in the bath. It was expected that energy requirements would be low and that only relatively small quantities of fuel, which can be natural gas, oil, or low-grade coal, would be used by the lance.

[1]Physical scientist, Division of Nonferrous Metals.
[2]Physical scientist, Division of Nonferrous Metals.
[3]Net import reliance as a percent of apparent consumption; defined as imports minus exports plus adjustments for Government and industry stock changes.
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[26]Page 9 of work cited in footnote 24.
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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]
1982	88	82	12	18
1983	89	85	11	15
1984	92	87	8	13
1985	88	89	12	11
1986	87	86	13	14

[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 State

(Metric tons)

	1982	1983	1984	1985	1986
Month:					
January	113,150	90,025	92,971	92,699	99,029
February	108,134	77,664	87,863	87,089	87,365
March	120,578	89,274	96,124	100,170	96,386
April	112,662	84,646	91,250	93,641	93,838
May	97,628	92,170	95,045	96,834	97,116
June	90,614	89,717	98,000	90,225	96,561
July	85,179	76,323	88,235	90,711	95,151
August	81,574	79,211	89,032	87,446	94,596
September	78,585	86,704	88,074	81,898	97,572
October	87,071	89,608	94,382	94,222	100,185
November	90,285	93,706	92,507	91,870	92,452
December	81,515	89,050	89,130	98,953	97,026
Total	1,146,975	1,038,098	1,102,613	1,105,758	1,147,277
State:					
Alaska	W	W	--	--	--
Arizona	769,521	678,216	746,453	796,556	789,175
California	W	W	W	W	W
Colorado	575	W	W	W	W
Idaho	3,074	3,556	3,701	3,551	W
Illinois	--	--	--	W	W
Michigan	W	--	--	W	W
Missouri	7,941	7,725	5,818	13,410	W
Montana	64,951	33,337	W	15,092	W
Nevada	W	W	W	W	W
New Mexico	W	W	W	W	W
Oregon	--	W	--	--	--
Tennessee	W	W	W	W	W
Utah	189,090	169,751	W	W	W
Washington	W	--	--	--	--
Total	1,146,975	1,038,098	1,102,613	1,105,758	1,147,277

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

Table 7.—Twenty-five leading copper-producing mines in the United States in 1986, 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	Chino	do	Chino Mines Co	Copper-molybdenum ore, concentrated and leached.
4	San Manuel	Pinal, AZ	Magma Copper Co	Copper-molybdenum ore and retreated slag, concentrated and leached.
5	Ray	do	ASARCO Incorporated	Copper ore, concentrated and leached.
6	Pinto Valley	Gila, AZ	Pinto Valley Copper Corp	Copper-molybdenum ore, concentrated and leached.
7	Sierrita[1]	Pima, AZ	Cyprus Sierrita Corp	Do.
8	Bagdad	Yavapai, AZ	Cyprus Bagdad Copper Co	Do.
9	Inspiration	Gila, AZ	Inspiration Consolidated Copper Co.	Do.
10	White Pine	Ontonagon, MI	Copper Range Co	Copper ore, concentrated.
11	Mission	Pima, AZ	ASARCO Incorporated	Do.
12	Troy	Lincoln, MT	do	Silver-copper ore, concentrated.
13	Eisenhower	Pima, AZ	do	Copper ore, concentrated.
14	Bingham Canyon	Salt Lake, UT	Kennecott	Copper-molybdenum ore, concentrated and leached.
15	Pima	Pima, AZ	ASARCO Incorporated	Copper ore, concentrated.
16	Casteel	Iron, MO	The Doe Run Co.[2]	Lead-copper ore, concentrated.
17	Continental	Silver Bow, MT	Montana Resources Inc	Copper-molybdenum ore, concentrated.
18	San Xavier	Pima, AZ	ASARCO Incorporated	Copper ore, concentrated.
19	Copperhill (1 mine)	Polk, TN	Tennessee Chemical Co	Copper-zinc-iron sulfide ore, concentrated.
20	Miami	Gila, AZ	Pinto Valley Copper Corp	Copper ore, leached.
21	Lakeshore	Pinal, AZ	Noranda Lakeshore Mines Inc	Do.
22	Silver Bell	Pima, AZ	ASARCO Incorporated	Do.
23	Ox-Hide	Gila, AZ	Inspiration Consolidated Copper Co.	Do.
24	Johnson	Cochise, AZ	Cyprus Johnson Copper Co	Do.
25	Magmont	Iron, MO	Cominco American Incorporated	Lead ore, concentrated.

[1]Owing to change of ownership, Sierrita and Esperanza have been combined to form one unit. All future reporting will reflect this change.
[2]Name change owing to merger between St. Joe Minerals Corp. and Homestake Mining Co. during 1986.

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	1982 Gross weight	1982 Recoverable copper	1983 Gross weight	1983 Recoverable copper	1984 Gross weight	1984 Recoverable copper	1985 Gross weight	1985 Recoverable copper	1986 Gross weight	1986 Recoverable copper
Mined copper ore:										
Concentrated[1]	174,537,000	883,153	171,776,000	810,090	168,226,000	883,338	160,258,000	906,438	166,891,000	909,136
Leached[2]	7,289,000	123,848	6,154,000	104,991	3,588,000	106,597	1,952,000	98,453	2,347,000	135,448
Total	181,826,000	1,007,001	177,930,000	915,081	171,814,000	989,935	162,210,000	1,004,891	169,238,000	1,044,584
Copper precipitates shipped; leached from tailings, dump, and in-place material	147,701	104,791	130,857	89,274	120,437	80,845	118,096	82,948	111,050	79,031
Miscellaneous:										
Silver ore	3,652,000	20,616	4,483,000	19,384	4,487,000	22,334	1,041,000	3,745	560,000	2,599
Lead ore	8,531,000	7,941	7,303,000	7,725	4,748,000	5,818	6,433,000	13,410	3,336,000	7,405
Other copper-bearing ores[3]	6,535,000	6,626	9,970,000	6,634	22,821,000	3,681	8,898,000	764	2,447,000	13,658
Grand total	XX	1,146,975	XX	1,038,098	XX	1,102,613	XX	1,105,758	XX	1,147,277

XX Not applicable.
[1]Includes the following methods of concentration: dual process (concentration followed by leaching), leach-precipitation-flotation, and froth flotation.
[2]At least 85% of leached ore processed by electrowinning.
[3]Includes gold ore, gold-silver ore, lead-zinc ore, molybdenum ore, tungsten ore, flux ores, cleanup, and tailings.

Table 9.—Recoverable copper, gold, and silver content of concentrated copper ore in 1986

State	Ore concentrated (thousand metric tons)	Recoverable metal content: Copper, Metric tons	Copper, Percent	Gold (troy ounces)	Silver (troy ounces)	Value of gold and silver per metric ton of ore
Arizona	125,387	652,836	0.52	36,951	4,093,610	$0.29
Other[1]	41,504	256,300	.62	10,086	6,706,545	.97
Total or average	166,891	909,136	.54	47,037	10,800,155	.46

[1]Includes 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	1982	1983	1984	1985[r]	1986
Ores and concentrates:					
Domestic	940,547	888,130	989,924	939,257	[1]908,087
Foreign	35,148	39,609	24,200	1,424	W
Secondary materials[2]	45,105	59,276	169,296	250,138	287,841
Total	1,020,800	987,015	1,183,420	1,190,819	1,195,928

[r]Revised. 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)

	1982	1983	1984	1985[r]	1986
PRIMARY					
Electrolytic	1,039,772	959,801	978,999	[1]947,559	[1]947,858
Electrowon	131,858	126,659	127,286	109,606	125,352
Fire refined	55,148	95,630	58,315	W	W
Total	1,226,778	1,182,090	1,164,600	1,057,165	1,073,210
SECONDARY					
Electrolytic	[2]268,952	[2]224,761	186,712	264,835	292,686
Fire refined	[3]198,597	[3]176,907	138,237	112,622	113,536
Total	467,549	401,668	324,949	377,457	406,222
Grand total	1,694,327	1,583,758	1,489,549	1,434,622	1,479,432
Primary domestic materials[4]	1,050,445	1,028,423	1,089,584	1,003,636	[5]1,073,210
Primary foreign materials[4]	176,333	153,667	75,016	53,529	W
Secondary materials	467,549	401,668	324,949	377,457	406,222
Total	1,694,327	1,583,758	1,489,549	1,434,622	1,479,432

[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 cast in forms at refineries in the United States

(Thousand metric tons)

	1985r	1986
Billets	87	93
Cakes	(1)	--
Cathodes	1,280	1,332
Ingots and ingot bars	22	28
Wirebars	27	16
Other forms	19	10
Total	1,435	1,479

rRevised.
1Revised to zero.

Table 13.—Production, shipments, and stocks of copper sulfate in the United States

(Metric tons)

Year	Production		Shipments[1]	Stocks, Dec. 31
	Quantity	Copper content		
1982	32,227	8,385	33,355	4,142
1983	37,500	9,789	36,614	5,029
1984	34,859	8,862	37,006	3,564
1985	32,740	8,265	31,952	4,353
1986	33,896	8,551	33,531	4,718

1Includes consumption by producing companies.

Table 14.—Byproduct sulfuric acid[1] (100% basis) produced in the United States

(Metric tons)

Plant type	1982	1983	1984	1985	1986
Copper[2]	1,879,983	1,837,827	2,251,312	2,230,257	2,308,804
Lead[3]	310,606	319,137	248,474	267,159	122,228
Zinc[4]	341,728	384,529	442,517	430,946	379,803
Total	2,532,317	2,541,493	2,942,303	2,928,362	2,810,835

1Includes acid from foreign materials.
2Excludes acid made from pyrite concentrates.
3Includes acid processed at molybdenum plants to avoid disclosing company proprietary data.
4Excludes 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)

	1982	1983	1984	1985[r]	1986
KIND OF SCRAP					
New scrap:					
Copper-base	649,406	611,890	637,201	621,984	633,615
Aluminum-base	20,192	21,926	21,919	13,330	22,891
Nickel-base	122	254	68	328	221
Zinc-base	20	31	31	35	27
Total	669,740	634,101	659,219	635,677	656,754
Old scrap:					
Copper-base	501,576	431,243	443,585	487,199	462,744
Aluminum-base	16,047	18,015	16,929	15,459	15,859
Nickel-base	76	158	102	689	91
Zinc-base	27	62	79	60	36
Total	517,726	449,478	460,695	503,407	478,730
Grand total	1,187,466	1,083,579	1,119,914	1,139,084	1,135,484
FORM OF RECOVERY					
As unalloyed copper:					
At electrolytic plants	268,952	224,761	186,712	264,835	292,686
At other plants	212,613	194,093	151,477	122,834	121,995
Total	481,565	418,854	338,189	387,669	414,681
In brass and bronze	660,152	625,349	735,154	716,833	677,308
In alloy iron and steel	1,492	1,434	1,705	2,498	1,411
In aluminum alloys	41,930	36,704	43,511	29,423	38,514
In other alloys	77	162	307	1,803	603
In chemical compounds[1]	2,250	1,076	1,048	858	2,967
Total	705,901	664,725	781,725	751,415	720,803
Grand total	1,187,466	1,083,579	1,119,914	1,139,084	1,135,484

[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	
	1985[r]	1986	1985[r]	1986	1985[r]	1986
Ingot makers and secondary smelters	39,983	19,782	154,854	113,163	194,837	132,945
Refineries[1]	97,380	122,678	280,077	283,544	377,457	406,222
Brass and wire-rod mills	463,926	472,271	16,143	31,588	480,069	503,859
Foundries and manufacturers	19,840	18,573	36,122	31,793	55,962	50,366
Chemical plants	855	311	3	2,656	858	2,967
Total	621,984	633,615	487,199	462,744	1,109,183	1,096,359

[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	1985	1986
UNALLOYED COPPER PRODUCTS		
Electrolytically refined copper	r264,835	292,686
Fire-refined copper	r112,622	113,536
Copper powder	9,776	7,898
Copper castings	r436	561
Total	r387,669	414,681
ALLOYED COPPER PRODUCTS		
Brass and bronze ingots:		
Tin bronzes	17,907	24,019
Leaded red brass and semired brass	106,877	99,014
High-leaded tin bronze	8,335	7,223
Yellow brass	8,575	7,641
Manganese bronze	8,069	8,563
Aluminum bronze	7,523	6,818
Nickel silver	2,931	3,215
Silicon bronze and brass	4,276	4,467
Copper-base hardeners and master alloys	13,274	13,909
Miscellaneous	2,898	4,210
Total	180,665	179,079
Brass and wire-rod mill products	r601,420	621,402
Brass and bronze castings	r35,708	34,086
Brass powder	396	393
Copper in chemical products	858	2,967
Grand total	r1,206,716	1,252,608

rRevised.

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]							
1985r	146,913	6,554	10,259	16,742	175	22	180,665
1986	146,630	5,946	9,740	16,448	253	62	179,079
Secondary metal content of brass mill products:							
1985r	[2]483,984	187	2,883	112,410	1,944	12	[2]601,420
1986	[2]507,421	203	2,594	109,684	1,498	2	[2]621,402
Secondary metal content of brass and bronze castings:							
1985r	29,785	894	1,827	3,123	22	57	35,708
1986	29,071	872	1,511	2,546	25	61	34,086

rRevised.
[1]About 94% from scrap and 6% from other than scrap in 1985 and in 1986.
[2]Includes copper recovered from scrap at wire mills to avoid disclosing company proprietary data.

Table 19.—Stocks and consumption of purchased copper scrap in the United States in 1986, by class of consumer and type of scrap

(Metric tons, gross weight)

Class of consumer and type of scrap	Stocks, Jan. 1[1]	Receipts	Consumption			Stocks, Dec. 31
			New scrap	Old scrap	Total	
SECONDARY SMELTERS-REFINERS						
No. 1 wire and heavy	10,067	132,130	71,117	66,157	137,274	4,923
No. 2 wire, mixed heavy and light	23,758	272,953	54,533	227,061	281,594	15,117
Composition or soft red brass	2,490	38,273	5,734	32,294	38,028	2,735
Railroad-car boxes	127	1,775	--	1,681	1,681	221
Yellow brass	3,476	31,100	4,901	26,929	31,830	2,746
Cartridge cases	20	156	--	145	145	31
Automobile radiators (unsweated)	2,922	53,132	66	52,396	52,462	3,592
Bronze	1,483	15,649	2,317	12,969	15,286	1,846
Nickel silver and cupronickel	360	2,570	760	1,815	2,575	355
Low brass	966	1,728	338	1,603	1,941	753
Aluminum bronze	103	84	92	18	110	77
Refinery brass	12,560	116,163	49,096	76,459	125,555	3,168
Low-grade scrap and residues	17,959	110,411	77,181	38,682	115,863	12,507
Total	76,291	776,124	266,135	538,209	804,344	48,071
BRASS AND WIRE-ROD MILLS[2]						
No. 1 wire and heavy	8,828	224,114	205,447	18,667	224,114	6,114
No. 2 wire, mixed heavy and light	430	52,802	45,632	7,170	52,802	--
Yellow brass	8,709	256,875	248,856	8,019	256,875	1,645
Cartridge cases and brass	7,156	66,937	66,271	666	66,937	3,056
Bronze	1,463	4,094	4,094	--	4,094	1,070
Nickel silver and cupronickel	3,905	10,561	10,092	469	10,561	2,108
Low brass	1,128	12,238	12,127	111	12,238	495
Aluminum bronze	--	7	7	--	7	--
Total	31,619	627,628	592,526	35,102	627,628	14,488
FOUNDRIES, CHEMICAL PLANTS, AND OTHER MANUFACTURERS						
No. 1 wire and heavy	2,730	27,136	8,686	19,124	27,810	2,056
No. 2 wire, mixed heavy and light	349	3,515	998	2,637	3,635	229
Composition or soft red brass	412	14,244	4,887	6,491	11,378	3,278
Railroad-car boxes	600	3,628	--	3,911	3,911	317
Yellow brass	785	11,111	7,462	3,599	11,061	835
Cartridge cases	--	95	--	19	19	76
Automobile radiators (unsweated)	1,232	3,419	909	2,184	3,093	1,558
Bronze	842	626	18	632	650	818
Nickel silver and cupronickel	16	94	--	93	93	17
Low brass	38	429	256	204	460	7
Aluminum bronze	40	899	162	691	853	86
Low-grade scrap and residues	--	88	74	--	74	14
Total[3]	7,044	65,284	23,452	39,585	63,037	9,291
GRAND TOTAL						
No. 1 wire and heavy	21,625	383,380	285,250	103,948	389,198	13,093
No. 2 wire, mixed heavy and light	24,537	329,270	101,163	236,868	338,031	15,346
Composition or soft red brass	2,902	52,517	10,621	38,785	49,406	6,013
Railroad-car boxes	727	5,403	--	5,592	5,592	538
Yellow brass	12,970	299,086	261,219	38,547	299,766	5,226
Cartridge cases	7,176	67,188	66,271	830	67,101	3,163
Automobile radiators (unsweated)	4,154	56,551	975	54,580	55,555	5,150
Bronze	3,788	20,369	6,429	13,601	20,030	3,734
Nickel silver and cupronickel	4,281	13,225	10,852	2,377	13,229	2,480
Low brass	2,132	14,395	12,721	1,918	14,639	1,255
Aluminum bronze	143	990	261	709	970	163
Low-grade scrap and residues[4]	30,519	226,662	126,351	115,141	241,492	15,689
Total	114,954	1,469,036	882,113	612,896	1,495,009	71,850

[1]Revised from 1985 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 2,767 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
1985:[r]					
Copper scrap	[1]607,136	W	66,662	726,945	1,400,743
Refined copper[2]	513,985	1,401,665	55,089	5,299	1,976,038
Brass ingot	13,314	--	141,371	--	154,685
Slab zinc	68,437	--	967	4,085	73,489
Miscellaneous	--	--	--	6,513	6,513
1986:					
Copper scrap	[1]627,628	W	63,037	804,344	1,495,009
Refined copper[2]	560,267	1,491,790	44,427	5,058	2,101,542
Brass ingot	15,308	--	141,568	--	156,876
Slab zinc	63,681	--	350	3,280	67,311
Miscellaneous	--	--	--	3,853	3,853

[r]Revised. W Withheld to avoid disclosing company proprietary data; included with consumption of copper scrap at brass mills.
[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
1982	1,226,778	517,726	227,881	[r]210,000	[r]1,762,385
1983	1,182,090	449,478	378,171	[r]-3,000	[r]2,012,739
1984	1,164,600	460,695	353,285	-128,000	2,106,580
1985	1,057,165	[r]503,407	339,788	[r]-244,000	[r]2,144,360
1986:					
January	87,150	44,778	48,702	13,000	167,630
February	75,452	40,158	39,507	-26,000	181,117
March	75,677	43,378	45,044	-29,000	193,099
April	87,252	42,219	40,595	-10,000	180,066
May	91,640	41,086	51,311	-4,000	188,037
June	90,689	40,502	30,643	-15,000	176,834
July	100,107	36,299	39,188	35,000	140,594
August	87,915	38,073	33,066	-14,000	173,054
September	89,061	40,510	44,330	-30,000	203,901
October	94,805	40,836	28,395	-22,000	186,036
November	90,137	34,649	58,271	-13,000	196,057
December	103,325	36,242	30,480	20,000	150,047
Total	1,073,210	478,730	489,532	-95,000	2,136,472

[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	Manganese bronze	Hardeners and master alloys	Nickel silver	Aluminum bronze	Total brass ingot[1]	Refined copper consumed	Copper scrap consumed
1982	24,577	75,402	12,584	5,220	2,499	1,619	5,038	126,939	28,812	57,992
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[r]	22,322	94,239	5,833	6,216	3,923	1,788	7,052	141,371	54,390	65,767
1986:										
New England:										
Connecticut	1,142	266	477	80			244	2,291	49	324
Maine, New Hampshire, Rhode Island, Vermont	76	2,236	102	124	12	299				
Massachusetts	343	1,686	11	176			100	5,083	962	320
Total	1,561	4,188	590	380	12	299	344	7,374	1,011	644
Middle Atlantic:										
New Jersey	461	706	41	55			131	1,395		
New York	409	6,302	264	437	67	203	44	7,515	3,287	6,221
Pennsylvania	5,180	6,265	525	647			689	13,516	3,629	4,858
Total	6,050	13,273	830	1,139	67	203	864	22,426	6,916	11,079
East North Central:										
Illinois		9,441	13	318			1,166	12,387	1,814	
Indiana	2,416	11,410	70	169	1,219	862	61	12,767	551	5,597
Michigan		3,528	121	1,202			215	7,057	5,963	10,508
Ohio		7,822	77	294			293	14,622		8,008
Wisconsin	4,907	6,445	2,478	491	2,250	114	59	10,608	5,793	3,435
Total	7,323	38,646	2,759	2,474	3,469	976	1,794	57,441	14,121	27,548

West North Central:										
Iowa, Kansas, Minnesota	143	4,233	455	282	108	4	213	5,377	3,355	4,184
Missouri, Nebraska, South Dakota	15	1,477	259	97			827	2,736		
Total	158	5,710	714	379	108	4	1,040	8,113	3,355	4,184
South Atlantic:										
Delaware, District of Columbia, Florida, Georgia, Maryland	247	381	338	87	6	597	63	1,093	6,781	3,553
North Carolina, South Carolina, Virginia, West Virginia	1,416	8,437		214			149	10,842		
Total	1,663	8,818	338	301	6	597	212	11,935	6,781	3,553
East South Central:										
Alabama, Kentucky, Mississippi, Tennessee	8,463	3,600	--	234				12,523		3,153
West South Central:					121	142	800		6,817	
Arkansas, Louisiana, Oklahoma, Texas	2,752	5,477	271	96				9,338		301
Mountain:										
Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah	235	409	126	60			14	939		96
Total	11,450	9,486	397	390	121	142	814	22,800	6,817	3,550
Pacific:										
California	1,347	7,608	1,121	643	26	124	423	10,981	4,491	9,078
Oregon and Washington	61	126						498		239
Total	1,408	7,734	1,121	643	26	124	423	11,479	4,491	9,317
Grand total	29,613	87,855	6,749	5,706	3,809	2,345	5,491	141,568	43,492	59,875

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

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
1985:[r]							
Wire-rod mills	1,345,295	55,706	W	W	--	664	1,401,665
Brass mills	206,231	13,723	43,346	114,360	136,267	58	513,985
Chemical plants	W	--	--	--	--	696	696
Ingot makers	1,054	--	4,243	--	--	2	5,299
Foundries	2,833	904	12,487	--	3,298	258	19,780
Miscellaneous[1]	7,961	W	4,162	1,412	W	21,078	34,613
Total	1,563,374	70,333	64,238	115,772	139,565	22,756	1,976,038
1986:							
Wire-rod mills	1,449,667	34,249	W	W	--	7,874	1,491,790
Brass mills	252,820	17,737	83,207	80,033	126,452	18	560,267
Chemical plants	W	--	--	--	--	935	935
Ingot makers	1,122	--	3,923	W	--	13	5,058
Foundries	2,855	533	15,209	W	1,495	535	20,627
Miscellaneous[1]	9,124	W	4,984	1,616	W	7,141	22,865
Total	1,715,588	52,519	107,323	81,649	127,947	16,516	2,101,542

[r]Revised. 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
1982	233	268	125	25	29	[r]248	[r]695
1983	174	154	116	26	25	371	692
1984	245	125	134	27	27	251	564
1985	146	66	[r]100	20	[r]25	109	[r]320
1986:							
January	134	68	114	17	25	109	333
February	127	52	105	17	25	108	307
March	142	34	98	15	25	106	278
April	103	31	93	15	25	104	268
May	139	31	93	17	25	98	264
June	136	27	82	21	25	94	249
July	106	46	109	17	25	87	284
August	123	43	105	15	25	82	270
September	137	39	81	16	25	79	240
October	128	28	75	14	25	76	218
November	141	27	64	13	25	76	205
December	135	36	66	14	25	84	225

[r]Revised.
[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)
1985:				
January	37.50	40.50	81.50	r69.75
February	37.50	40.50	81.50	r69.75
March	37.50	40.50	81.50	r69.75
April	37.50	40.50	81.50	r69.75
May	37.50	39.50	r80.00	r68.59
June	37.50	39.50	r81.13	r70.25
July	37.50	39.50	81.50	70.75
August	37.50	39.50	81.50	70.75
September	37.50	39.50	81.50	70.75
October	37.50	39.50	81.50	70.75
November	37.50	39.50	81.50	70.75
December	37.50	39.50	81.50	70.75
Average	37.50	39.83	r81.34	r70.20
1986:				
January	38.08	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	37.89	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	37.50	36.50	81.50	70.75
Average	38.58	38.29	81.50	70.75

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	1985					1986				
	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	64.49	64.49	59.15	61.19	61.63	69.88	69.88	65.29	63.28	64.31
February	66.45	66.45	60.57	62.79	62.96	68.25	68.25	63.86	62.96	63.73
March	65.55	65.55	60.09	62.91	63.02	70.14	70.14	66.02	65.26	65.52
April	70.32	70.32	63.62	67.11	68.08	68.80	68.80	63.80	64.93	65.05
May	69.86	69.86	62.95	67.67	69.38	67.09	67.09	62.72	63.29	64.24
June	67.09	67.09	60.15	64.31	64.95	67.47	67.47	62.57	63.20	64.07
July	66.77	66.77	60.78	64.73	66.86	63.82	63.82	58.94	58.44	60.96
August	66.35	66.35	60.19	62.40	64.39	62.37	62.37	57.59	57.52	59.08
September	65.72	65.72	59.57	60.74	61.96	64.84	64.84	60.71	59.43	61.08
October	66.68	66.68	60.97	61.57	62.79	63.46	63.46	59.19	58.27	59.71
November	66.29	66.29	60.64	60.70	62.10	62.86	62.86	58.93	57.71	59.10
December	68.03	68.03	63.18	62.13	63.07	63.64	63.64	60.17	58.68	60.56
Average	66.97	66.97	60.99	63.19	64.27	66.05	66.05	61.65	61.08	62.28

[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		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)
1985	116,308	$131,123	12,084	$23,200	37,937	$52,464	134,300	$132,386	39,632	$20,984
1986:										
Australia	--	--	--	--	--	--	--	--	126	123
Belgium-Luxembourg	151	200	349	3,509	--	--	3,221	4,027	14	20
Brazil	--	--	--	--	110	213	3,967	3,855	(2)	3
Canada	6,345	10,288	1,407	2,556	3,694	5,353	13,744	21,664	396	676
China	12,493	11,898	--	--	--	--	336	179	--	--
Finland	4,623	4,337	--	--	--	--	19	8	--	--
France	(2)	3	14	8	385	855	175	199	78	143
Germany, Federal Republic of	(2)	2	379	3,115	1,376	2,935	8,514	10,559	--	--
Ghana	--	--	--	--	223	57	37	55	--	--
Hong Kong	--	--	--	--	552	1,146	5,727	2,242	168	375
India	--	--	1,472	993	19	10	717	631	--	--
Italy	--	--	2	2	21	28	12,326	12,421	--	--
Japan	131,637	141,291	107	372	1	1	12,552	15,732	705	941
Korea, Republic of	14,105	15,165	--	--	1,250	940	12,368	13,867	13,500	14,123
Mexico	--	--	--	--	218	246	5,885	5,919	48	74
Netherlands	--	--	37	15	--	--	1,713	1,691	3	5
Philippines	--	--	--	--	--	--	263	110	2	2
Portugal	--	--	--	--	--	--	18	14	113	19
Singapore	--	--	--	--	--	--	684	466	85	170
Spain	--	--	--	--	--	--	5,615	3,781	91	108
Sweden	--	--	--	--	56	108	33	76	--	--
Switzerland	--	--	4	22	99	204	104	109	--	--
Taiwan	4,994	4,642	44	29	2,247	2,362	46,898	23,835	576	510
United Kingdom	--	--	--	--	2,197	3,978	1,485	1,674	2	2
Other	--	--	11	50	4	8	21	24	56	140
Total	174,348	187,826	3,826	10,671	12,452	18,444	136,422	123,138	15,963	17,434

See footnotes at end of table.

Table 27.—U.S. exports of copper, by country—Continued

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)
1985	4,542	$13,452	786	$3,236	r7,955	r$27,318	51,073	$357,887	7,883	$17,522
1986:										
Australia	10	53	(2)	3	41	144	948	7,797	(2)	7
Bahamas	4	10	2	9	63	189	610	1,660	1	2
Belgium-Luxembourg	(2)	1	--	--	2	41	129	1,767	21	53
Brazil	177	507	(2)	2	(2)	2	84	2,424	1	9
Canada	1,448	3,929	472	1,348	529	2,100	27,791	68,026	3,639	7,280
China	10	49	(2)	4	16	62	403	4,802	(2)	3
Dominican Republic	13	57	3	6	195	1,294	638	2,225	1,093	1,711
Ecuador	25	66	--	--	2	9	290	1,525	17	28
Egypt	82	256	--	--	1,157	2,985	1,686	5,157	368	622
France	10	115	1	4	8	149	876	25,827	14	101
Germany, Federal Republic of	14	39	1	12	88	617	1,994	25,611	54	401
Hong Kong	1	4	(2)	1	54	429	258	2,374	62	448
India	14	143	--	--	145	938	181	1,665	7	44
Israel	2	17	9	25	20	329	286	4,442	40	81
Italy	(2)	3	1	8	125	618	248	5,817	8	79
Jamaica	15	9	--	--	26	91	406	1,263	169	301
Japan	5	39	11	104	97	685	505	19,334	21	207
Korea, Republic of	3	5	1	10	40	332	1,457	10,581	5	82
Kuwait	174	450	--	--	2	11	26	990	30	93
Mexico	1,298	4,239	30	177	3,762	16,937	11,336	56,602	380	918
Netherlands	239	632	4	24	35	548	536	11,330	6	214
Philippines	13	51	4	60	73	232	105	588	35	88
Saudi Arabia	524	1,376	--	--	7	78	2,109	7,991	1	21
Singapore	7	30	(2)	1	128	542	465	4,730	4	50
Spain	216	492	--	--	2	13	100	3,354	19	58
Sweden	--	--	3	17	11	60	427	5,686	5	47
Switzerland	3	28	--	--	2	91	203	5,370	14	41
Taiwan	136	344	50	36	42	242	331	4,183	115	640
Trinidad and Tobago	1	2	1	2	15	66	169	887	2	5
United Arab Emirates	144	331	--	--	5	66	20	255	104	317
United Kingdom	175	497	9	62	90	714	2,465	40,531	48	320
Venezuela	117	411	14	68	223	234	417	1,869	1,744	3,219
Other	463	1,420	25	168	388	1,634	3,317	22,014	1,556	3,309
Total	5,343	15,605	641	2,151	7,393	32,482	60,816	358,677	9,583	20,799

rRevised.
[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			
	1985		1986		1985		1986	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Belgium-Luxembourg	9,418	$12,535	3,221	$4,027	6,314	$6,875	5,645	$4,453
Brazil	2,590	1,737	3,967	3,855	364	360	3,994	4,053
Canada	16,582	20,989	13,746	21,664	23,968	35,329	20,970	33,410
China	126	102	336	179	1,575	763	109	131
France	166	196	175	199	205	230	114	153
Germany, Federal Republic of	16,924	18,574	8,514	10,560	17,067	18,435	5,050	5,722
Hong Kong	1,442	776	5,726	2,242	1,165	603	752	445
India	999	859	717	631	13,822	15,078	16,566	16,801
Italy	6,854	6,625	12,326	12,421	8,893	8,610	19,606	17,927
Japan	13,451	15,803	12,551	15,732	24,791	27,023	25,712	28,096
Korea, Republic of	13,865	10,459	12,368	13,868	12,422	13,498	14,463	15,842
Mexico	12,254	13,774	5,885	5,919	3,845	4,307	923	1,170
Netherlands	3,986	4,081	1,713	1,691	3,915	4,078	1,497	1,363
Philippines	13	4	263	110	206	83	23	87
Singapore	964	461	684	466	312	281	305	221
Spain	4,802	4,715	5,615	3,781	6,928	7,382	7,799	3,507
Sweden	211	228	33	76	1,808	2,520	2,346	3,130
Switzerland	441	530	104	109	646	633	278	238
Taiwan	25,084	14,691	46,898	23,835	14,724	10,635	22,027	19,333
United Kingdom	3,904	4,988	1,485	1,675	2,081	2,366	4,221	3,503
Other	[r]224	[r]259	95	101	[r]808	[r]790	571	1,336
Total	134,300	132,386	136,422	[1]123,138	145,859	159,879	152,971	160,921

[r]Revised.
[1]Data do not add to total 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)
1985	2,869	$1,739	3,997	$6,997	12,979	$15,529	377,725	$491,798	23,014	$25,680	420,584	$541,743
1986:												
Australia	1,131	695	--	--	--	--	--	--	--	--	1,131	695
Bahamas	--	--	--	--	--	--	--	--	226	110	226	110
Belgium-Luxembourg	--	--	--	--	--	--	2,164	3,047	25	39	2,189	3,086
Canada	1,240	891	556	282	1,989	1,740	199,228	274,623	20,438	25,432	223,451	302,968
Chile	3	2	43	44	14,583	17,966	167,854	222,293	--	--	182,483	240,305
Congo	--	--	--	--	--	--	2,862	3,852	--	--	2,862	3,852
Costa Rica	--	--	--	--	--	--	--	--	115	129	115	129
Dominican Republic	--	--	--	--	--	--	--	--	241	293	241	293
Finland	--	--	--	--	--	--	122	202	--	--	122	202
France	--	--	--	--	--	--	400	568	36	50	436	618
Germany, Federal Republic of	--	--	--	--	244	617	--	--	57	98	301	715
Israel	--	--	--	--	--	--	300	462	--	--	300	462
Jamaica	--	--	--	--	--	--	--	--	116	106	116	106
Japan	580	271	--	--	--	--	--	--	(1)	2	580	273
Korea, Republic of	--	--	--	--	--	--	--	--	101	123	101	123
Mexico	--	--	--	--	17,679	39,825	1,288	1,630	5,164	4,602	24,131	46,057
Netherlands	--	--	--	--	--	--	53	63	--	--	53	63
Norway	--	--	--	--	--	--	509	726	--	--	509	726
Panama	--	--	--	--	--	--	--	--	343	326	343	326
Peru	1,262	726	103	247	--	--	45,534	60,155	--	--	46,899	61,128
Philippines	--	--	--	--	--	--	962	1,270	--	--	962	1,270
South Africa, Republic of	--	--	--	--	--	--	10,071	13,863	--	--	10,071	13,863
United Kingdom	--	--	--	--	(1)	4	5,789	1,869	--	--	5,789	1,873
Venezuela	--	--	--	--	--	--	18	15	1	6	19	21
Zaire	--	--	--	--	--	--	36,005	51,969	--	--	36,005	51,969
Zambia	--	--	--	--	50	70	28,678	40,200	--	--	28,728	40,270
Other	16	8	--	--	(1)	14	147	203	353	330	516	555
Total	4,232	2,593	702	573	34,545	60,236	501,984	677,010	27,216	31,646	568,679	772,058

[1]Less than 1/2 unit.

Source: Bureau of the Census.

Table 30.—U.S. imports for consumption of copper scrap, by country

Country	Unalloyed copper scrap		Copper-alloy scrap		
	Quantity (metric tons)	Value (thousands)	Gross weight (metric tons)	Copper content (metric tons)	Value (thousands)
1985	23,014	$25,680	31,934	23,348	$33,203
1986:					
Bahamas	226	110	42	31	24
Belgium-Luxembourg	25	39	13	13	21
Canada	20,438	25,432	25,676	19,719	26,583
Chile	--	--	71	57	88
Costa Rica	115	129	13	11	25
Dominican Republic	241	293	298	241	273
France	36	50	19	16	39
Germany, Federal Republic of	57	98	133	81	97
Guatemala	18	14	15	8	11
Honduras	34	26	18	15	16
Jamaica	116	106	127	99	80
Japan	([1])	2	--	--	--
Korea, Republic of	101	123	295	289	647
Malaysia	--	--	102	92	222
Mexico	5,164	4,602	10,811	7,068	10,748
Panama	343	326	663	540	549
Philippines	--	--	63	61	139
Sweden	--	--	71	46	92
Trinidad and Tobago	16	20	37	31	33
United Kingdom	--	--	96	91	97
Venezuela	1	6	--	--	--
Other	285	270	454	335	466
Total	27,216	31,646	39,017	28,844	40,250

[1]Less than 1/2 unit.

Source: Bureau of the Census.

Table 31.—Copper: World mine production,[1] by country

(Thousand metric tons)

Country	1982	1983	1984	1985[p]	1986[e]
Albania[e]	13.2	14.3	16.1	16.2	17.6
Algeria	.1	.1	.1	([2])	--
Argentina	[r].3	.3	.2	.4	.3
Australia	245.3	261.5	236.0	260.0	[3]239.0
Bolivia	2.3	2.0	1.6	1.7	.4
Botswana[4]	18.4	[r]20.6	21.5	21.7	[3]19.0
Brazil	24.4	[r]32.1	35.2	41.0	45.0
Bulgaria[e]	70.0	80.0	80.0	80.0	80.0
Burma	([4] [5])	4.2	12.0	16.7	[3]11.4
Canada[6]	612.4	653.0	712.8	738.6	768.2
Chile[7]	1,242.2	1,257.5	1,290.7	1,356.4	1,385.9
China[e]	175.0	175.0	180.0	185.0	185.0
Colombia	[r].1	[r].2	.2	([2])	--
Congo (Brazzaville)	.1	([5])	([8])	.5	.5
Cuba	2.6	2.7	2.7	3.1	3.3
Cyprus[9]	[r]1.5	[r]2.1	2.3	2.1	[3]1.2
Czechoslovakia	9.3	9.8	10.0	[e]10.3	10.0
Ecuador	([5])	([5])	[e].2	[e].1	.1
Finland	37.8	39.3	31.3	[e]30.0	30.0
France	.2	.1	.1	.2	.2
German Democratic Republic[e]	13.0	12.0	12.0	[r]12.0	10.0
Germany, Federal Republic of[6]	1.3	1.2	1.0	.9	[3].8
Guatemala	[e].7	--	--	--	--
Honduras	.5	.6	[e].7	5.1	5.0
India	[e]24.0	37.8	44.1	45.9	44.0
Indonesia	75.1	78.6	82.5	88.7	[3]95.8
Iran[10]	43.0	[r]57.6	43.3	50.0	48.0
Ireland	1.6	--	--	--	--
Israel	3.5	3.5	[e]2.9	--	--

See footnotes at end of table.

Table 31.—Copper: World mine production,[1] by country —Continued

(Thousand metric tons)

Country	1982	1983	1984	1985[p]	1986[e]
Italy	.1	1.5	.9	.1	--
Japan	50.7	46.0	43.3	43.2	[3]35.0
Korea, North[e]	15.0	15.0	15.0	15.0	15.0
Korea, Republic of	[e].3	.4	.3	.2	.2
Malaysia	30.1	29.0	28.9	30.5	28.0
Mexico	229.2	196.0	303.5	276.1	285.0
Mongolia[e]	90.0	104.0	118.0	128.0	128.0
Morocco	[r]23.3	[r]25.4	22.1	22.0	[3]20.2
Mozambique	.3	.2	.3	.1	.1
Namibia	49.8	50.4	47.4	48.0	[3]49.6
Nepal	([5])	([5])	([5])	([5])	([5])
Norway	27.6	22.6	25.0	19.0	[3]21.9
Oman	--	11.3	16.2	17.7	[3]18.0
Papua New Guinea	170.0	201.9	164.5	175.0	[3]174.0
Peru[7]	[r]353.8	[r]318.8	353.9	391.3	[3]397.4
Philippines	292.1	271.4	233.4	222.2	[3]222.6
Poland	376.0	402.3	431.0	[e]431.3	431.0
Portugal[7]	[r].5	[r].3	.4	.3	[3].2
Romania[e 6]	26.0	27.0	25.0	26.0	27.0
South Africa, Republic of[7]	188.7	205.0	198.2	195.4	[3]184.2
Spain	47.6	50.0	63.1	55.5	[3]46.9
Sweden	55.4	74.6	87.0	91.8	[3]86.3
Turkey[11]	[r]32.8	[r]24.9	27.1	33.0	33.0
U.S.S.R.[e 6]	560.0	570.0	590.0	600.6	620.0
United Kingdom	.6	.7	.7	.6	.6
United States:[6]					
By concentration or leaching	1,023.2	933.1	996.0	1,007.3	1,021.9
Leaching (electrowon)	123.8	105.0	106.6	98.5	125.4
Yugoslavia[11]	119.3	129.8	137.6	[e]150.0	150.0
Zaire	519.0	536.5	562.0	562.7	563.0
Zambia:[12]					
By concentration or leaching	[r]455.5	[r]406.6	406.8	354.7	340.0
Leaching (electrowon)	[r]119.0	[r]134.4	125.9	103.9	110.0
Zimbabwe	24.7	21.6	24.0	21.6	21.0
Total	[r]7,622.3	[r]7,661.8	7,973.6	8,088.2	8,156.2

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Data represent copper content by analysis of concentrates produced except where otherwise specified. Table includes data available through July 7, 1987.
[2]Revised to zero.
[3]Reported figure.
[4]Copper content of matte produced.
[5]Less than 50 tons.
[6]Recoverable content.
[7]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.
[8]Revised to not available.
[9]Includes copper content of cupriferous pyrite.
[10]Data are for years beginning Mar. 21 of that stated.
[11]Copper content by analysis of ore mined.
[12]Data are for fiscal years begining Apr. 1 of year stated.

Table 32.—Copper: World smelter production,[1] by country

(Thousand metric tons)

Country[2] and metal origin	1982	1983	1984	1985[p]	1986[e]
Albania, primary	10.2	11.0	12.6	[e]12.6	13.7
Australia:					
Primary	175.5	173.6	179.8	167.7	[3]168.9
Secondary	4.8	8.2	8.3	[r e]8.0	8.0
Total	180.3	181.8	188.1	[r e]175.7	176.9
Austria, secondary	30.0	30.0	30.0	30.0	36.0
Belgium:[e]					
Primary	2.5	2.8	.5	[r].9	2.0
Secondary	[r]79.4	[r]70.5	[r]75.5	[r]114.2	106.0
Total	[r]81.9	[r]73.3	[r]76.0	[r]115.1	108.0
Brazil, primary	4.8	63.1	61.3	[e]60.0	65.0
Bulgaria:[e]					
Primary	59.0	57.0	57.0	87.0	87.0
Secondary	3.0	3.0	3.0	3.0	3.0
Total	62.0	60.0	60.0	90.0	90.0
Canada:					
Primary	394.3	499.7	504.3	493.3	479.0
Secondary[e]	10.0	11.0	11.0	17.0	12.0
Total[e]	404.3	510.7	515.3	[r]510.3	491.0
Chile, primary[4]	1,046.8	1,058.9	1,098.3	1,088.5	1,113.0
China, primary[e]	205.0	195.0	210.0	225.0	225.0
Czechoslovakia:					
Primary	10.8	10.0	10.0	10.2	10.0
Secondary	2.4	2.4	2.4	[e]2.4	2.4
Total[e]	13.2	12.4	12.4	12.6	12.4
Finland:					
Primary	66.3	74.5	71.2	[e]71.0	70.0
Secondary	19.1	12.6	12.1	[e]12.0	12.0
Total	85.4	87.1	83.3	[e]83.0	82.0
France, secondary	8.1	7.2	6.8	7.0	6.0
German Democratic Republic, primary[e]	17.0	17.0	14.0	[r]14.0	12.0
Germany, Federal Republic of:					
Primary	161.8	159.1	148.8	150.0	149.5
Secondary	78.2	94.5	76.7	97.0	96.5
Total	240.0	253.6	225.5	247.0	246.0
Hungary, secondary[e]	.1	.1	.1	.1	.1
India, primary	32.6	35.5	40.5	32.5	40.0
Iran, primary[e]	18.0	18.0	50.0	40.0	60.0
Japan:					
Primary	948.2	944.6	821.1	802.3	[3]827.7
Secondary	98.1	117.3	107.9	130.3	[3]123.7
Total	1,046.3	1,061.9	929.0	932.6	[3]951.4
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	119.4	124.0	100.2	112.7	112.3
Mexico, primary	[r]63.8	[r]59.4	70.4	68.0	70.0
Namibia, primary	49.8	54.2	46.4	43.3	[3]45.7
Norway, primary	24.4	[r]25.7	36.8	38.2	[3]35.2
Oman, primary	--	7.6	21.3	18.8	[3]20.0
Peru, primary	294.4	258.3	298.8	326.6	297.7
Philippines, primary	--	57.6	109.2	133.8	[3]119.7
Poland:[e]					
Primary	338.0	349.0	360.0	370.0	375.0
Secondary	13.0	13.0	15.0	20.0	25.0
Total	351.0	362.0	375.0	390.0	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	1982	1983	1984	1985[p]	1986[e]
Portugal:[e]					
Primary	1.1	3.2	2.5	[r]2.6	3.0
Secondary	.4	3.0	1.0	2.0	3.0
Total	1.5	6.2	3.5	[r]4.6	6.0
Romania:[e]					
Primary	35.0	34.0	32.0	32.0	32.0
Secondary	4.0	6.0	6.0	6.0	7.0
Total	39.0	40.0	38.0	38.0	39.0
South Africa, Republic of, primary	191.8	192.3	178.7	191.7	180.0
Spain:					
Primary	105.0	100.0	97.0	88.0	90.0
Secondary	30.0	18.0	30.0	40.0	40.0
Total	135.0	118.0	127.0	128.0	130.0
Sweden:					
Primary	72.5	[r]78.8	79.8	74.7	83.0
Secondary	17.4	23.1	22.9	26.0	20.0
Total	89.9	[r]101.9	102.7	100.7	103.0
Taiwan, primary	47.3	37.9	48.4	55.1	49.6
Turkey:					
Primary	25.5	18.8	31.8	33.7	34.8
Secondary	.2	.3	.2	.2	.2
Total	25.7	19.1	32.0	33.9	35.0
U.S.S.R.:[e]					
Primary	680.0	700.0	[r]735.0	750.0	770.0
Secondary	138.0	139.0	141.0	143.0	145.0
Total	818.0	839.0	[r]876.0	893.0	915.0
United States:					
Primary[5]	975.7	927.7	1,014.1	940.7	[3]908.1
Secondary	45.1	59.3	169.3	250.1	[3]287.8
Total	1,020.8	987.0	1,183.4	1,190.8	[3]1,195.9
Yugoslavia, primary	94.0	86.8	[e]90.0	[e]100.0	100.0
Zaire, primary:					
Electrowon	302.4	304.1	309.1	[e]310.0	310.0
Other	171.1	175.0	171.5	[e]170.0	170.0
Total	473.5	479.1	480.6	[e]480.0	480.0
Zambia, primary	584.7	562.7	531.8	522.6	[3]452.0
Zimbabwe, primary	[e]23.2	21.6	22.7	20.7	21.0
Grand total	[r]7,951.2	[r]8,135.0	8,404.1	8,584.5	8,553.6
Of which:					
Primary:					
Electrowon	302.4	304.1	309.1	310.0	310.0
Other	[r]6,945.1	[r]7,085.4	7,272.6	7,250.5	7,194.6
Secondary	[r]584.3	[r]621.5	722.2	911.3	936.7
Undifferentiated	119.4	124.0	100.2	112.7	112.3

[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 7, 1987.

[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]Reported figure.

[4]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.

[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: 1982—104,791; 1983—89,274; 1984—80,845; 1985—82,948; and 1986—79,031. 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	1982	1983	1984	1985[p]	1986[e]
Albania, primary[e]	9.5	10.5	11.5	11.5	11.7
Australia:					
Primary	160.2	168.5	171.2	163.8	[2]162.6
Secondary	17.9	34.1	[e]35.0	[e]35.0	35.0
Total	178.1	202.6	[r e]206.2	[e]198.8	197.6
Austria:					
Primary	8.8	8.8	9.6	8.2	8.0
Secondary	32.8	33.1	34.3	35.0	35.0
Total	41.6	41.9	43.9	43.2	43.0
Belgium:					
Primary	420.6	360.3	351.7	340.5	340.0
Secondary	81.0	71.0	76.0	115.0	110.0
Total	501.6	431.3	427.7	455.5	450.0
Brazil:					
Primary	4.8	63.1	61.3	93.9	[2]114.0
Secondary	52.0	39.3	36.0	49.0	[2]50.0
Total	56.8	102.4	97.3	142.9	[2]164.0
Bulgaria, primary and secondary[e]	65.0	62.0	62.0	93.0	95.0
Canada:					
Primary	337.8	464.3	504.3	499.6	487.0
Secondary[e]	16.5	33.0	35.0	34.0	33.0
Total[e]	354.3	497.3	539.3	[r]533.6	520.0
Chile, primary	852.5	834.2	879.7	884.3	935.0
China, primary and secondary[e]	[r]280.0	310.0	310.0	400.0	400.0
Czechoslovakia, primary and secondary	25.6	25.7	26.1	[e]26.5	26.5
Egypt, secondary	2.4	2.4	2.6	[r e]2.6	2.7
Finland:					
Primary	38.0	45.4	47.3	[e]46.5	47.0
Secondary[e]	10.0	10.0	10.0	12.0	12.0
Total	48.0	55.4	57.3	[e]58.5	59.0
France:					
Primary[e]	[r]20.0	[r]7.8	[r]15.0	[r]13.7	14.7
Secondary	27.0	37.3	25.9	30.0	26.0
Total[3]	47.1	45.1	40.9	43.7	40.7
German Democratic Republic, primary and secondary[e]	[r]60.0	[r]68.0	[r]65.0	[r]63.0	63.0
Germany, Federal Republic of:					
Primary	313.7	332.8	297.9	329.8	330.0
Secondary	80.4	87.9	80.8	84.6	95.0
Total[3]	394.1	420.8	378.6	414.4	425.0
Hungary, primary and secondary[e]	12.2	12.5	12.8	12.8	12.8
India, primary:					
Electrolytic	25.6	28.4	32.6	28.0	36.0
Fire refined	1.2	1.0	1.0	1.0	1.0
Total	26.8	29.4	33.6	29.0	37.0
Iran, primary[4]	1.0	10.0	5.0	[e]12.0	12.0
Italy, secondary	19.6	31.2	50.3	64.3	60.0

See footnotes at end of table.

Table 33.—Copper: World refinery production,[1] by country —Continued

(Thousand metric tons)

Country	1982	1983	1984	1985[p]	1986[e]
Japan:					
Primary	948.2	944.6	821.1	802.3	[2]827.7
Secondary	126.8	147.4	114.1	133.6	[2]115.4
Total[3]	1,075.0	1,091.9	935.2	936.0	[2]943.0
Korea, North, primary and secondary[e]	22.0	22.0	22.0	22.0	22.0
Korea, Republic of:					
Primary	110.8	123.3	129.1	140.1	157.8
Secondary[e]	5.0	11.5	7.9	11.5	8.8
Total[e]	115.8	134.8	137.0	151.6	166.6
Mexico:					
Primary	61.4	80.9	69.8	108.6	105.0
Secondary[e]	14.0	15.0	[2]13.8	14.0	15.0
Total[e]	75.4	95.9	[2]83.6	[r]122.6	120.0
Norway:					
Primary (electrowon)[5]	[r]18.6	22.7	30.3	31.1	[2]30.5
Secondary[e]	(6)	(6)	(6)	(6)	--
Total	[r]18.6	[r]22.7	30.3	31.1	[2]30.5
Oman, primary	--	3.8	15.1	14.0	[2]14.5
Peru, primary:					
Electrowon	33.9	33.0	31.5	27.4	[2]27.5
Other	[r]190.9	[r]161.4	188.6	203.0	[2]198.4
Total[3]	[r]224.8	[r]194.4	220.0	230.5	[2]225.9
Philippines, primary	--	38.8	99.2	130.3	134.5
Poland, primary[5]	348.0	360.0	372.3	387.0	[2]388.0
Portugal, primary	4.6	[e]4.6	5.3	4.5	4.5
Romania:[e]					
Primary	38.0	35.0	33.0	33.0	32.0
Secondary	12.0	12.0	12.0	12.0	11.0
Total	50.0	47.0	45.0	45.0	43.0
South Africa, Republic of, primary[7]	142.8	157.7	155.7	164.3	[2]158.6
Spain:					
Primary	145.9	[r]137.6	117.4	101.7	113.2
Secondary	26.0	[r]21.0	39.0	50.0	45.0
Total	171.9	158.6	156.4	151.7	158.2
Sweden:					
Primary	[r]50.6	[r]50.1	53.5	[r e]52.0	60.0
Secondary	[r]11.7	[r]13.2	10.4	12.7	20.0
Total[3]	62.3	63.4	63.9	64.7	80.0
Taiwan:					
Primary[e]	39.4	30.0	40.4	[r]46.7	50.0
Secondary[e]	8.0	8.0	8.0	8.0	8.0
Total	47.4	38.0	48.4	54.7	58.0
Turkey, primary	32.2	31.8	39.0	[e]30.0	35.0
U.S.S.R.:[e]					
Primary	759.0	776.0	798.0	810.0	820.0
Secondary	138.0	139.0	141.0	143.0	145.0
Total	897.0	915.0	939.0	953.0	965.0
United Kingdom:					
Primary	63.2	67.5	69.5	63.9	[2]62.4
Secondary	71.0	76.8	67.4	61.6	[2]63.2
Total[3]	134.1	144.4	136.8	125.4	[2]125.6
United States:					
Primary:					
Electrowon	131.9	126.7	127.3	109.6	125.4
Other	1,094.9	1,055.4	1,037.3	947.6	947.8
Secondary	467.5	401.7	324.9	377.4	406.2
Total	1,694.3	1,583.8	1,489.5	1,434.6	1,479.4

See footnotes at end of table.

Table 33.—Copper: World refinery production,[1] by country —Continued

(Thousand metric tons)

Country	1982	1983	1984	1985[p]	1986[e]
Yugoslavia:					
Primary	82.5	82.9	[e]94.0	[e]100.0	100.0
Secondary	44.4	40.8	33.6	[e]35.4	35.0
Total	126.9	123.7	127.6	135.4	135.0
Zaire, primary	175.0	227.2	224.8	226.8	227.0
Zambia, primary:					
Electrowon	130.9	119.0	134.4	125.9	[2]103.9
Other	453.7	456.4	387.5	353.5	[2]356.5
Total	584.6	575.4	521.9	479.4	[2]460.4
Zimbabwe, primary	23.0	21.6	[e]22.7	20.4	20.0
Grand total[3]	[r]9,001.8	[r]9,249.1	9,140.5	9,404.7	9,549.8
Of which:					
Primary	[r]7,273.0	[r]7,483.0	7,484.7	7,466.7	7,599.2
Secondary	[r]1,264.0	[r]1,265.8	1,158.0	1,320.6	1,331.2
Primary and secondary, undifferentiated	[r]464.8	[r]500.2	497.9	617.3	619.3

[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 7, 1987.

[2]Reported figure.

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

[4]Data are for years beginning Mar. 21 of that stated.

[5]May include small quantities of secondary.

[6]Revised to zero.

[7]Although only primary production is reported, an unknown but small additional output of secondary refined copper may have been produced.

Diatomite

By A. C. Meisinger[1]

U.S. sales of processed diatomite declined slightly compared with that of 1985 to 628,000 short tons valued at more than $128 million. Although domestic consumption decreased, diatomite exports increased for the first time since 1983 and comprised nearly 21% of domestic production. California continued to be the leading producing State. Two new operations, one each in California and Oregon, went on-stream during the year.

World production was estimated to be nearly 2 million tons, with the United States accounting for 32% of the total.

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.

Table 1.—Diatomite sold or used by producers in the United States

(Thousand short tons and thousand dollars)

	1982	1983	1984	1985	1986
Domestic production (sales)	613	619	627	635	628
Total value of sales	$107,619	$114,279	$120,926	$127,030	$128,362

DOMESTIC PRODUCTION

Domestic production of diatomite declined compared with that of 1985 to 628,000 tons valued at more than $128 million. Seven companies processed diatomite in 11 plants in 4 States. California continued to be the leading producing State, followed by Nevada, Washington, and Oregon. Development of a deposit in Arizona continued during the year.

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 Lassenite Industries Inc., Yuba City, CA; Cyprus Minerals Co., Fernley, NV; and Oil-Dri Production Co., Christmas Valley, OR.

CONSUMPTION AND USES

Apparent domestic consumption of processed diatomite was 498,000 tons, a decrease of about 4% from that of 1985. Domestic and export sales of filter-grade diatomite increased slightly from 417,000 tons in 1985 to 422,000 tons in 1986. Sales of filler-grade diatomite decreased in 1986 from 137,500 tons to 109,000 tons, a decline of nearly 21%, while sales of diatomite used for absorbents, additives, and insulation increased more than 21% from 80,000 tons to 97,000 tons during the same period.

Table 2.—Diatomite sold or used,[1] by principal use

(Percent of U.S. production)

Use	1982	1983	1984	1985	1986
Fillers	19	21	22	21	17
Filtration	68	66	67	66	67
Insulation	1	3	1	1	3
Other[2]	12	10	10	12	13

[1]Includes exports.
[2]Includes abrasives (1982), absorbents, additives, and silicate admixtures.

PRICES

The average unit value of sales for processed diatomite increased more than $4 per ton to $204.

Table 3.—Average annual value per ton[1] of diatomite, by use

Use	1984	1985	1986
Fillers	$175.10	$184.49	$220.53
Filtration	210.60	220.80	219.69
Insulation	136.98	110.95	129.96
Other[2]	120.85	118.39	116.72
Weighted average	192.62	199.93	204.28

[1]Based on unrounded data.
[2]Includes absorbents, additives, and silicate admixtures.

FOREIGN TRADE

U.S. exports of processed diatomite increased about 9% in quantity, and the average unit value also increased from nearly $238 per ton to more than $245 per ton. Diatomite was exported to 75 countries, and the quantity represented nearly 21% of domestic production. The following five countries received 53% of the total: Canada, 25,900 tons; Japan, 15,500 tons; Australia, 10,400 tons; the United Kingdom, 9,700 tons; and the Federal Republic of Germany, 8,500 tons.

Diatomite imports totaled only 784 tons, of which 63% was supplied by Venezuela.

Table 4.—U.S. exports of diatomite

(Thousand short tons and thousand dollars)

Year	Quantity	Value[1]
1983	146	31,569
1984	127	29,461
1985	120	28,519
1986	131	32,180

[1]U.S. Customs.

WORLD REVIEW

World production of diatomite was estimated to be nearly 2 million tons, of which the United States, Romania, the U.S.S.R., and France, together, accounted for 1.5 million tons or 76% of the total.

A feasibility study to develop a diatomite deposit with estimated reserves of 3.5 million tons near Tuxpan, Michoacán State, Mexico, was reported to be under consideration as a joint venture project between Minerales No Metálicos Mexicanos, Canadian group Sidam, and private Mexican investors.[2]

[1]Industry economist, Division of Industrial Minerals.
[2]Industrial Minerals (London). Mexico. Feb. 1986, No. 221, p. 12.

Table 5.—Diatomite: World production, by country[1]

(Thousand short tons)

Country	1982	1983	1984	1985[p]	1986[e]
Algeria	[e]5	[e]5	2	3	3
Argentina	7	12	6	[e]12	11
Australia	2	9	7	[r] [e]8	8
Brazil (marketable)	14	16	18	19	20
Canada[e]	2	2	2	2	10
Chile	(2)	1	2	3	2
Colombia[e]	1	1	1	1	1
Costa Rica	1	[e]1	[e]1	(3)	--
Denmark:[4]					
Diatomite	4	[e]7	[r] [e]11	[r] [e]7	8
Moler	78	[e]72	70	79	83
Egypt[e]	--	[5](2)	(2)	(2)	(2)
France	269	244	273	[e]276	265
Germany, Federal Republic of	47	49	54	53	50
Iceland	28	28	30	32	26
Italy[e]	22	28	31	33	30
Kenya	2	2	2	3	3
Korea, Republic of	61	62	53	59	55
Mexico	62	48	49	50	50
Peru	[e]8	15	8	16	17
Portugal	2	2	[e]2	[e]2	2
Romania[e]	320	320	331	331	331
South Africa, Republic of	1	1	(2)	(2)	2
Spain	70	61	80	106	88
Thailand	(2)	(2)	1	(2)	(2)
Turkey	[e]11	11	3	[e]3	3
U.S.S.R.[e]	260	260	265	270	276
United Kingdom	[e]1	(2)	(2)	(2)	(2)
United States	613	619	627	635	[5]628
Total	[r]1,891	[r]1,876	1,929	2,003	1,972

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through Apr. 21, 1987.
[2]Less than 1/2 unit.
[3]Revised to zero.
[4]Data represent sales.
[5]Reported figure.

Feldspar, Nepheline Syenite, and Aplite

By Michael J. Potter[1]

Total U.S. feldspar output in 1986, including soda, potash, or mixed feldspar and feldspar-silica mixtures, was 735,000 short tons with a value of $26.1 million. Housing construction, which was at a high level in early 1986 but decreased somewhat during the remainder of the year, resulted in relatively strong demand for the related markets of plumbing fixtures, tile, and fiberglass insulation in which feldspar is used. Imports of crude and ground nepheline syenite decreased 10% to about 299,000 tons with a total value of about $11.3 million.

Domestic Data Coverage.—Domestic production data for feldspar are developed by the Bureau of Mines by means of a voluntary survey. Of the 15 active mines, 12, or 80%, responded, representing an estimated 92% of the total production data for feldspar shown in table 1. The remaining 8% 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 1986, the depletion rate allowed on domestic and foreign feldspar production was 14%.

Table 1.—Salient feldspar and nepheline syenite statistics

	1982	1983	1984	1985	1986
United States:					
Feldspar:					
Produced[1] short tons	615,000	710,000	710,000	700,000	735,000
Value thousands	$20,300	$22,500	$23,500	$22,800	$26,100
Exports short tons	10,800	9,360	10,080	9,280	12,000
Value thousands	$989	$856	$920	$680	$1,024
Imports for consumption short tons	48	64	25	952	1,251
Value thousands	$24	$31	$15	$1,150	$542
Nepheline syenite:					
Imports for consumption short tons	455,596	407,351	377,945	332,604	298,806
Value thousands	$13,751	$13,997	$14,218	$11,435	$11,280
Consumption, apparent[2] (feldspar plus nepheline syenite) thousand short tons	1,060	1,108	1,078	1,024	1,023
World: Production (feldspar) do	[r]3,883	[r]3,931	4,223	[p]4,496	[e]4,631

[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, in order 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 1986. 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 27% of total feldspar output during 1986.

Feldspar was mined in six States, led by North Carolina and followed in descending order by Connecticut, Georgia, California, Oklahoma, and South Dakota. North Carolina accounted for 72% of the total. Twelve U.S. companies operating 13 beneficiating plants and 1 grinding plant produced feldspar or feldspar-silica mixtures for shipment to more than 31 States and foreign countries, primarily Canada and Mexico. Of the 12 companies, 3 produced potash feldspar, and the remainder produced 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).

On January 1, 1986, three companies, The English Mica Co., U.S. Mica Co. Inc., and Kings Mountain Mica Co. Inc., merged to form KMG Minerals Inc. of Kings Mountain, NC. KMG Minerals is the only producer of high-potash feldspar in North Carolina and is a major supplier to the television glassmaking industry.

In November 1986, the International Minerals & Chemical Corp. operation in Spruce Pine, NC, was purchased by Applied Industrial Materials Corp. of Mundelein, IL. In December, the operation was purchased by Unimin Corp.

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
1982	10	172	457	16,090	147	4,040	615	20,300
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

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 1986

Company	Plant location	Product
Arkhola Sand & Gravel Co	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.
Crystal Silica Co	Oceanside, CA	Feldspar-silica mixture.
The Feldspar Corp	Middletown, CT	Soda feldspar.
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.
International Minerals & Chemical Corp	do	Do.
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.

CONSUMPTION AND USES

Of the total feldspar consumed in the United States, 54% was used in glassmaking, including container glass and glass fiber, and 46% was used in pottery.

The use of feldspar in glass containers increased 5% while its use in pottery articles such as plumbing fixtures and tile increased by 4% compared with that of 1985. This was a result of continued demand for plumbing fixtures and tile in the relatively strong housing market.

The use of feldspathic minerals in glass, ceramics, welding electrodes, and paints and plastics, including some technical aspects, was discussed in a journal article.[2]

Table 4.—Destination of shipments of feldspar[1] sold or used by producers in the United States, by State

(Short tons)

State	1982	1983	1984	1985	1986
Alabama	16,500	14,600	15,100	W	20,100
California[e 2]	30,000	45,000	45,000	50,000	50,000
Connecticut	18,800	W	W	W	W
Florida	21,000	22,700	20,300	16,900	20,000
Georgia	74,600	96,900	96,000	95,300	91,600
Illinois	26,900	46,600	38,000	37,000	27,900
Indiana	20,200	37,200	35,700	W	W
Kentucky	13,400	11,400	13,300	16,200	16,900
Louisiana	12,200	17,400	21,300	12,200	14,100
Maryland	4,600	4,500	7,400	7,400	7,000
Massachusetts	9,300	1,200	10,800	W	W
Michigan	2,000	W	W	W	W
Mississippi	15,800	15,900	12,000	W	W
Missouri	4,100	5,000	4,400	4,700	6,100
New Jersey	51,700	56,600	53,200	W	W
New York	17,800	18,300	10,800	W	W
North Carolina	16,500	20,100	16,400	17,000	20,700
Ohio	51,600	53,600	64,900	65,800	68,200
Oklahoma	31,900	W	W	W	W
Pennsylvania	28,800	33,200	37,200	31,100	33,600
South Carolina	14,900	18,400	17,400	W	W
Tennessee	15,300	W	W	W	W
Texas	36,700	41,900	41,400	42,000	45,000
West Virginia	31,600	38,100	28,500	27,000	24,400
Wisconsin	W	9,400	11,100	W	W
Other destinations[3]	43,800	102,000	99,800	277,400	289,400
Total	610,000	710,000	700,000	700,000	735,000

[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, Kansas, Minnesota, Rhode Island, Virginia, States indicated by symbol W, and unspecified States. Also includes exports to Canada, Mexico, and other foreign countries.

Table 5.—Destination of shipments of potash feldspar[1] sold or used by producers in the United States

(Short tons)

Destination	1982	1983	1984	1985	1986
Illinois, Indiana, Wisconsin	8,000	6,000	5,800	5,800	5,500
Maryland, New York, West Virginia	21,600	25,300	21,800	28,000	25,600
Ohio	8,100	8,100	9,000	8,200	W
Pennsylvania	6,400	7,100	13,500	8,200	W
Texas	200	300	200	200	300
Canada	3,200	4,300	4,600	5,200	3,500
Mexico	2,400	W	W	W	W
Other[2]	16,300	14,100	16,400	21,400	39,200
Total	66,200	65,200	71,300	77,000	74,100

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]K_2O content of 8% or higher.
[2]Includes Alabama, Arkansas, California, Colorado, Connecticut, Florida, Georgia, Kansas, Kentucky, Michigan, Massachusetts, Minnesota, Missouri, New Jersey, North Carolina, South Carolina, Tennessee, States indicated by symbol W, and other unspecified States. May also include foreign countries.

Table 6.—Feldspar[1] sold or used by producers in the United States, by use

(Thousand short tons and thousand dollars)

Use	1985 Quantity	1985 Value	1986 Quantity	1986 Value
Hand-cobbed:				
Pottery	12	W	11	W
Other	1	W	1	W
Total	13	W	12	W
Flotation concentrate:				
Glass	216	7,207	221	7,304
Pottery	276	14,135	300	14,892
Total	492	21,342	521	22,196
Feldspar-silica mixtures:[2]				
Glass	173	8,351	176	8,866
Pottery	25	W	25	W
Total	198	W	201	W
Total:[3]				
Glass[4]	389	15,558	394	16,170
Pottery	313	W	339	W
Other[5]	1	W	2	W
Total	700	32,000	735	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 7.—Potash feldspar[1] sold or used by producers in the United States, by use

Use	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)
Pottery	59,300	W	57,100	W
Other[2]	17,700	W	17,000	W
Total	77,000	W	74,100	W

W Withheld to avoid disclosing company proprietary data.
[1]K_2O content of 8% or higher.
[2]Includes glass, enamel, etc.

PRICES

Some feldspar prices increased compared with those of 1985. Engineering and Mining Journal, December 1986, listed the following prices for feldspar, per short ton, f.o.b. mine or mill, carload lots, bulk, depending on grade:

	1985	1986
Connecticut:		
20 mesh, granular	$41.35	$43.00
200 mesh	56.50	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	76.50	77.80

Source: Engineering and Mining Journal, v. 187, No. 12, Dec. 1986, p. 19.

FOREIGN TRADE

U.S. exports classified as feldspar, leucite, and nepheline syenite, but presumably mostly feldspar, increased 29% to 12,000 tons valued at $1,024,000. Chief recipients were Canada, 32%; Panama, 27%; and the Dominican Republic, Mexico, and Taiwan, 9% each. The remaining 14% was shared among 10 other countries.

In addition to feldspar and nepheline syenite, the United States imported 1,649 tons of "Other mineral fluxes, crushed" with a value of $959,400. This represented a 184% increase in tonnage compared with that of 1985. Also, 70,400 tons of "Other crude natural mineral fluxes" was imported with a value of $2 million. This was a 17% increase in tonnage compared with that of 1985.

The tariff schedule in force throughout 1986 for most favored nations provided for a 2.9% ad valorem duty on ground feldspar; imports of unground feldspar were admitted duty free.

Table 8.—U.S. exports of feldspar, by country

Country	1985		1986	
	Short tons	Value	Short tons	Value
Canada	4,700	$290,100	3,850	$227,600
Dominican Republic	1,640	100,300	1,100	85,900
Italy	--	--	600	26,000
Mexico	1,000	54,800	1,090	80,400
Panama	--	--	3,200	262,000
Taiwan	560	100,400	1,100	202,900
Venezuela	270	60,000	500	32,000
Other	1,110	74,100	560	107,400
Total	9,280	679,700	12,000	1,024,200

Source: Bureau of the Census.

Table 9.—U.S. imports for consumption of feldspar, by type and country

Type and country	1985		1986	
	Short tons	Value[1]	Short tons	Value[1]
Crude:				
Canada	20	$9,000	22	$8,000
Mexico	214	19,328	256	29,017
Venezuela	702	1,097,600	290	436,584
Ground, crushed, or pulverized:				
Mexico	--	--	683	68,440
Netherlands	9	19,116	--	--
Switzerland	1	2,428	--	--
United Kingdom	6	2,991	--	--
Total	952	1,150,463	1,251	542,041

[1]Customs value.

Source: Bureau of the Census.

WORLD REVIEW

A journal article provided information on both feldspathic mineral production and producers in Australia, Austria, Brazil, Canada, Finland, France, the Federal Republic of Germany, Greece, India, Italy, the Republic of Korea, Mexico, Norway, the Philippines, Portugal, the Republic of South Africa, Spain, Sweden, and the United States.[3]

Brazil.—The major consuming industries, glass and ceramics, are between Rio de Janeiro and São Paulo, 200 miles apart. The glass sector uses approximately 80% of the feldspar consumed, and ceramics, 20%. Most feldspar is produced by a number of small mines from pegmatite outcroppings in the northern part of Minas Gerais State, 600 miles north of Rio de Janeiro and 840 miles from São Paulo.

A potential development near Brasilia, in the State of Goiás, involved Minerãçao Matheus Lema Ltd. based in São Paulo. Already a producer of certain industrial minerals, the company holds a large deposit of soda feldspar with reserves in excess of 2 million tons. Plans were under way for its development in early 1988, with the major market expected to be the ceramics industry.

Mexico.—The majority of feldspar output came from two companies operated by Materias Primas Monterrey S.A. The larger, Materias Primas Minerales de San José S.A., operated a quarry and plant at San José de Iturbide, in the Guanajuato District of central Mexico. Plant capacity was 77,000 tons of processed potash feldspar; sales were 50,000 tons in 1984 and 33,000 tons in 1985. The product contained 10.4% K_2O and 0.08% Fe_2O_3. The second company, Materias Primas Minerales de Ahuazotepec S.A., produced soda-rich feldspar and quartz at Ahuazotepec in the Puebla District. Another company, General de Minerales S.A., also mined feldspar in the same region. Plant capacity was 13,000 tons per year. The 200-mesh product was largely for the manufacture of sanitary ware.

Norway.—Norfloat A/S, the country's largest producer, is one of Western Europe's major feldspar suppliers, with 90% of output being exported, especially to the United Kingdom and the Federal Republic of Germany. The company mined pegmatite at Glamsland, near Lillesand. Both potash and soda feldspars were produced, as well as mica and "Norflux," which contains 70% feldspar and 30% quartz. Annual production capacity was approximately 30,000 tons of potash feldspar, 47,000 tons of soda feldspar, and 33,000 tons of quartz.

United Kingdom.—Imports of feldspar in 1985 were 61,600 tons. Principal countries of origin and the share supplied were Finland, 42%; Norway, 29%; and Sweden, 18%.[4]

Table 10.—Feldspar: World production, by country[1]

(Thousand short tons)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Argentina	17	22	20	[e]22	22
Australia	5	[r]5	4	[r] [e]9	9
Austria	3	1	3	15	3
Brazil[3]	145	136	116	[e]132	132
Burma	3	3	7	3	3
Chile	1	3	3	3	3
Colombia	33	35	36	38	37
Egypt	9	7	8	21	16
Finland	77	57	62	[e]61	61
France	191	193	230	[e]231	220
Germany, Federal Republic of	365	364	328	355	353
Guatemala[e]	13	7	6	[4]6	7
Hong Kong	36	62	127	120	110
India	49	46	44	51	50
Iran[e]	3	3	3	3	3
Italy	864	[r]911	1,086	1,230	[4]1,364
Japan[5]	33	34	39	34	36
Kenya	--	1	1	1	1
Korea, Republic of	94	121	140	160	154
Mexico	127	130	93	[e]110	110
Morocco[e]	[4]1	1	1	1	1
Mozambique	1	1	[e]1	([6])	([6])
Nigeria[e]	6	6	6	6	4
Norway[7]	69	64	75	[r] [e]72	72
Pakistan	9	6	6	6	13
Peru	[r] [e]11	3	4	([8])	--
Philippines	17	7	13	6	7
Poland[e]	88	88	88	88	88
Portugal	46	39	[e]44	[e]39	35
Romania[e]	93	94	94	95	95
South Africa, Republic of	53	50	43	36	59
Spain[9]	144	128	151	150	149
Sri Lanka	3	3	6	11	11
Sweden	60	58	55	[r] [e]55	55
Taiwan	12	13	17	12	11
Thailand	21	53	82	115	110
Turkey[e]	77	[4]10	11	22	22
U.S.S.R.[e]	360	360	360	370	370
United Kingdom (china stone)	6	[r]6	7	[e]7	7
United States	615	710	710	700	[4]735
Uruguay	1	1	[e]1	[e]1	1
Venezuela	74	41	44	46	39
Yugoslavia	47	46	[e]46	[e]50	50

See footnotes at end of table.

Table 10.—Feldspar: World production, by country[1] —Continued

(Thousand short tons)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Zambia	(6)	(6)	(6)	(6)	(6)
Zimbabwe	1	2	2	3	3
Total	r3,883	r3,931	4,223	4,496	4,631

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

[1]Table includes data available through May 5, 1987.

[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: 1982—87; 1983—71; 1984—93; 1985—91; and 1986—94 (estimated).

[4]Reported figure.

[5]In addition, the following quantities of aplite were produced, in thousand short tons: 1982—385; 1983—442; 1984—486; 1985—517; and 1986—495 (estimated).

[6]Less than 1/2 unit.

[7]Excludes nepheline syenite.

[8]Revised to zero.

[9]Includes pegmatite.

NEPHELINE SYENITE

Nepheline syenite is a quartz-free, light-colored rock that, although resembling medium-grained granite in texture, consists principally of nepheline and alkali feldspars, usually in association with minor amounts of other minerals. Large quantities of nepheline syenite, after processing to remove contaminants, especially iron-bearing minerals, were consumed in making glass and ceramics. There was no domestic production of nepheline syenite in grades suitable for these purposes, and U.S. needs were wholly supplied by imports.

Output from the two operations of Indusmin Ltd., a division of Falconbridge Ltd., at Blue Mountain, Ontario, was an estimated 515,000 tons in 1985, the latest year for which published data were available. Of this total, 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.

U.S. demand for nepheline syenite has decreased in recent years because of competition from plastic polyethylene terephthalate containers and metal cans, from increased recycling of glass cullet, and because of the trend toward thinner glass containers to compete with lighter packaging materials.[5]

Table 11.—U.S. imports for consumption of nepheline syenite

Year	Crude		Ground	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1984	410	$17	377,535	$14,201
1985	920	62	331,684	11,373
1986	2,970	205	295,836	11,075

Source: Bureau of the Census.

Prices for Canadian and Norwegian nepheline syenite appeared in Industrial Minerals (London), December 1986. Canadian prices 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. Prices for Norwegian material were $75 per ton, bulk, and $102 per ton, bagged, c.i.f. United Kingdom port, glass grade, 32 mesh; and $88 per ton, bulk, and $116 per ton, bagged, ceramic grade, 325 mesh.[6]

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 500,000 tons, has been the world's largest producer of aplite.

Aplite of glassmaking quality was produced in the United States from one surface mine. The Feldspar Corp. mined aplite near Montpelier, Hanover County, VA, and treated the material by wet grinding, classification, and spiraling to remove biotite, ilmenite, and rutile, followed by dewatering and high-intensity magnetic separation to eliminate iron-bearing minerals.

Domestic output of aplite increased over that of 1985. The data are company proprietary and cannot be released for publication. Aplite traditionally has a somewhat lower price than feldspar. Industrial Minerals (London), December 1986, 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, Division of Industrial Minerals.

[2]Robbins, J. Feldspar and Nepheline Syenite, Filling a Need? Ind. Miner. (London), No. 228, Sept. 1986, pp. 69-79.

[3]Pages 79-99 of work cited in footnote 2.

[4]Industrial Minerals (London). United Kingdom Industrial Mineral Statistics. No. 224, May 1986, p. 64.

[5]Midgette, W. B. Nepheline Syenite. Am. Ceram. Soc. Bull., v. 65, No. 5, May 1986, p. 740.

[6]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=US$1.50.

Ferroalloys

By Gerald F. Murphy[1]

Total world demand for ferroalloys in 1986 was about the same as in 1985. Overall demand for ferroalloys was greater in countries with centrally planned economies than in market economy countries. Demand for ferroalloys in Belgium, the Federal Republic of Germany, Japan, Spain, and the United States was down by a larger percentage than in most other countries.

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 46 operations to which a survey request was sent, 41 responded, representing an estimated 96% of the total production and/or shipments shown in table 2. Production and shipments for the remaining seven nonrespondents were estimated using reported prior year production and shipment levels adjusted by trends in employment and other guidelines.

Legislation and Government Programs.—As of October 28, the U.S. Customs Service stopped imports of ferroalloys from the Republic of South Africa pending clarification of the Comprehensive Anti-Apartheid Act of 1986 (H.R. 4868). The act bans the importation of iron and steel products from the Republic of South Africa. Ferroalloys are listed with iron and steel products in U.S. Tariff Schedule 6, part 2, subpart B. Subsequently, the U.S. Department of the Treasury determined that ferroalloys, except for spiegeleisen, would be excluded from the ban on iron and steel products. Ferroalloys and other material from the Republic of South Africa have been impounded by Customs since the ban was imposed on October 2. Treasury officials determined that including alloys in the ban would be too wide an interpretation of the Executive order and would cause too great a disruption in that market.

The U.S. Congress authorized continuation of the General Services Administration (GSA) ferroalloy upgrading program for each of the fiscal years 1987 through 1993 under Title II—National Defense Stockpile of the Defense Authorization Act of 1987. Under the program, which has been running for 3 years, chromium and manganese ores are converted to the ferroalloy form. GSA was also authorized to use tungsten concentrate as payment to contractors for upgrading these ores. Congress also enacted legislation freezing the National Defense Stockpile goals at current levels for another year, pending debate on whether to restructure the stockpile.

A provision in the Omnibus Water Resources Act, signed by the President in November 1986, places a 0.04% ad valorem levy on all cargo loaded or unloaded at U.S. ports. The port fee, part of legislation aimed at raising $12 billion for refurbishing ports, harbors, and inland waterways, will be assessed beginning on April 1, 1987. The importer will pay the fee on incoming material, the exporter on outgoing material, and the shipper on domestic material. The port fee is in addition to the Customs "user fee," which places a 0.22% levy on all items, dutiable or otherwise, imported into the United States.

In October, the President signed into law the new 5-year, $8.5 billion Superfund Amendments and Reauthorization Act of 1986. The act sets goals for cleanup of abandoned hazardous waste sites and requires the Environmental Protection Agency (EPA) to begin cleaning up at least 375 sites within 5 years. Funding will come from a $2.75 billion tax on crude oil, a $2.50 billion tax on corporations, a $1.4 billion tax on 42 chemical feedstocks, $1.25 billion from general Treasury revenues, and $600 million recovered from designated responsible parties.

EPA let stand regulations exempting mining waste from the hazardous water requirement of the Resource Conservation and Recovery Act (RCRA) until studies in progress are completed. EPA had proposed to list six mining wastes as hazardous in 1985, when it undertook to determine which specific processing waste streams came under RCRA's 1980 mining waste exemption. Ferrochromium-silicon emission control dust or sludge was one of the waste streams that was proposed as hazardous. EPA's action leaves the original November 19, 1980, interpretation of the mine waste exemption in effect.

A congressionally mandated study assigned to the U.S. Department of Defense and conducted for the Defense Department by the Logistics Management Institute, a private consulting firm, on the effects of a complete loss of U.S. bulk ferroalloy processing capacity was completed in June. The study found that there is enough available capacity in reliable countries to compensate for a total loss of current ferroalloy capacity in the United States in a peacetime scenario. However, defense requirements during mobilization would create immediate shortages of silicon metal and ferrosilicon if supply disruption occurred. The study concluded that the Defense Department should closely monitor industry trends and be prepared to react to further significant erosion of capacity.[2] The second phase of a study led by the U.S. Air Force on the need for 21 materials in time of war was begun in August. The interagency group conducting the study consists of representatives from the Air Force, the U.S. Department of Commerce, the Bureau of Mines, and the GSA. The study's first phase dealt with the development of research methodology. The current agenda calls for scrutiny of "seven superalloy constituents" and their current production capacity and prospective capacity utilization under national emergency conditions. The metals under review are chromium, cobalt, columbium, manganese, nickel, rhenium, and tantalum.

Table 1.—Government inventory of ferroalloys, December 31, 1986

(Thousand short tons)

Alloy	Stock-pile grade	Non-stock-pile 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

Domestic production and shipments of ferroalloys were lower by about one-sixth and one-tenth, respectively, in 1986, compared with those of 1985. The decline was the result of continued weak demand by major consuming industries and competition from low-priced imports. Capacity utilization by bulk ferroalloy producers of chromium, manganese, and silicon, and their respective metals in 1986 was even lower than in 1985, less than 40%. Three companies considered selling their ferroalloy divisions.

Two companies, Moore McCormack Resources Inc. and International Minerals & Chemical Corp., announced plans to sell their ferroalloy plants. Foote Mineral Co., also a ferroalloy producer, was put up for sale.

Elkem Metals Co. announced plans to invest $3 million in a briquetting plant for its Marietta, OH, plant. The new plant would produce chromium-aluminum briquets. Elkem was also attempting to increase use of its powerplant associated with that plant.

Strategic Minerals Corp. (STRATCOR) completed purchase of Umetco Minerals Corp., Union Carbide Corp.'s U.S. operation. STRATCOR became the U.S. representative for ferrochromium produced by Tubatse Ferrochrome (Pty.) Ltd. in the Republic of South Africa and owned by South African Manganese Amcor Ltd. Union Carbide retained its chromium operations in Zimbabwe and continued to represent Union Carbide Southern Africa, owner of Zimbabwe Mining and Smelting Co., a low- and high-carbon ferrochromium (H-C-FeCr) producer in Zimbabwe, through the Union Carbide Carbon Products Div.

SKW Alloys Inc. planned to convert one

of its two furnaces at Niagara Falls, NY, to silicon metal production at a cost of about $7 million. SKW was to continue production of ferrochromium-silicon at the rate of about 5,000 short tons per year.

A strike at SKW's Calvert City, KY, plant that began in September 1983 finally ended as of January 13, 1986.

Chemetals Inc. ended all operations at its Kingwood, WV, plant late in 1986. The plant had produced low- and medium-carbon ferromanganese by a fused-salt electrolytic process. Chemetals entered into a 5-year agreement to market throughout North America a similar manganese product manufactured in France by Pechiney Électrométallurgie. Chemetals' Kingwood plant, established in 1962, had been disabled by a flood in November 1985. Chemetals continued to manufacture nitrogen-bearing manganese, weld-grade powders, and manganese-aluminum briquets at its other plant in Baltimore, MD.

Ohio Ferro-Alloys Corp. (OFA), Canton, OH, filed for reorganization of its finances under Chapter 11 of the U.S. Bankruptcy Code. The company planned to continue the production of silicon metal at its Montgomery, AL, facility while a financial restructuring plan was sought. OFA's other facilities, ferrosilicon plants in Philo and Powhatan Point, OH, have been closed since 1984.

Estimated ferrous scrap consumption by the domestic ferroalloys industry was 250,000 tons in 1986, down from 310,000 tons in 1985.

The Ferroalloys Association reported that its member companies consumed 4.2 billion kilowatt hours of electricity in 1986, down from 4.5 billion kilowatt hours in 1985. Additionally, its member companies employed 3,800 workers and reported losses, before taxes, amounting to $5 million in 1986, compared with 4,100 workers and a reported loss amounting to $15 million (revised) in 1985.

Table 2.—Ferroalloys[1] produced and shipped from furnaces in the United States

	1985				1986			
	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)
Ferromanganese[2]	153,550	77	156,582	$100,903	117,368	81	111,592	$90,941
Silicomanganese	(3)	66	(3)	(3)	(3)	66	(3)	(3)
Manganese metal	(3)	100	(3)	(3)	(3)	100	(3)	(3)
Ferrosilicon[4]	441,673	53	404,733	190,392	339,441	53	371,310	218,382
Silicon metal	120,965	99	121,640	157,231	123,893	99	126,077	148,797
Chromium alloys:								
Ferrochromium	109,563	62	108,472	97,723	105,407	62	115,659	87,624
Other[5]	(6)	--	(6)	(6)	(6)	--	(6)	(6)
Total	109,563	62	108,472	97,723	105,407	62	115,659	87,624
Ferrocolumbium	W	65	W	8,843	W	65	W	W
Ferrophosphorus	61,962	24	54,912	7,921	58,147	24	53,758	7,161
Other[7]	89,469	XX	95,360	136,179	72,109	XX	76,231	111,848
Grand total[8]	977,182	XX	941,698	699,191	816,365	XX	854,627	664,752

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 fused-salt electrolytic low- and medium-carbon ferromanganese (massive manganese), and includes silicomanganese and manganese metal.
[3]Included with ferromanganese.
[4]Includes miscellaneous silicon alloys.
[5]Includes ferrochromium-silicon, chromium briquets, exothermic chromium additives, other miscellaneous chromium alloys, and chromium metal.
[6]Included with ferrochromium.
[7]Includes ferroaluminum, ferroboron and other complex boron additive alloys, ferromolybdenum, ferronickel, ferrotitanium, ferrotungsten, ferrovanadium, ferrozirconium, silvery iron, and other miscellaneous alloys.
[8]Data may not add to totals shown because of independent rounding.

Table 3.—Producers of ferroalloys in the United States in 1986

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., KBI Div., Penn Rare Metals Div	Revere, PA	FeCb	Metallothermic.
Cyprus Minerals Co., Pennzoil Sulphur Co	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	Cambridge, OH Graham, WV Keokuk, IA	FeSi, FeV, silvery pig iron, other.[2]	Electric.
M. A. Hanna Co.:			
Hanna Nickel Smelting Co	Riddle, OR	FeNi, FeSi	Do.
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	Newfield, NJ	Cr, FeAl, FeB, FeCb, FeTi, FeV, other.[2]	Metallothermic.
Moore McCormack Resources Inc., Globe Metallurgical Inc.	Beverly, OH Selma, AL	FeCr, FeSi, Si	Electric.
Ohio Ferro-Alloys Corp	Montgomery, AL Powhatan Point, OH	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.
Reynolds Metals Co	Sheffield, AL	Si	Electric.
SEDEMA S.A., Chemetals Inc	Baltimore, MD	FeMn	Electric and electrolytic.
SKW Alloys Inc	Calvert City, KY Niagara Falls, NY	FeCr, FeCrSi, FeSi	Electric.
Strategic Minerals Corp. (STRATCOR):			
U.S. Vanadium Corp U.S. Tungsten Corp	do	FeV, FeW	Do.
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.
FERROPHOSPHORUS			
FMC Corp., Industrial Chemical Div	Pocatello, ID	FeP	Electric.
Monsanto Co., Monsanto Industrial Chemicals Co.	Columbia, TN 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.

CONSUMPTION AND USES

Although overall demand for ferroalloys and their respective metals by the iron and steel industry in 1986 was down by about one-tenth compared with that of 1985, imports for consumption of these materials increased by approximately one-sixth. Consumption patterns for ferroalloys followed the production patterns of the steel and ferrous castings industries, its major end-use markets.

A labor dispute shut down the steelmaking operations of USX Corp. on July 31. USX is a major consumer of ferroalloys. LTV Corp., another major consumer of ferroalloys, filed for bankruptcy reorganization on July 17. Cabot Corp.'s aluminum master alloys business was sold in late 1986 to Harbour Group Investments Inc., a multi-interest private company headquartered in St. Louis, MO. The two plants involved in the transaction were at Henderson County, KY, and Wenatchee, WA. Both plants had been producing aluminum-manganese master alloys.

Imports for consumption of bulk ferroalloys and their respective metals represented 62% of the domestic market in 1986, up from 59% in 1985. H-C-FeCr and high-carbon ferromanganese produced under the National Defense Stockpile upgrading program were included in U.S. demand calculations.

Table 4.—U.S. consumption of ferroalloys as additives in 1986, by end use[1]

(Short tons of alloys unless otherwise specified)

End use	FeMn	SiMn	FeSi	FeTi	FeP	FeB
Steel:						
Carbon	288,617	69,614	[2]59,763	732	7,915	286
Stainless and heat-resisting	[2]14,630	3,136	[2]59,709	2,185	13	([3])
Other alloy	[2]62,356	[2]24,206	[2]50,047	297	874	226
Tool	393	([3])	[2]2,009	([3])	--	--
Unspecified	856	402	9,176	25	--	114
Total	366,852	97,358	180,704	3,239	8,802	626
Cast irons	[4]9,407	2,563	192,567	65	1,945	W
Superalloys	152	W	269	630	W	W
Alloys (excluding alloy steels and superalloys)	19,608	W	51,474	323	49	W
Miscellaneous and unspecified	3,972	2,849	75,585	10	149	125
Total consumption	399,991	102,770	500,599	4,267	10,945	751
Percent of 1985	82	98	92	103	90	90

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.—U.S. consumption of ferroalloys as alloying elements in 1986, by end use[1]

(Short tons of contained elements unless otherwise specified)

End use	FeCr	FeMo	FeW	FeV	FeCb	FeNi
Steel:						
Carbon	[2]3,663	40	([3])	1,026	698	--
Stainless and heat-resisting	163,585	266	38	41	401	12,346
Other alloy	[2]22,363	766	26	1,992	858	405
Tool	3,157	W	112	510	([4])	--
Unspecified	([3])	([3])	--	W	24	--
Total[2 5]	192,768	1,072	176	3,569	1,980	12,751
Cast irons	3,878	454	([3])	24	--	353
Superalloys	8,193	54	W	12	504	W
Alloys (excluding alloy steels and superalloys)	2,070	158	W	658	9	131
Miscellaneous and unspecified	3,399	308	31	45	3	21
Total consumption[5]	210,308	2,047	207	4,308	2,497	13,256
Percent of 1985	102	90	105	88	84	74

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]Part included with "Miscellaneous and unspecified."
[3]Included with "Miscellaneous and unspecified."
[4]Included with "Steel: Unspecified."
[5]Data may not add to totals shown because of independent rounding.

Table 6.—Stocks of ferroalloys held by producers and consumers in the United States at yearend

(Short tons)

	Producer		Consumer		Total	
	1985 (gross weight)	1986 (gross weight)	1985 (gross weight)	1986 (gross weight)	1985 (gross weight)	1986 (gross weight)
Manganese ferroalloys[1]	W	W	W	W	119,342	303,608
Silicon alloys[2]	120,017	140,788	25,399	21,264	145,416	162,052
Ferrochromium[3]	20,387	14,105	32,166	31,790	52,553	45,895
Ferroboron[4]	157	137	212	217	369	354
Ferrophosphorus	60,388	63,530	1,495	1,380	61,883	64,910
Ferrotitanium	W	W	667	609	667	609
Total	200,949	218,560	59,939	55,260	380,230	577,428
	1985 (contained element)	1986 (contained element)	1985 (contained element)	1986 (contained element)	1985 (contained element)	1986 (contained element)
Ferrocolumbium[5]	W	W	W	W	559	W
Ferromolybdenum[6]	1,257	909	298	309	1,555	1,218
Ferronickel	W	--	1,930	1,028	1,930	1,028
Ferrotungsten	W	W	40	29	40	29
Ferrovanadium[7]	W	W	360	314	360	314
Total	1,257	909	2,628	1,680	4,444	2,589

W Withheld to avoid disclosing company proprietary data.
[1]Includes ferromanganese, silicomanganese, and manganese metal.
[2]Includes ferrosilicon, miscellaneous silicon alloys, and silicon metal.
[3]Includes other chromium alloys and chromium metal.
[4]Consumer totals include other boron materials.
[5]Consumer totals include nickel columbium.
[6]Consumer totals include calcium molybdate.
[7]Includes other vanadium-iron-carbon ferroalloys.

PRICES

Published prices for most ferroalloys continued to weaken in 1986 owing to declining demand by major consuming industries and stronger competition among producers.

The average posted price of most imported bulk ferroalloys, except for silicomanganese, was lower in 1986 compared with that of 1985; for example, by 7% to $0.43 per pound of chromium for charge chrome containing 60% to 65% chromium, by 5% to $0.83 per pound of chromium for low-carbon ferrochromium containing up to 0.05% carbon, by 2% to $0.32 per pound of manganese for medium-carbon ferromanganese, by 5% to $0.35 per pound of silicon for 50% ferrosilicon, by 6% to $0.33 per pound of silicon for 75% ferrosilicon, and by 3% to $0.56 per pound of silicon for silicon metal containing up to 1% iron. Average listed prices for comparable domestically produced bulk ferroalloys were appreciably higher than these six imports by 26%, 15%, 29%, 15%, 22%, and 12%, respectively. The average price of imported charge chrome containing 50% to 55% chromium declined by 8% to $0.39 per pound of chromium, while that of imported high-carbon ferromanganese declined by 4% to $313.45 per long ton of alloy. The posted prices for comparably produced domestic material have been suspended. However, the price of imported silicomanganese increased slightly to $0.17 per pound of alloy. Domestically produced silicomanganese was priced 36% higher than the imported material.

Except for some vanadium products that increased in the range of 5% to 10%, prices for most specialty ferroalloys were depressed.

Published prices were lowered from a range of $1.40-$1.45 to $1.35-$1.40 per long ton unit for manganese ore on April 3. The price of chromium ore did not change in 1986.

Alloy	Yearend price[1]	
	1985	1986
Charge chromium (66% to 70%)	$0.54	$0.54
Low-carbon ferrochromium, 0.02% maximum carbon (Simplex)	1.00	1.00
Standard 78% ferromanganese, per long ton of alloy[2]	320.00	305.00
Ferromolybdenum, dealer export	3.26	3.65
Ferronickel	3.16	[3]3.16
Ferrosilicon, 50%	.40	.40
Ferrosilicon, 75%	.40	.40

[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.
[3]List price suspended on Sept. 18, 1986.

Source: Metals Week.

FOREIGN TRADE

The trade deficit for ferroalloys increased from $425 million in 1985 to $505 million in 1986, while that for ferroalloy metals declined from $40 million in 1985 to $21 million in 1986.

Quantity, on a gross weight basis, and value of exported ferroalloys and ferroalloy metals declined by 21% to 84,000 short tons and 15% to $115 million, respectively. The quantity and value of exported ferroalloys and ferralloy metals were 6% and 18% of the quantity and value of imports for consumption in 1986, respectively, compared with 9% and 23%, respectively, in 1985.

Total imports for consumption of ferroalloys and ferralloy metals increased 16% in quantity to 1.3 million tons and 7% in value to $641 million, compared with those of 1985. Of the imported bulk ferroalloys, the quantity of chromium ferroalloys and manganese ferroalloys increased by 19% and 12%, respectively, while that of silicon ferroalloys increased by 44%. Imports of chromium metal and manganese metal each increased by 13%. However, imports of silicon metal declined by 21%. Imports increased by 4% for ferronickel but declined by 15% for all other ferroalloys. Ferroalloy and ferroalloy metal imports were equal to about 90% of reported consumption in 1986, higher than those in 1985.

Imports for consumption of ferroalloys and ferroalloy metals to the United States were supplied by 37 countries. The geographic sources were Africa, 42%; Europe, 26%; the Western Hemisphere, 24%; the Middle East, 4%; Oceania, 4%; and Asia, 1%. The four principal suppliers were the Republic of South Africa, 37%; Brazil, 9%; Canada, 8%; and France, 7%. Combined imports of chromium ferroalloys from the Republic of South Africa and Zimbabwe were 71% of total chromium ferroalloys, about the same as those for 1985. Of the total chromium ferroalloys, the Republic of South Africa supplied 59%. Turkey was the second leading supplier of chromium ferroalloys with 12% of the total. Major sources of imported manganese ferroalloys were the Republic of South Africa, 39%; France, 15%; Canada, 9%; Mexico, 8%; Brazil, 7%; and Australia, 5%. The principal sources of ferrosilicon were Brazil, 22%; Norway, 19%; Venezuela, 18%; Canada, 17%; the U.S.S.R., 7%; and Iceland, 6%. The leading suppliers of ferronickel were New Caledonia, 40%; the Dominican Republic, 38%; and Colombia, 17%. The main suppliers of all other ferroalloys were Brazil, 43%; the United Kingdom, 16%; France, 9%; Austria, 7%; and Canada, 5%. Major suppliers of ferroalloy metal imports were the United Kingdom, Japan, China, and France, with 44%, 22%, 21%, and 8%, respectively, of the chromium metal; the Republic of South Africa with over 99% of the manganese metal; and Brazil, Canada, Argentina, Yugoslavia, Portugal, and France, with 32%, 29%, 9%, 8%, 7%, and 6%, respectively, of the silicon metal. In 1985, the leading suppliers of silicon metal were Brazil, 26%; Canada, 20%; Portugal, 12%; France, 8%; and the Republic of South Africa, 8%.

Table 7.—U.S. exports of ferroalloys and ferroalloy metals

Alloy	1984		1985		1986	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Ferroalloys:						
Ferrocerium and alloys	29	$304	28	$314	37	$319
Ferrochromium and ferrochromium-silicon	15,388	10,542	10,262	7,688	6,035	5,693
Ferromanganese	6,764	4,397	6,927	4,762	4,323	2,650
Silicomanganese	5,333	2,237	3,089	136	2,004	687
Ferromolybdenum	325	1,567	631	2,698	166	928
Ferrophosphorus	39,603	5,279	49,674	5,776	38,377	4,393
Ferrosilicon	29,364	21,185	12,970	12,671	11,331	8,306
Ferrovanadium	469	5,205	454	4,791	513	4,647
Ferroalloys, n.e.c	27,485	16,158	14,498	24,581	10,029	11,561
Total ferroalloys[1]	124,761	66,875	98,533	63,417	72,814	39,184
Metals:						
Manganese	4,082	5,915	5,162	7,242	5,146	7,892
Silicon	4,420	88,543	2,120	61,647	5,378	65,157
Chromium	259	3,627	222	2,964	321	2,972
Total ferroalloy metals[1]	8,761	98,084	7,504	71,854	10,845	76,020
Grand total[1]	133,522	164,959	106,037	135,271	83,660	115,204

[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	1985			1986		
	Gross weight (short tons)	Content (short tons)	Value (thousands)	Gross weight (short tons)	Content (short tons)	Value (thousands)
Manganese alloys:						
Ferromanganese containing 1% or less carbon	5,575	4,877	$5,098	18,130	16,179	$16,782
Ferromanganese containing more than 1% to 4% carbon	30,383	24,689	12,923	66,225	54,068	28,483
Ferromanganese containing more than 4% carbon	330,916	257,178	86,368	311,296	240,800	75,216
Ferrosilicon manganese	165,523	[1]109,719	51,423	198,646	[1]131,425	58,839
Spiegeleisen	270	([2])	111	213	([2])	113
Total manganese alloys[3]	532,667	396,463	155,922	594,510	442,472	179,434
Ferrosilicon:						
8% to 30% silicon	345	43	41	103	19	103
30% to 60% silicon, over 2% magnesium	7,586	3,484	4,981	3,797	1,741	2,781
30% to 60% silicon, n.e.c	41,887	20,788	14,590	49,690	24,644	16,717
60% to 80% silicon, over 3% calcium	8,554	5,340	7,714	11,227	6,971	9,846
60% to 80% silicon, n.e.c	96,154	72,228	46,222	156,322	117,620	70,221
80% to 90% silicon	875	754	460	--	--	--
Over 90% silicon	20	19	11	1,892	1,800	910
Total ferrosilicon	155,421	102,656	74,019	223,031	152,795	100,578
Chromium alloys:						
Ferrochromium containing 3% or more carbon	304,829	171,587	131,570	348,443	198,168	139,983
Ferrochromium containing less than 3% carbon	26,236	17,525	24,976	39,969	25,582	32,707
Ferrosilicon-chromium	3,940	1,493	2,085	9,221	3,532	5,743
Total chromium alloys[3]	335,005	190,605	158,631	397,633	227,282	178,432
Ferronickel	36,529	12,742	60,253	37,902	13,056	53,672

See footnotes at end of table.

Table 8.—U.S. imports for consumption of ferroalloys and ferroalloy metals —Continued

Alloy	1985 Gross weight (short tons)	1985 Content (short tons)	1985 Value (thousands)	1986 Gross weight (short tons)	1986 Content (short tons)	1986 Value (thousands)
Other ferroalloys:						
Ferrocerium and other cerium alloys	125	(2)	$1,302	104	(2)	$1,151
Ferromolybdenum	712	473	3,721	800	538	3,626
Ferrophosphorus	--	--	--	(4)	(2)	2
Ferrotitanium and ferrosilicon-titanium	483	(2)	982	681	(2)	1,421
Ferrotungsten and ferrosilicon-tungsten	130	103	951	122	92	1,418
Ferrovanadium	966	778	7,757	736	594	6,423
Ferrozirconium	629	(2)	729	503	(2)	573
Ferroalloys, n.e.c.[5]	4,197	(2)	24,179	3,180	(2)	17,902
Total other ferroalloys[3]	7,241	XX	39,620	6,126	XX	32,515
Total ferroalloys[3]	1,066,863	XX	488,445	1,259,203	XX	544,632
Metals:						
Manganese	8,570	(2)	9,054	9,674	(2)	9,803
Silicon (96% to 99% silicon)	9,354	(2)	9,684	8,856	(2)	8,397
Silicon (99% to 99.7% silicon)	41,563	41,128	42,954	31,263	31,006	31,507
Silicon (over 99.7% silicon)	885	(2)	30,729	732	(2)	25,276
Chromium	3,954	(2)	19,615	4,485	(2)	21,647
Total ferroalloy metals[3]	64,326	XX	112,036	55,010	XX	96,631
Grand total[3]	1,131,189	XX	600,481	1,314,212	XX	641,263

XX Not applicable.
[1]Manganese content only.
[2]Not recorded.
[3]Data may not add to totals shown because of independent rounding.
[4]Less than 1/2 unit.
[5]Principally ferrocolumbium.

Source: Bureau of the Census.

WORLD REVIEW

The European Economic Community (EEC) raised its duty-free quotas of not less than 6% carbon ferrochromium from 231,000 to 314,000 tons, and not less than 4% carbon ferrochromium from 7,700 to 314,000 tons. The EEC 1987 quotas were set at 13,900 tons for ferrosilicon, 20,400 tons for silicomanganese, and 3,250 tons for ferrochromium with less than 0.10% carbon. The quota for charge chrome was not fixed, and an 8% duty will be payable on all imports into the EEC beginning on January 1, 1987, with the exception of material from the European Free Trade Association or Lome convention countries such as Zimbabwe. In September 1986, the EEC announced a package of sanctions against the Republic of South Africa. The EEC responded to its Comité de Liaison des Industries de Ferro-Alliages' dumping complaint against Brazilian ferrosilicon producers and launched an investigation into possible Brazilian dumping of ferrosilicon into the EEC.

Albania.—Albania included an expansion of ferrochromium production in that country's eighth 5-year plan (1986-90). About 39,000 to 44,000 tons of additional capacity was expected to be installed at the state-owned Burrel plant. This expansion would require an additional 110,000 tons of ore per year. The 5-year plan also included a provision to increase ferronickel production by 30% to 40%.[3]

Brazil.—Ferroalloys production in Brazil has increased dramatically in recent years. The Associação Brasileira dos Produtores de Ferroligas (ABRAFE), the Brazilian ferroalloy producers association, reportedly projected that installed ferroalloy capacity was expected to reach about 1.8 million tons per year and that the country's ferroalloy producers would capture 15% to 20% of the world market by the year 2000. Much of the current increase in ferroalloy production has focused on silicon materials. Brazil's main export markets are Japan, the United

States, and the EEC.[4]

The fourth International Ferroalloys Congress (INFACON 86) was held in Rio de Janeiro, from August 31 to September 3, 1986.

In September, Brazil's House of Representatives approved a measure to restrict the participation of foreign companies in mining ventures that involve minerals considered to be of strategic importance to the country. The legislation, if adopted by the Senate and signed by the President, would prohibit foreign firms from owning more than 49% of Brazilian companies.[5]

Brazil's ferroalloy producers dropped their suit against the Government's 20% increase in energy costs. The increase was implemented shortly after the Government instituted its "Cruzado Plan," which changed currency value and froze prices of all domestic products including ferroalloys. The producers were expected to win their case in the Supreme Courts. The action to drop the suit was taken in anticipation that the Government would instigate a long-range energy pricing policy. Present energy supply contracts are signed without knowing what the price will be at any given time.

Several Brazilian ferroalloy producers reportedly joined together to construct a 100,000-kilowatt electric-energy generating plant in Minas Gerais. The producers will build and operate the plant and, thereafter, will pay only for the transportation of energy to their own facilities.

Prometal Produtos Metalúrgicos S.A., a leading ferromanganese producer, and Mineração Benedito Cruz Caniello formed a joint venture to mine manganese ore at Jacutinga in Minas Gerais. The new company, Mineração Morro do Guerreiro Ltda., 60% owned by Prometal, began mining operations in December. The Jacutinga deposit was estimated to contain 1 million tons of ore with 30% manganese. Production was expected to reach about 1,600 tons of refined manganese per month by April 1987. The mine is about 120 miles from Prometal's ferromanganese plant at Aruja, São Paulo. Prometal previously had announced plans to build a 40,000-ton-per-year ferromanganese and silicomanganese plant at Carajás.[6]

In mid-1986, Brazil's state-owned mining company, Cia. Vale do Rio Doce (CVRD), announced plans to construct a 165,000-ton-per-year ferromanganese plant in Carajás. The U.S.S.R. was expected to furnish 50% of the financing for the $100 million plant, which will come on-stream in 1990. In return for its one-half of the financing, the U.S.S.R. will take one-half of the plant's production over a 12-year period. Subsequently, the linkup between CVRD and the U.S.S.R. was criticized by ABRAFE. The association claimed that existing producers already had sufficient capacity to sell 165,000 tons per year to the U.S.S.R. and should be approached first. The producers planned to meet with the Government to discuss the possibility of overturning the agreement with the U.S.S.R. and abandoning construction plans for the plant. However, prefeasibility studies were reportedly under way. In October, Cia. Paulista de Ferro-Ligas announced that it had postponed plans for a 40,000-ton-per-year ferromanganese plant in Carajás. This action came as a result of CVRD's agreement with the U.S.S.R. to build its 165,000-ton-per-year plant in Carajás. Market economy countries looking to Brazil as an alternative source of supply for ferromanganese could have their options further narrowed by this Brazilian-Soviet agreement, in the event of supply disruptions of material from the Republic of South Africa.[7]

Cia. Paulista de Ferro-Ligas planned to spend $1 million to refurbish its No. 3 furnace at its Corumbá plant. The plant was shut down in April because of excessive gas emissions. The plant has a total of three furnaces and produced high-carbon ferromanganese and silicomanganese. Italmagnésio S.A. Indústria e Comércio postponed its plan to start silicon metal production in March indefinitely. Italmagnésio had planned to convert a 24-megavolt-ampere (MV•A) ferrosilicon furnace to produce about 13,000 tons of silicon metal per year.

Ferro-Ligas Assofun S.A. reached an agreement with Nippon Kokan K.K. and Mitsui & Co. Ltd. to set up a joint ferrosilicon manufacturing venture. Under the agreement, the two Japanese firms will hold a 49% interest in Assofun. Assofun planned to build a new 7,500-kilovolt-ampere (kV•A) ferrosilicon furnace at its São João da Boa Vista plant in São Paulo. Ligas de Aluminio S.A. announced plans to increase its silicon metal capacity at its Pirapora plant by building three 21,000-kV•A furnaces with a capacity of about 26,000 tons per year.

Cia. de Ferro-Ligas da Bahia S.A. (FERBASA) announced in June that it planned to invest $10.5 million in the mining of chromium deposits and on modernizing its installations, in anticipation of the export problems that could be faced by the Republic of South Africa. In December, FERBASA reported that a survey of its chromite deposits showed that reserves at the company's Campo Formoso and Jacruici Mines amounted to an estimated 40 million tons and 28 million tons, respectively. FERBASA's 1986 production of H-C-FeCr was about 104,000 tons, compared with about 126,000 tons in 1985. The falloff in production was attributed to periodic repairs to the company's five H-C-FeCr electric furnaces that began in the latter part of the year. Exports of ferrochromium declined in 1986 to about 26,000 tons, compared with about 62,000 tons in 1985, a consequence of increased local demand and the required furnace repairs. FERBASA installed two new 18,000-kV•A ferrosilicon furnaces in 1986, which were brought on-line in the first half of the year. Production of ferrosilicon was expected to be about 26,000 tons per year, most of which was slated for the export market.[8]

Canada.—A feasibility study was conducted on the production of ferrochromium from Bird River chromite concentrates in a submerged-arc electric furnace. Results of the study showed that 46% to 51% ferrochromium could be produced from concentrates of Bird River chromite with a chromium recovery of about 80% to 91%.

China.—Chinese ferrosilicon exporters called upon the Government to remove the 30% export levy on ferrosilicon. The levy was imposed in 1982, and exports of ferrosilicon remained at low levels until 1986. China's exports to Japan in 1986 reached a level of about 15,000 tons. Removal of the levy would put China in a position to export significant tonnages to Europe. Two new ferrosilicon plants were expected to come on-stream in Xibei, Gansu Province, and Hubei Province by the end of 1987. A silicon metal plant with an annual capacity of about 11,000 tons per year was also expected to come on-stream in Qinghai Province by the end of 1987.[9]

The China National Technical Import Corp., Beijing, signed an agreement with Mannesmann Demag Hüttentechnik AG, Duisburg, Federal Republic of Germany, to supply three electric reduction furnaces for the Zunyi ferroalloy plant in the Province of Guizhou. Addition of the furnaces will double the plant's capacity from about 88,000 to about 176,000 tons per year.[10] As part of China's economic development program to increase the output and variety of metal products, equipment was solicited by the Government for the production of 10,000 tons of ferrosilicon per year and 1,000 tons of silicon metal per year at the Chuxiong ferrosilicon plant and for production of 10,000 tons of ferromanganese per year for first-phase production output at the Dounan ferromanganese plant.

Colombia.—Cerro Matoso S.A., Colombia's ferronickel producer, reported that it expected to reach a record-high output of about 21,500 tons of contained nickel in 1986. The plant operated at 80% to 85% of capacity. The company's 1985 output was less than one-half of total capacity because of problems with one furnace. Cerro Matoso was 46.5% owned by Billiton Metals and Ores International BV, which was responsible for all of its ferronickel sales.[11]

Dominican Republic.—The ferronickel producer Falconbridge Dominicana C. por A. (Falcondo) was struck by workers on April 1, Falcondo's first major strike in several years. However, the company resisted worker demands for a pay bonus and the strike ended on May 7. The company reported that about 1 month's output, 5 million pounds of contained nickel, was lost. The plant's normal production was scheduled at about 60 million pounds of contained nickel per year.[12]

Egypt.—Sinai Manganese Co. of Egypt began negotiations with Elkem A/S, Norway, to rebuild the Egyptian ferromanganese smelter on the west coast of the Sinai Peninsula. The plant was just coming into commission in 1967 but was ravaged during the Arab-Israeli war. Manganese ore will be supplied from Sinai Manganese's nearby Abu Zeneima Mine. However, the local ore is relatively poor in manganese, and it will be necessary to use a process that first produces pig iron and leaves a manganese-rich slag, which will be used for ferromanganese production. The plant was expected to be equipped with a 17-MV•A submerged-arc electric furnace. Brown, Boveri & Cie. AG was awarded a contract in 1986 to rehabilitate the gas-fired powerplant and 21-megawatt gas turbine that will supply power to the smelter.[13]

France.—About midyear, Pechiney Électrométallurgie and Chemetals, United States, announced a long-term agreement on the supply of special manganese alloys to Canada, Mexico, and the United States. Under the agreement, Chemetals ceased operations at its Kingwood, WV, plant. Most of the plant's operations had been idle since a flood in November 1985. Chemetals will market Pechiney Électrométallurgie's low-carbon ferromanganese under Chemetals' Massive Manganese trademark.[14]

Pechiney, the parent company, announced in June that it planned to form a new materials research center at Aix-en-Provence in the south of France. The center will enable a number of Pechiney subsidiaries to cooperate in the development of new products. The Chromium Association met in France. The major subject of discussion was the stainless steel industry.

Germany, Federal Republic of.—Bayer AG, an international chemicals producer, announced that it purchased over 90% of Hermann C. Starck Berlin KG, a Berlin-based metals and chemicals processor. Starck, which will remain a separate legal entity, produces charge-grade ferrochromium, ferrocolumbium, ferromolybdenum, ferrotungsten, ferrovanadium, and molybdenum oxide.[15]

Elektrowerk Weisweiler GmbH planned to cease ferrochromium production for the first quarter of 1987. This action was attributed to poor market conditions.

Greece.—Société Minière et Métallurgique de Larymna S.A. (LARCO) began studying a restructuring plan to close down part of its nickel mines and reduce ferronickel production, owing to the low level of nickel prices. LARCO was subject to intermittent labor disruptions during the second half of 1986. The company planned to use its spare furnace capacity to produce ferrochromium, pending approval by the Government of Greece.[16]

India.—OMC Alloys Ltd., a subsidiary of Orissa Mining Corp. Ltd., began operating its 35,000-kV•A furnace in September. OMC Alloys had initially attempted to begin operations in 1985 but had to shut down owing to technical difficulties. Hot furnace gases were planned to be used for preheating the pelletized chromium ore once the operating rate reached about 60%. Technical assistance was provided by Outokumpu Oy, Finland.[17]

Indian Metals and Ferro Alloys Ltd. (IMFA) continued building its ferrochromium plant at Choudar, Cuttack District, Orissa State. The company also was building a coal-fired electric generating plant that was to supply power to IMFA's ferrochromium plants at Choudar and Therubali, Koraput District. The Therubali plant has been restricted to a 15% operating rate, owing to electrical power shortages. Both Orissa State and Karnataka State have suffered power shortages.

Indian Chrome Metals Private Ltd., Rourkela, Sundargarh District, Orissa State, began production of electrolytically produced chromium metal. The plant was equipped with 28 electrodeposition cells, each capable of producing 4 kilograms of metal per day. The plant's annual capacity was rated at about 44 tons per year.

Ispat Alloys Ltd., Balasore, Orissa, commissioned its new silicon metal and calcium silicon plant at Balgopalpur, Orissa. One furnace was expected to produce both products. Carborundum Universal Ltd. began production of silicon carbide at its plant at Koratts in Kerala State. The facility was rated at 3,300 tons per year but could be upscaled to 5,500 tons per year if demand increases.

Indonesia.—State-owned Aneka Tambang P.T. sought technical assistance and new equipment from Sumitomo Metal Mining Co. Ltd., of Japan, for a planned modernization of its ferronickel smelter at Pomalaa. Sumitomo's diagnostic report on the smelter advised renovation of the smelter's electric furnaces and injection of new technology.[18]

Iran.—Iran announced plans to build a 20,000-ton-per-year ferrosilicon plant that was expected to produce 75% ferrosilicon. The smelter will be operated by a new company formed by the state-owned Bank of Industry and Mines. The plant was scheduled to begin production in 1989. The construction contract was awarded to Elkem A/S, of Norway.[19]

Italy.—OET Calusco S.p.A., a subsidiary of Officine Elettrochimiche Trentine S.p.A., in December reversed an earlier decision to reduce ferrotitanium production owing to poor market conditions. The company decided to maintain normal production levels, despite high titanium scrap prices, rather than lose its market share. Liguria Gas purchased Salem Sta. per Azioni Leghe e Metalli, a subsidiary of AMAX Inc., of the United States. Salem produced ferromolybdenum and molybdenum oxide prior to its shutdown in December 1985. The plant, in Spigno Monferrato, was dismantled prior to sale.[20]

Japan.—The Ministry of International Trade and Industry announced in August 1986 that it planned to eliminate the semigovernment stockpile. Japan's metals stockpile program became three-tiered in October 1983, consisting of a Government stockpile, a semigovernment stockpile, and a private industry stockpile. The overall goal of a 60-day stockpile of ferrochromium, manganese, molybdenum, nickel, tungsten, and vanadium was not changed. Under the new program, the Government of Japan would control 42 days' worth of supply, while the industry stockpile would contain 18 days' worth.[21]

Daiichi Fuji Kogyo Co., a Tokyo-based ferrosilicon dealer, filed for voluntary bankruptcy on October 31—an action attributed to a poor market, a global oversupply of ferrosilicon, and a sharp appreciation of the yen.

Mitsui, a ferroalloys trader, and Nippon Commerce Co., a processor of offgrade ferrosilicon, formed a new joint venture company, Metals Supply Corp., and planned to begin a feasibility study with respect to establishing large-scale warehousing facilities in the Kitakyushu area with good access to the sea for shipping. Nippon Kokan and Mitsui agreed to set up a joint venture with Assofun of Brazil to produce ferrosilicon. The two Japanese companies purchased a 49% interest in Assofun. Mitsubishi Metal Corp. and Reactive Metals and Alloys Corp., a U.S. ferroboron producer, formed a joint venture to manufacture neodymium-iron-boron alloys in the United States. The new company, Neomet Corp., was initially capitalized at $2 million, with Mitsubishi Metal holding a 51% interest. Mitsubishi Metal and Mitsubishi Mining and Cement Co. reached an agreement in September to acquire Siltec Corp., a U.S. silicon wafer producer based in Menlo Park, CA. The purchase was about $33 million, of which 70% will be put up by Mitsubishi Metal. The transaction was expected to be formalized in December. Siltec established a joint venture with Rhône-Poulenc S.A. in 1984.

Awamura Metal Industry Co. Ltd. announced that it planned to cease ferrochromium production early in 1987. Awamura, based in Uji, had a production capacity of about 36,000 tons per year from one 25,000-kV•A furnace. The availability of low-price imports was cited as the reason for this action. The company already has idled four furnaces, the last two in 1984. The company planned to continue production of ferrocolumbium, ferrotungsten, and ferrovanadium.[22]

Mexico.—Compañía Minera Autlán S.A. de C.V. planned to increase its production capacity for silicomanganese by converting one of its existing ferrosilicon furnaces. The company has manganese ferroalloys plants at Tamos and Teziutlán.

Norway.—Early in 1986, Elkem A/S announced that it acquired 100% ownership of Orkla Metall A/S and Co. and Orkla's 51% interest in Bjolvefossen A/S. Elkem A/S also established cooperative agreements with Tinfos Jernverk A/S. As a result, the Norwegian ferroalloys producing groups have been reduced to two, Elkem A/S and the Fesil Group. The industry rationalization was expected to establish a better structure in the Norwegian ferroalloys industry and strengthen the international competitiveness of Norwegian producers.

Work resumed at Elkem A/S' ferroalloys plants in Norway after a tentative agreement between the Employers Association of Norway and the central union. The work stoppage began on April 8 and lasted about a week.

In August, A/S Norsk Jernverk, Norway's state-controlled steel producer, announced plans to convert two of its six furnaces at its Mo i Rana works from pig iron production to ferrochromium production. The company, which relies on exports for sales of its pig iron, suffered from quota reductions and falling market shares. Chromite ore was to be obtained from Albania and Turkey. The plant was expected to export all of its production. However, Norsk Jernverk subsequently postponed its conversion plan indefinitely at the request of Norway's Industry Ministry. Tinfos Jernverk announced that it stopped producing both silicon metal and ferrosilicon at its Notodden facility on November 21 for a period of at least 4 weeks. Subsequently, the company indicated that the closure could become permanent unless the Government provided a cut in the electricity tax and some relief on the cost of investments to meet environmental legislation. The decision to close operations was a result of poor market conditions. Finnfjord Smelteverk A/S lost ferrosilicon production from its 24,000-kV•A furnace in November, owing to a transformer breakdown. The furnace was expected to be back in operation by February 1987.

Toward yearend, the Norwegian Government introduced a bill for an economic boycott of the Republic of South Africa. After debate in the Norwegian Parliament, the proposal was expected to become law in about 6 months. The bill included a total ban on transportation of passengers and goods and on investments in the Republic of South Africa. Companies within the metal sector that were dependent on the Republic of South Africa for supplies of ores were exempted for a period of 2 years, provided they changed operations so that they were no longer dependent on South African ores by the end of that period.[23]

Philippines.—Workers at Nonoc Mining and Industrial Corp.'s (NMIC) ferronickel smelter struck the facility on March 22 for higher wages. Subsequently, the Government of the Philippines gave NMIC $20 million to modernize its facility and pay workers about $700,000 in additional benefits. Production was expected to resume in July.

Electro Alloys Corp. (EAC) stopped production at its Ilagan 13,000-ton-per-year ferrosilicon plant on Mindanao Island. EAC, 46.8% owned by Nippon Denko Co. Ltd. and C. Itoh & Co. Ltd., exported its output to Japan. Nippon Kokan and Marubeni Corp. gave up on their plans for a 16,500-ton-per-year ferrosilicon joint venture on Mindanao with Maria Cristina Chemical Industries Inc.

Ferrochrome Philippines Inc. (FPI) experienced intermittent strikes early in 1986. After the strikes, FPI shut down the furnace for repairs. FPI had planned to begin export of about 10,000 tons of high-carbon ferrochromium annually to the United States but was delayed owing to technical problems. Ferro-Chemicals Inc. took under consideration the installation of a 9,000-kV•A furnace for the production of ferrochromium.

Portugal.—Eurominas Electro Metalurgia S.A.R.L., a producer of manganese ferroalloys, temporarily halted production at its Setubal plant in August, owing to weak market conditions and the need for furnace repairs. Cia. Portuguesa de Fornos Eléctricos S.A.R.L., a producer of ferrosilicon and silicon metal, stopped production at its Nelas facility in November when its power supply was turned off. Both Eurominas and Fornos began negotiating their power contracts with the Government.

South Africa, Republic of.—Ferrometals Ltd., a subsidiary of South African Manganese Amcor Ltd. (Samancor), completed construction of its intermediate-carbon ferrochromium plant in the fourth quarter of 1986. The plant is equipped with two decarburizing vessels equipped for bottom blowing with oxygen, with a capacity of about 50,000 tons per year. The basic raw material is liquid high-carbon charge chrome from existing furnaces. The carbon content of the product was expected to range from 1.5% to 5%. Ferrometals' total plant capacity remained unchanged.

Batlhako Ferrochrome (Pty.) Ltd., in Bophuthatswana, planned to start operating its single ferrochromium furnace by the first week of January 1987. The plant's capacity was rated at about 22,000 tons of charge chrome per year. Feed material was expected to be obtained from Samancor's Ruighoek Mine. Another venture, Swazi Chrome (Pty.) Ltd., planned to build a high-carbon ferrochromium plant in Swaziland, pending the outcome of negotiations with the Government of Swaziland. The main obstacle to be cleared is the power supply arrangement for the smelter, which entails building a new 60-mile power distribution line.[24]

Consolidated Metallurgical Industry Ltd. (CMI) was listed on the Johannesburg Stock Exchange and traded on the London Unlisted Securities Market by its parent company, Johannesburg Consolidated Investment Co. Ltd. (JCI). JCI holds 66% of CMI. Anglo American Corp. of South Africa Ltd., DAB Investments, and Allegheny Corp. hold 25%, 4%, and 4%, respectively.

Spain.—Ferroaleaciones Especiales Asturianas S.A. (FERROASTUR) reportedly was studying the possibility of producing ferrolithium. FERROASTUR also was considering participating in the Western European technological program Eureka through the INI Group's Construcciones Aeronáuticas. The company currently produces ferroaluminum, ferromolybdenum, ferrotitanium, and ferrovanadium.[25]

Sweden.—Ferrolegeringar Trollhätteverken AB, a low-carbon ferrochromium producing subsidiary of Metallurg Inc. of the United States, based at Trollhättan, ceased production of ferrochromium. The Trollhättan plant had been producing 25,000 to 30,000 tons annually with a capacity of about 40,000 to 50,000 tons.

SwedeChrome AB, a joint venture to produce high-carbon ferrochromium and supply power as hot water and surplus gas, started operation of its plant by producing pig iron. Pig iron was produced in the process of developing stable operating conditions for the two furnaces. The plant uses plasma torch heating technology developed by SKF Steel Engineering AB and previously applied to stainless steel dust recovery. Ferrochromium production was expected in 1987, at which time different ores were to be tested in the process.

Zimbabwe.—Zimbabwe Alloys Ltd. (Zimalloys) restarted its ferrochromium-silicon furnace owing to strong demand. Zimalloys also converted one of its high-carbon ferrochromium furnaces to ferrochromium-silicon production. Zimalloys planned to convert its silicon furnace to high-carbon ferromanganese production, which was to be used to supply the local market.

Table 9.—Ferroalloys: World production, by country, furnace type, and alloy type[1]

(Thousand short tons)

Country, furnace type,[2] and alloy type[3]	1982	1983	1984	1985[p]	1986[e]
Albania: Electric furnace, ferrochromium[e]	33	39	44	47	51
Argentina: Electric furnace:					
Ferromanganese	27	28	26	26	25
Silicomanganese	17	15	15	8	9
Ferrosilicon	19	17	22	21	21
Other	5	([4])	4	5	5
Total[5]	67	60	67	60	60
Australia: Electric furnace:[6]					
Ferromanganese	60	59	84	76	64
Silicomanganese	33	22	34	30	25
Ferrosilicon	22	21	17	[e]20	17
Total[5]	115	101	135	126	106
Austria: Electric furnace, undistributed	15	15	14	14	15
Belgium: Electric furnace, ferromanganese[e]	[r]94	[r]96	105	99	96
Brazil: Electric furnace:					
Ferromanganese	135	114	117	149	[7]181
Silicomanganese	179	197	205	199	[7]196
Ferrosilicon	157	193	216	206	[7]243
Silicon metal	20	23	30	32	[7]41
Ferrochromium	107	85	138	140	[7]121
Ferrochromium-silicon	3	6	8	10	[7]10
Ferronickel	4	9	10	10	[7]11
Other	16	14	23	26	[7]68
Total[5]	621	641	747	773	[7]871
Bulgaria: Electric furnace:					
Ferromanganese[e 8]	37	33	24	33	35
Ferrosilicon[e]	22	19	17	15	17
Other[e]	1	1	1	1	1
Total[5]	60	53	42	50	53
Canada: Electric furnace:[e]					
Ferromanganese[8]	152	118	128	130	139
Ferrosilicon	116	[7]94	88	93	97
Silicon metal	30	[7]28	28	28	29
Total[5]	298	[7]239	244	250	265
Chile: Electric furnace:					
Ferromanganese	3	6	5	7	[7]7
Silicomanganese	NA	NA	NA	1	[7]2
Ferrosilicon	2	5	7	([9])	--
Other	2	2	2	1	[7]2
Total[5]	6	13	15	8	10
China: Furnace type unspecified:[e 10]					
Ferromanganese[8]	520	540	540	540	540
Ferrosilicon	215	215	215	215	215
Silicon metal	24	24	24	24	24
Ferrochromium[11]	130	130	130	130	130
Other[12]	80	80	80	80	80
Total[5]	970	990	990	990	990
Colombia: Electric furnace, ferrosilicon[e 13]	1	1	1	1	1
Czechoslovakia: Electric furnace:					
Ferromanganese[e 8]	105	103	96	103	101
Ferrosilicon[e]	[r]35	33	[r]33	[r]31	33
Silicon metal[e]	5	5	4	5	6
Ferrochromium[e]	28	28	26	28	28
Other[e 12]	10	10	9	10	9
Total[5 14]	181	179	166	177	176
Dominican Republic: Electric furnace, ferronickel	16	58	71	76	65
Egypt: Electric furnace, ferrosilicon	7	7	8	[e]8	[7]8
Finland: Electric furnace, ferrochromium	60	65	65	147	[7]147

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]	1982	1983	1984	1985[p]	1986[e]
France:					
Blast furnace:					
Spiegeleisen[e]	1	1	1	1	1
Ferromanganese	365	297	362	367	[7]302
Electric furnace:					
Silicomanganese[15]	[r]33	36	38	26	[7]24
Ferrosilicon	186	212	226	217	[7]216
Silicon metal	63	[r]72	78	[r e]77	77
Ferrochromium[11]	[r]42	22	21	1	1
Other[16]	[r]114	[r]117	134	107	[7]85
Total[5]	[r]805	[r]757	860	797	707
German Democratic Republic: Electric furnace:					
Ferromanganese[e 8]	69	69	71	69	75
Ferrosilicon[e]	26	26	26	25	29
Silicon metal[e]	3	4	4	4	4
Ferrochromium[e]	22	19	21	21	24
Other[e 12]	17	20	18	17	17
Total[5 14]	138	141	140	137	149
Germany, Federal Republic of:					
Blast furnace:					
Ferromanganese	220	148	263	179	212
Ferrosilicon[e]	46	44	77	47	53
Electric furnace:[e]					
Ferromanganese[8]	21	19	28	34	33
Ferrosilicon	37	34	66	66	63
Ferrochromium	46	42	77	79	75
Other[12]	40	36	72	67	63
Total[5]	411	323	583	473	498
Greece: Electric furnace:					
Ferrochromium	--	20	36	39	39
Ferronickel[e]	56	55	58	[r]66	66
Total	56	75	94	105	105
Hungary: Electric furnace:[e]					
Ferrosilicon	12	11	10	10	10
Silicon metal	2	2	2	2	2
Other	3	2	2	2	2
Total[14]	17	15	14	14	14
Iceland: Electric furnace, ferrosilicon	46	55	67	67	[7]74
India: Electric furnace:					
Ferromanganese	174	[r]166	134	180	176
Silicomanganese	15	3	35	[e]1	1
Ferrosilicon	44	[r]54	56	44	44
Silicon metal[e]	4	4	[7]3	3	3
Ferrochromium	46	[r]39	61	73	88
Ferrochromium-silicon	[e]5	[r]2	4	14	11
Other	[r]11	[r]([4])	[r]([4])	[e]1	1
Total[5]	[r]300	[r]269	295	316	325
Indonesia: Electric furnace, ferronickel	24	23	25	26	24
Italy: Electric furance:					
Ferromanganese	82	69	56	19	28
Silicomanganese	64	41	80	71	66
Ferrosilicon	70	57	78	83	55
Silicon metal[e]	17	15	15	15	13
Ferrochromium	40	13	14	64	22
Other[17]	13	[r]47	56	17	33
Total[5 17]	286	[r]242	299	270	217
Japan: Electric furnace:					
Ferromanganese	593	429	535	487	[7]396
Silicomanganese	297	245	257	239	[7]164
Ferrosilicon	212	174	169	166	[7]118
Silicon metal	9	--	--	--	--

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]	1982	1983	1984	1985[p]	1986[e]
Japan: Electric furnace —Continued					
Ferrochromium	362	335	357	385	[7]316
Ferronickel	236	199	239	250	[7]221
Other[e]	7	5	7	4	[7]4
Total[5]	1,716	1,387	1,564	1,531	[7]1,218
Korea, North: Furnace type unspecified:[e 10]					
Ferromanganese[8]	77	77	77	77	77
Ferrosilicon	33	33	33	33	33
Other[12]	22	22	22	22	22
Total	132	132	132	132	132
Korea, Republic of: Electric furnace:					
Ferromanganese	66	58	65	68	[7]59
Ferrosilicon	35	36	39	38	[7]34
Other	37	48	55	60	[7]84
Total[5]	139	142	159	167	[7]178
Mexico: Electric furnace:					
Ferromanganese	[r]149	[r]155	177	169	[7]172
Silicomanganese	[r]35	46	46	43	[7]67
Ferrosilicon	[r]27	[r]27	25	30	[7]19
Ferrochromium	7	3	8	7	[7]3
Other	[r]2	[r]2	2	3	[7]2
Total[5]	[r]220	[r]232	258	253	[7]263
New Caledonia: Electric furnace, ferronickel	120	93	[e]125	155	142
Norway: Electric furnace:					
Ferromanganese	224	312	314	237	209
Silicomanganese	238	215	310	267	287
Ferrosilicon	326	407	482	425	[7]389
Silicon metal	72	85	[e]100	[e]112	110
Ferrochromium[e]	11	4	4	--	--
Ferrochromium-silicon[e]	1	([4])	([4])	--	--
Other[e 16]	5	7	4	3	3
Total[5]	876	1,028	1,215	1,045	998
Peru: Electric furnace:					
Ferromanganese	--	([4])	--	([9])	--
Ferrosilicon	--	([4])	--	([9])	--
Total	--	([4])	--	([9])	--
Philippines: Electric furnace:					
Ferrosilicon[e]	30	22	20	[r]22	22
Ferrochromium	13	[r]30	53	56	61
Total	43	[r]52	73	78	83
Poland:					
Blast furnace:					
Spiegeleisen	4	4	4	3	3
Ferromanganese	96	93	99	88	94
Electric furnace:					
Ferromanganese[e 8]	39	53	53	54	54
Ferrosilicon[e]	41	57	56	57	56
Silicon metal[e]	8	11	11	12	12
Ferrochromium[e]	39	53	53	54	54
Other[e 12]	14	19	19	18	18
Total[5 14]	241	290	295	287	291
Portugal: Electric furnace:					
Ferromanganese[e 18]	[7]50	[r]44	[r]51	[r]46	22
Silicomanganese[e 18]	[r]26	[r]20	[r]26	[r]28	11
Ferrosilicon[e]	[r]9	[7]9	[r]10	[r]10	6
Silicon metal[e]	[r]11	[7]11	[r]12	[r]12	8
Other	([4])	([4])	([4])	([4])	([4 7])
Total[5 14]	[r]96	[r]85	99	96	46

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]	1982	1983	1984	1985[p]	1986[e]
Romania: Electric furnace:[e]					
Ferromanganese	83	88	96	88	90
Silicomanganese	39	42	45	43	44
Ferrosilicon	50	53	57	55	56
Silicon metal	4	4	5	5	5
Ferrochromium	43	46	50	49	49
Total[5]	218	234	253	240	244
South Africa, Republic of: Furnace type unspecified:[e 10]					
Ferromanganese	490	160	210	[7]365	[7]372
Silicomanganese	40	160	210	[7]262	300
Ferrosilicon	100	100	120	[7]83	[7]92
Silicon metal	30	25	35	[7]39	[7]39
Ferrochromium	520	800	980	[7]940	[7]1,013
Ferrochromium-silicon	20	15	35	[7]5	6
Other[19]	1	1	([4])	([4 7])	1
Total[5]	1,200	1,260	1,590	[7]1,695	1,822
Spain: Electric furnace:					
Ferromanganese[e]	[7]96	94	94	95	95
Silicomanganese[e]	[7]78	77	77	77	77
Ferrosilicon[e]	[7]70	68	66	67	67
Silicon metal[e]	20	19	66	68	68
Ferrochromium[e]	[7]17	15	15	19	19
Other[e]	[7]6	6	1	4	4
Total[5 14]	286	279	321	331	331
Sweden: Electric furnace:					
Ferrosilicon	16	21	26	31	28
Silicon metal	[r]16	[r]22	22	[r e]22	22
Ferrochromium	129	132	148	149	143
Ferrochromium-silicon	22	20	34	29	28
Other	1	1	1	([4])	([4])
Total[5 14]	[r]184	[r]197	230	232	221
Switzerland: Electric furnace:[e]					
Ferrosilicon	3	2	3	3	3
Silicon metal	2	2	2	2	2
Total	5	4	5	5	5
Taiwan: Electric furnace:					
Ferromanganese	21	24	22	20	[7]22
Ferrosilicomanganese	23	20	25	25	[7]23
Ferrosilicon	19	20	26	19	[7]15
Total[5]	63	65	73	64	[7]61
Turkey: Electric furnace:					
Ferrosilicon[e]	5	5	[7]8	8	8
Ferrochromium	44	33	53	[e]53	55
Total	49	38	61	[e]61	63
U.S.S.R.:					
Blast furnace:					
Spiegeleisen[e]	55	55	55	55	55
Ferromanganese[e]	606	606	606	606	606
Electric furnace:[20]					
Ferromanganese[e]	496	551	661	744	772
Silicomanganese[e]	[r]176	[r]187	[r]198	[r]209	220
Ferrosilicon[e]	750	794	827	827	882
Silicon metal[e]	70	70	70	66	72
Ferrochromium[e]	457	457	463	463	468
Ferrochromium-silicon[e]	11	13	13	13	14
Other[16]	248	250	250	254	265
Total[5]	[r]2,866	[r]2,984	3,144	3,237	3,354

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]	1982	1983	1984	1985[p]	1986[e]
United Kingdom:					
Blast furnace, ferromanganese	67	91	83	85	83
Electric furnace, undistributed[e]	12	14	14	[r]11	11
Total[5]	79	106	97	96	94
United States: Electric furnace:[21]					
Ferromanganese	119	86	[22]171	[22]154	[22]117
Silicomanganese	69	W	([23])	([23])	([23])
Ferrosilicon	299	314	490	442	339
Silicon metal	77	122	141	121	124
Ferrochromium	92	20	[24]95	[24]110	[24]105
Ferrochromium-silicon[25]	27	16	([26])	([26])	([26])
Other[27]	136	198	190	151	130
Total[5]	819	757	1,088	977	816
Uruguay: Electric furnace, ferrosilicon	([4])	([4])	([4])	([4])	([4])
Venezuela: Electric furnace:					
Ferromanganese	2	2	2	[e]2	2
Silicomanganese	2	10	10	[e]8	10
Ferrosilicon	52	51	49	[e]46	51
Total	56	63	61	[e]56	63
Yugoslavia: Electric furnace:					
Ferromanganese	43	44	[e]55	[e]52	50
Silicomanganese	22	29	[e]42	[e]42	44
Ferrosilicon	78	86	[e]105	[e]103	99
Silicon metal	33	29	[e]41	[e]41	44
Ferrochromium	56	70	[e]74	[e]74	72
Ferrochromium-silicon	7	7	[e]7	[e]7	6
Other	4	12	[e]12	[e]12	17
Total[5]	243	277	335	330	[7]331
Zimbabwe: Electric furnace:					
Ferromanganese	2	2	2	2	2
Ferrosilicon	14	30	47	59	55
Ferrochromium	198	174	196	172	171
Total[5]	215	207	245	233	228
Grand total[5]	[r]14,493	[r]14,369	16,514	16,333	16,011
Of which:					
Blast furnace:					
Spiegeleisen[28]	60	60	60	59	59
Ferromanganese[28]	1,354	1,235	1,413	1,325	1,297
Ferrosilicon	46	44	77	47	53
Total blast furnace	1,460	1,339	1,550	1,431	1,409
Electric furnace:[10]					
Ferromanganese[29]	[r]2,942	[r]2,822	3,172	3,143	3,022
Silicomanganese[29 30]	[r]1,363	[r]1,345	1,628	1,554	1,547
Ferrosilicon	[r]3,187	[r]3,363	3,809	3,648	3,515
Silicon metal	[r]525	[r]577	693	690	705
Ferrochromium[31]	[r]2,542	[r]2,674	3,182	3,300	3,252
Ferrochromium-silicon[25 31]	96	[r]79	101	78	75
Ferronickel[32]	456	437	528	583	529
Ferrosilicomanganese	23	20	25	25	23
Other[32]	[r]795	[r]900	964	865	916
Undistributed	27	29	28	25	26

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]	1982	1983	1984	1985[p]	1986[e]
Total electric furnace[5]	[r]11,956	[r]12,246	14,130	13,911	13,611
Furnace type unspecified:					
Ferromanganese[10]	1,087	777	827	982	989

[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 14, 1987.

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

[6]Data for year ending Nov. 30 of that stated.

[7]Reported figure.

[8]Includes silicomanganese.

[9]Revised to zero.

[10]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.

[11]Includes ferrochromium-silicon, if any was produced.

[12]Includes ferrochromium-silicon and ferronickel, if any was produced.

[13]Colombia is reported to produce ferromanganese also, but output is not reported quantitatively, and no basis is available for estimation.

[14]Totals for 1982-86 represent estimates for silicon metal plus reported totals for all other types.

[15]Includes silicospiegeleisen.

[16]Includes ferronickel, if any was produced.

[17]Series excludes calcium silicide.

[18]Estimated figures based on reported exports and an allowance for domestic use.

[19]Ferrovanadium only; other minor ferroalloys may be produced, but no basis is available for estimation.

[20]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.

[21]U.S. production of ferronickel cannot be reported separately in order to conceal corporate proprietary information.

[22]U.S. output of ferromanganese for 1984-86 includes silicomanganese and manganese metal.

[23]U.S. output of silicomanganese for 1984-86 included with ferromanganese.

[24]U.S. output of ferrochromium for 1984-86 includes ferrochromium-silicon, chromium briquets, exothermic chromium additives, other miscellaneous chromium alloys, and chromium metal.

[25]U.S. output of ferrochromium-silicon includes chromium briquets, exothermic chromium additives, other miscellaneous chromium alloys, and chromium metal.

[26]U.S. output of ferrochromium-silicon for 1984-86 included with "Ferrochromium."

[27]Includes ferronickel.

[28]Spiegeleisen for the Federal Republic of Germany is included with "Blast furnace ferromanganese."

[29]Ferromanganese includes silicomanganese (if any was produced) for countries carrying footnote 8 on "Ferromanganese" data line.

[30]Includes silicospiegeleisen for France.

[31]Ferrochromium includes ferrochromium-silicon (if any was produced) for countries carrying footnote 11 on "Ferrochromium" data line.

[32]Includes ferronickel production for France, Norway, the U.S.S.R., and the United States.

TECHNOLOGY

Westinghouse Electric Corp., Pittsburgh, PA, reported that it delivered the largest amorphous metal core power transformer ever built to Niagara Mohawk Power Co. The 500-kV•A prototype transformer contains a stacked core of 1-millimeter-thick amorphous metal sheets, which were reported to be about one-tenth the thickness of silicon-steel sheets used in conventional cores. Researchers estimate that several years of development work would be required before stacked amorphous metal core transformers are commercialized. The Electric Power Research Institute and the Empire State Electric Energy Research Corp. provided financial assistance for this program.[26]

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[1]Physical scientist, Division of Ferrous Metals.

[2]Myers, M. G., Peterson, D. J. S., and R. L. Arnberg. The Effect of a Loss of Domestic Ferroalloy Capacity. Dep. Defense, MDA 903-85-C-0139 (Task AL611), June 1986, p. ii.

[3]Metal Bulletin (London). No. 7138, Nov. 21, 1986, p. 15.

[4]Metals Week. V. 57, No. 37, Sept. 15, 1986, p. 8.

[5]American Metal Market. V. 94, No. 171, Sept. 3, 1986, p. 1.

[6]Mining Journal (London). V. 307, No. 7893, Nov. 28, 1986, p. 396.

[7]Metal Bulletin (London). No. 7131, Oct. 28, 1986, p. 13.

[8]The Tex Report. V. 18, No. 4336, Dec. 8, 1986, p. 11.

[9]———. V. 18, No. 4337, Dec. 9, 1986, p. 2.

[10]Metal Bulletin (London). No. 7110, Aug. 12, 1986, p. 11.

[11]———. No. 7137, Nov. 18, 1986, p. 9.

[12]Metals Week. V. 57, No. 19, May 12, 1986, p. 6.

[13]Mining Journal (London). V. 307, No. 7888, Oct. 24, 1986, p. 306.

[14]Metal Bulletin (London). No. 7095, June 20, 1986, p. 17.

[15]———. No. 7132, Oct. 31, 1986, p. 15.

[16]The Tex Report. V. 18, No. 4339, Dec. 11, 1986, p. 3.

[17]———. V. 18, No. 4296, Oct. 8, 1986, p. 2.

[18]American Metal Market. V. 94, No. 40, Feb. 26, 1986, p. 4.

[19]Metal Bulletin (London). No. 7147, Dec. 23, 1986, p. 11.

[20]Metals Week. V. 57, No. 18, May 5, 1986, p. 6.

[21]———. V. 57, No. 34, Aug. 25, 1986, p. 1.

[22]Metal Bulletin (London). No. 7145, Dec. 16, 1986, p. 15.

[23]———. No. 7137, Nov. 18, 1986, p. 15.

[24]———. No. 7125, Oct. 7, 1986, p. 25.

[25]———. No. 7083, May 7, 1986, p. 15.

[26]33 Metal Producing. V. 24, No. 6, June 1986, pp. 9, 11.

Fluorspar

By Lawrence Pelham[1]

Fluorspar was recovered by one major producer and three small producers. Domestic recovery of fluosilicic acid (H_2SiF_6), a byproduct of some phosphoric acid and hydrofluoric acid (HF) plants, decreased, causing a temporary shortage of water fluoridation chemicals. In the chemical industry, fluosilicic acid continued to augment fluorspar as a source of fluorine.

The United States depended on foreign sources for over 90% of its fluorspar requirements. Imports and consumption were essentially unchanged.

Domestic Data Coverage.—Domestic production 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, fluorspar briquet production, and fluorspar 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, 77% responded, representing 96% of the quantity reported. Of the five briquet producers, 80% responded, representing 77% of the quantity reported. The consumption survey was sent to approximately 80 operations quarterly and 40 additional operations annually. Of the operations surveyed quarterly, approximately 88% responded. Of the 40 operations surveyed annually, 30% responded. Together, quarterly and annual responses represented 90% of the apparent consumption data shown in table 1.

Table 1.—Salient fluorspar statistics[1]

	1982	1983	1984	1985	1986
United States:					
Production:					
Mine production — short tons	199,714	W	W	W	W
Material beneficiated — do.	231,726	W	W	W	W
Material recovered — do.	76,316	W	W	W	W
Finished (shipments) — do.	77,017	[e]61,000	[e]72,000	[e]66,000	[e]78,000
Value, f.o.b. mine — thousands	$13,293	[e]$10,000	W	W	W
Exports — short tons	10,573	9,236	12,266	9,671	16,215
Value — thousands	$1,084	$962	$1,292	$1,063	$1,801
Imports for consumption — short tons	543,723	453,314	703,711	552,959	552,785
Value[2] — thousands	$67,665	$47,032	$65,241	$49,639	$45,675
Consumption (reported) — short tons	530,565	564,187	752,581	567,623	578,837
Consumption (apparent)[3] — do.	618,493	613,705	742,431	682,965	571,288
Stocks, Dec. 31:					
Domestic mines:					
Crude — do.	164,094	W	W	W	W
Finished — do.	10,816	W	W	W	W
Consumer — do.	207,880	99,253	120,267	46,590	89,872
World: Production — do.	[r]4,998,292	[r]4,657,212	5,275,999	[p]5,372,224	[e]5,367,183

[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 inventory was unchanged from 1985 levels at 895,983 short tons of acid grade and 411,738 tons of metallurgical grade. The stockpile goals for fluorspar remained at 1.4 million tons for acid grade and 1.7 million tons for metallurgical grade.

As in previous years, a 22% depletion allowance was granted against Federal income tax applied to the mining of domestic fluorspar compared with a 14% allowance for foreign production.

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. Hastie mined and shipped metallurgical-grade fluorspar. 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.

In the West, J. Irving Crowell, Jr. & Son produced and shipped metallurgical-grade fluorspar from its Crowell-Daisy Mine in Nye County, NV. Machaca Resources Inc., formerly D&F Minerals Co., produced and shipped a small quantity of metallurgical-grade fluorspar from its Paisano Mines, south of Alpine, TX. The Spor Bros. fluorine mine in Millard County, UT, was inactive.

Reported shipments of fluorspar briquets for use in steel furnaces decreased 41% to approximately 87,000 tons valued at $12 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.

Twelve plants processing phosphate rock for the production of phosphoric acid and 1 plant producing HF sold or used 57,000 tons of byproduct fluosilicic acid, which was equivalent to 100,000 tons of fluorspar, valued at $4 million.

The continental United States experienced a shortage of fluoride chemicals for water fluoridation of public drinking water supplies in January and February. The shortage occurred primarily because major phosphate fertilizer producers were idle for most of December 1985 and January 1986. The result was shortages of fluosilicic acid and the solid derivative sodium silicofluoride. Twelve municipal water systems, including those of 7 cities with populations over 100,000, stopped fluoridating for various lengths of time. The Centers for Disease Control sponsored a seminar in June to evaluate the shortage and to propose recommendations to keep the problem from recurring.[2]

CONSUMPTION AND USES

Acid-grade fluorspar, containing greater than 97% calcium fluoride (CaF_2), was used as feedstock in the manufacture of HF, the key ingredient in the manufacture of fluorine chemicals for the aluminum, fluorochemical, and uranium industries. Ceramic-grade fluorspar, containing 85% to 95% CaF_2, was used in the ceramic industry for the production of glass and enamel, to make welding rods, and as a flux in making steel. Metallurgical-grade fluorspar, containing 60% to 85% or more CaF_2, was used primarily by the iron and steel industry as a flux.

Reported domestic consumption of fluorspar was essentially unchanged. The HF and steel industries accounted for 73% and 25%, respectively, of reported consumption. According to the American Iron and Steel Institute (AISI), raw steel production decreased from a revised figure of 88.26 million tons in 1985 to 80.47 million tons in 1986. A comparison of the AISI data with fluorspar consumption data collected in the Bureau of Mines canvass of U.S. steel producers shows, on the average, a decreasing rate of fluorspar consumption per ton of raw steel produced during 1984-86. On the basis of furnace type, the average fluorspar consumption per ton of raw steel was as follows:

Type of furnace	Fluorspar consumption (pounds per short ton)		
	1984	1985	1986
Open hearth	8.61	10.78	13.53
Basic oxygen	3.99	2.68	2.96
Electric	2.94	2.08	2.07
Industry average	4.06	3.08	3.07

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.

Six companies produced HF in six plants. 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 approximately 181,400 tons, compared with the revised 1985 figure of 243,278 tons. HF produced and consumed for captive plant applications in 1985 was reported as 43,817 tons.

The consumption pattern of HF was most recently reported as follows: fluorocarbons, 41%; aluminum production, 31%; petroleum alkylation, 4%; stainless steel production, 4%; uranium processing, 4%; rare metals, 4%; and other, including glass etching, fluoride salts, and herbicides, 12%.[3] Chlorofluorocarbons were produced by five companies. According to U.S. International Trade Commission data, production of trichlorofluoromethane (F-11) increased 14% to 100,600 tons; dichlorodifluoromethane (F-12) output increased 7% to 161,200 tons; and chlorodifluoromethane (F-22) production increased 16% to 137,000 tons, compared with revised 1985 figures.

Another major use of HF was in the synthesis of fluorine chemicals used in aluminum reduction cells. An estimated 40 to 60 pounds of fluorine was consumed for each ton of aluminum produced. Aluminum fluoride was used by aluminum producers to lower the melting point and increase the conductivity of electrolytes in the smelting process. It was also used as a flux ingredient for the removal of magnesium in the refining of aluminum scrap. 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 concentrating uranium isotope 235 for use as nuclear fuel. It was also used in stainless steel pickling, petroleum alkylation, glass etching, oil and gas well treatment, and in the manufacture of a host of fluorine chemicals used in dielectrics, metallurgy, wood preservatives, pesticides, mouthwashes and decay-preventing dentifrices, plastics, and water fluoridation.

Fluosilicic acid was used primarily in water fluoridation, either directly or after being processed to sodium silicofluoride, and by 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	
	1985	1986	1985	1986	1985	1986
Hydrofluoric acid (HF)	408,880	420,180	--	--	408,880	420,180
Glass and fiberglass	1,337	1,230	1,083	897	2,420	2,127
Enamel and pottery	--	W	1,211	2,298	1,211	2,298
Welding rod coatings	9,867	9,100	1,460	2,178	11,327	11,278
Primary aluminum and magnesium	--	W	W	--	W	W
Iron and steel castings	--	--	8,689	5,827	8,689	5,827
Open-hearth furnaces	--	W	34,647	22,528	34,647	22,528
Basic oxygen furnaces	--	W	69,615	70,904	69,615	70,904
Electric furnaces	2,065	1,256	28,087	29,121	30,152	30,377
Other	--	12,607	682	711	682	13,318
Total	422,149	444,373	145,474	134,464	567,623	578,837
Stocks, Dec. 31	37,732	70,304	8,858	19,568	46,590	89,872

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

Table 3.—U.S. consumption (reported) of subacid grades of fluorspar in 1986, 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	1,758	420	--
Glass, ceramic, bricks:			
Glass	897	--	--
Other glass, clay products	2,298	--	--
Primary metals:			
Iron and steel foundries	--	5,633	194
Steel mills:			
Basic oxygen furnaces	5,188	15,773	49,943
Electric furnaces	6,824	22,296	1
Open-hearth furnaces	2,704	19,693	131
Other identified end uses	68	643	--
Total	19,737	64,458	50,269

Table 4.—U.S. consumption of fluorspar (domestic and foreign), by State

(Short tons)

State	1985	1986
Alabama, Kentucky, Tennessee	56,490	72,899
Arizona, Colorado, Utah	9,028	1,906
Arkansas, Kansas, Louisiana, Missouri	125,306	182,853
Connecticut, Massachusetts, New York, Rhode Island	4,108	3,108
Illinois	5,827	8,086
Indiana	37,306	43,316
Ohio	36,538	37,602
Pennsylvania	30,130	30,845
Texas	237,484	178,162
West Virginia	1,633	1,357
Other[1]	23,773	18,703
Total	567,623	578,837

[1]Includes California, Iowa, Maryland, Michigan, New Jersey, Oregon, Virginia, Washington, and Wisconsin.

STOCKS

Fluorspar consumer stocks increased 93% to about 90,000 tons.

PRICES

Domestic producer prices of all grades of fluorspar and fluorspar briquets reported in the Engineering and Mining Journal (E&MJ) remained at 1985 levels. E&MJ yearend price quotations serve as a general guide but do not necessarily reflect actual transactions.

Yearend price quotations in 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. The CMR yearend price for cryolite was $550 per ton. All of these prices were unchanged from those of 1985.

The CMR yearend price quotation for fluosilicic acid was $210.00 per ton in tanks, 100% basis.

Table 5.—Prices of domestic and imported fluorspar

(Dollars per short ton)

	1985	1986
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	179	180
European and South African:[1] Acid, term contracts	140-180	140-180
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

[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. 1985 and 1986.

FOREIGN TRADE

According to Bureau of the Census data, U.S. fluorspar exports of all grades increased 68% and had an average value of $111 per ton. Synthetic cryolite exports, primarily to Canada, were essentially unchanged at 12,700 tons, representing 15,300 tons of equivalent fluorspar, valued at $2.95 million. According to the reported data, the unit value for synthetic cryolite exports decreased $415 per ton to $232 per ton.

Imports for consumption of fluorspar, by weight, were essentially unchanged. Mexico, the largest foreign supplier, increased its share of the U.S. market from 51% in 1985 to 57%. The Republic of South Africa supplied 33%; Spain, 5%; Morocco, 3%; and Kenya, 1%. Small quantities were also imported from Brazil, Canada, France, the Federal Republic of Germany, Italy, Malaysia, and the United Kingdom. The absence of China in all grades and Italy in acid grade as U.S. suppliers was unexpected, as was the return of Kenya as a supplier. The average unit value, in dollars per ton, of imported acid- and subacid-grade fluorspar was $90.63 and $54.80, respectively, representing decreases of 7% and 14%, 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 grades.

Imports for consumption of HF increased 10% to a quantity equivalent to about 172,000 tons of fluorspar with an average unit c.i.f. value of $867 per ton. Imports for consumption of natural and synthetic cryolite decreased 32% and had an average c.i.f. value of $613 per ton. Cryolite imports represented 14,000 tons of equivalent fluorspar.

The United States also imported many fluorochemicals, including ammonium bifluoride, chlorodifluoromethane, dichlorodifluoromethane, fluorocarbon polymers, hexafluoropropylene, polytetrafluoroethylene, and trichlorodifluoromethane.

Table 6.—U.S. exports of fluorspar, by country

Country	1985		1986	
	Quantity (short tons)	Value	Quantity (short tons)	Value
Australia	33	$3,287	19	$1,914
Canada	8,503	851,036	14,969	1,546,600
Dominican Republic	1,018	185,447	1,186	245,361
Ghana	--	--	21	3,990
Mexico	25	3,287	--	--
Venezuela	90	19,563	20	3,177
Total	[1]9,671	1,062,620	16,215	1,801,042

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

Source: Bureau of the Census.

Table 7.—U.S. imports for consumption of fluorspar, by country and customs district

Country and customs district	1985		1986	
	Quantity (short tons)	Value[1] (thousands)	Quantity (short tons)	Value[1] (thousands)
CONTAINING MORE THAN 97% CALCIUM FLUORIDE (CaF_2)				
Canada:				
Buffalo	24	$1	4	$2
Laredo	437	41	--	--
Total	461	42	4	2
China: New Orleans	5,882	551	--	--
France: Houston	517	199	138	55
Germany, Federal Republic of: Milwaukee	--	--	3	2
Italy:				
Houston	15,765	1,557	--	--
New Orleans	2,480	259	--	--
Total	18,245	1,816	--	--
Kenya:				
Houston	--	--	6,468	878
New Orleans	--	--	1,456	135
Total	--	--	7,924	1,013
Mexico:				
Baltimore	--	--	455	27
El Paso	72,255	6,657	92,982	8,625
Houston	6,112	675	--	--
Laredo	95,580	8,967	84,324	7,384
New Orleans	3,451	194	16,284	1,469
Nogales	290	6	--	--
Total	177,688	16,499	194,045	17,505
Morocco: New Orleans	15,674	1,564	16,132	1,405
South Africa, Republic of:				
Houston	36,772	3,259	28,292	2,422
New Orleans	132,245	13,598	138,554	12,173
Philadelphia	12,085	1,294	14,732	1,432
Total	181,102	18,151	181,578	16,027
Spain:				
Cleveland	12,968	1,337	6,562	880
New Orleans	19,449	1,794	22,957	2,021
Total	32,417	3,131	29,519	2,901
United Kingdom: Milwaukee	24	2	--	--
Grand total	432,010	41,955	429,343	38,910
CONTAINING NOT MORE THAN 97% CALCIUM FLUORIDE (CaF_2)				
Brazil: New York	--	--	9	8
Canada:				
Buffalo	284	19	--	--
Detroit	153	6	242	15
Pembina	97	11	--	--
Total	534	36	242	15
China: Baltimore	16,831	1,334	--	--
Germany, Federal Republic of: Chicago	37	15	--	--
Italy: New York	--	--	283	9
Malaysia: Laredo	--	--	147	7
Mexico:				
Buffalo	1,318	82	--	--
Detroit	2,555	137	2,217	139
El Paso	9,453	441	8,411	510
Laredo	23,204	1,325	22,241	1,007
New Orleans	57,148	3,754	78,808	4,433
Philadelphia	9,869	560	9,737	627
Total	103,547	6,299	121,414	6,716

See footnotes at end of table.

Table 7.—U.S. imports for consumption of fluorspar, by country and customs district—Continued

Country and customs district	1985		1986	
	Quantity (short tons)	Value[1] (thousands)	Quantity (short tons)	Value[1] (thousands)
CONTAINING NOT MORE THAN 97% CALCIUM FLUORIDE (CaF_2)—Continued				
United Kingdom:				
Boston	--	--	1,346	$7
Houston	--	--	1	3
Total	--	--	1,347	10
Grand total	120,949	$7,684	123,442	6,765

[1]Customs, insurance, and freight (c.i.f.) value at U.S. port.

Source: Bureau of the Census.

Table 8.—U.S. imports for consumption of hydrofluoric acid (HF), by country

Country	1985		1986	
	Quantity (short tons)	Value[1] (thousands)	Quantity (short tons)	Value[1] (thousands)
Canada	36,637	$33,869	35,433	$33,448
Germany, Federal Republic of	119	112	362	380
Japan	4,137	2,859	5,214	6,303
Korea, Republic of	17	13	--	--
Mexico	62,504	56,233	73,086	58,539
Mozambique	601	533	--	--
Netherlands	20	18	--	--
Spain	35	28	--	--
Taiwan	17	16	--	--
United Kingdom	324	336	701	893
Total	104,411	94,017	114,796	[2]99,561

[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 9.—U.S. imports for consumption of cryolite, by country

Country	1985		1986	
	Quantity (short tons)	Value[1] (thousands)	Quantity (short tons)	Value[1] (thousands)
Canada	2,414	$1,287	3,929	$2,025
China	--	--	50	23
Denmark	3,737	2,492	4,032	2,270
Germany, Federal Republic of	666	380	144	99
Italy	3,327	1,960	--	--
Japan	5,169	3,244	2,826	2,308
Netherlands	907	532	137	97
United Kingdom	376	108	40	21
Other	--	--	186	116
Total	16,596	10,003	11,344	6,959

[1]Customs, insurance, and freight (c.i.f.) value at U.S. port.

Source: Bureau of the Census.

WORLD REVIEW

Brazil.—E. I. du Pont de Nemours & Co. Inc. was developing fluorspar deposits and building a flotation mill in Paraná State. The flotation plant was designed for an initial capacity of 55,000 tons per year of acid-grade fluorspar. Metallurgical-grade fluorspar production was also planned.

Canada.—Minworth Ltd., a British firm, continued development work to reopen a fluorspar mine near St. Lawrence, Newfoundland. The mine had been operated for the last time in 1977 by the St. Lawrence Corp. and Newfoundland Fluorspar Ltd., formerly a subsidiary of Aluminum Co. of Canada Ltd. A new flotation mill was designed with a capacity of 100,000 tons per year of acid-grade fluorspar. Commercial operation was expected to begin in the first half of 1987.

Japan.—Du Pont announced construction of a new plant in Utsunomiya to manufacture perfluoroelastomer parts. The parts are used as fluid seals in the chemical, semiconductor, chemical transportation, aircraft, and atomic energy industries. Du Pont, in a joint venture with Showa Denko K.K., announced plans to construct a 1-million-pound-per-year capacity precompounding facility for fluoroelastomers at the Kawasaki Works near Tokyo.[4]

Kenya.—Laboratory tests, conducted by Robertson Research International Ltd. of Llandudno in North Wales, showed that the phosphorus content of fluorspar produced by Kenya Fluorspar Co. Ltd. could be reduced from 0.45% to 0.05%. The high phosphorus content of Kenya's fluorspar has in the past severely restricted its marketability.[5]

Mexico.—Applied Industrial Materials Corp. acquired International Minerals & Chemical Corp.'s Industry Group, which included a 49% ownership of Fluorita de México S.A. and a 40% interest in Fluorita de Río Verde S.A. Minera Muzquiz S.A. de C.V. began operation of a facility with a capacity of 20,000 tons per year of acid-grade fluorspar containing little or no arsenic. Grupo Industrial Camesa S.A. de C.V., a major wire rope producer, became owner of Cía. Minera Las Cuevas S.A. de C.V., Mexico's largest fluorspar producer. By the same transaction, Noranda Inc. became owner of 41% of Camesa. Noranda continued to market Las Cuevas fluorspar.

Spain.—Fluoruros S.A., Spain's second largest producer, discontinued production in September for economic reasons.

Thailand.—Thai Fluorite Processing Co. Ltd. discontinued operation of its flotation plant for economic reasons.

Table 10.—Sales of Mexican fluorspar, by grade

(Short tons)

Grade	1982	1983	1984	1985	1986
Acid	338,732	400,579	508,235	409,800	427,181
Ceramic	27,202	49,285	54,562	51,982	51,541
Metallurgical	120,478	117,190	230,375	309,490	246,226
Submetallurgical	116,030	93,563	117,113	57,779	73,242
Total	602,442	660,617	910,285	829,051	798,190

Source: Instituto Mexicano de la Fluorita A.C.

Table 11.—Fluorspar: World production, by country[1]

(Short tons)

Country[2] and grade[3]	1982	1983	1984	1985[p]	1986[e]
Argentina	26,155	31,950	25,526	[e]27,500	26,500
Brazil (marketable):					
Acid grade	[r]35,120	[r]48,439	48,878	47,048	48,500
Metallurgical grade	[r]21,183	[r]29,415	34,578	32,754	33,000
Total	[r]56,303	[r]77,854	83,456	79,802	81,500
China:[e]					
Acid grade	88,000	110,000	110,000	110,000	110,000
Metallurgical grade	440,000	440,000	606,000	606,000	606,000
Total	528,000	550,000	716,000	716,000	716,000
Czechoslovakia[e]	106,000	106,000	106,000	105,000	105,000
Egypt	99	13	893	94	110
France:					
Acid and ceramic grades	177,725	155,957	175,378	175,267	176,000
Metallurgical grade	90,825	60,488	80,469	80,193	83,000
Total	268,550	216,445	255,847	255,460	259,000

See footnotes at end of table.

Table 11.—Fluorspar: World production, by country[1] —Continued

(Short tons)

Country[2] and grade[3]	1982	1983	1984	1985[p]	1986[e]
German Democratic Republic[e]	110,000	110,000	110,000	110,000	110,000
Germany, Federal Republic of (marketable)	86,685	88,964	91,787	91,644	92,600
Greece[e]	330	330	330	330	330
India:					
Acid grade	13,676	[e]12,000	[e]13,000	12,243	12,100
Metallurgical grade	6,294	[e]5,000	[e]6,000	5,511	5,500
Total	19,970	[e]17,000	[e]19,000	17,754	17,600
Italy:					
Acid grade	147,850	113,439	121,618	105,215	[4]100,200
Metallurgical grade	36,180	82,409	85,904	62,569	[4]60,116
Total	184,030	195,848	207,522	167,784	[4]160,316
Kenya: Acid grade	97,804	65,129	51,343	64,126	66,100
Korea, North: Metallurgical grade[e]	44,000	44,000	44,000	44,000	44,000
Korea, Republic of: Metallurgical grade	4,042	7,012	5,150	777	550
Mexico:					
Acid grade	450,845	448,640	379,725	417,469	[4]466,954
Ceramic grade	59,525	50,706	40,307	30,011	[4]14,984
Metallurgical grade	182,983	80,469	235,079	297,897	[4]290,076
Submetallurgical grade[5]	116,845	87,082	115,878	57,779	[4]73,263
Total	810,198	666,897	770,989	803,156	[4]845,277
Mongolia: Metallurgical grade[e]	739,000	772,000	816,000	816,000	816,000
Morocco: Acid grade	55,336	66,469	72,642	81,956	82,700
Pakistan	897	([6])	3,002	3,499	6,600
Romania: Metallurgical grade[e]	22,000	22,000	22,000	22,000	22,000
South Africa, Republic of:					
Acid grade	323,882	256,563	318,892	341,949	331,000
Ceramic grade	10,613	7,061	4,963	6,310	10,700
Metallurgical grade	30,188	31,356	28,010	36,676	33,000
Total	364,683	294,980	351,865	384,935	374,700
Spain:					
Acid grade	[r]217,761	210,265	279,128	294,068	298,000
Metallurgical grade	40,868	45,840	46,788	42,808	33,000
Total	[r]258,629	256,105	325,916	336,876	331,000
Thailand:					
Acid grade	89,314	51,466	62,998	39,506	28,000
Metallurgical grade	194,099	176,324	253,783	289,972	253,000
Total	283,413	227,790	316,781	329,478	281,000
Tunisia: Acid grade	36,607	37,493	49,064	44,767	44,100
Turkey: Metallurgical grade[e]	2,200	2,200	2,200	2,200	2,200
U.S.S.R.[e]	595,000	595,000	606,000	617,000	617,000
United Kingdom	221,344	144,733	150,686	184,086	187,000
United States (shipments)[e]	[4]77,017	61,000	72,000	66,000	78,000
Grand total	[r]4,998,292	[r]4,657,212	5,275,999	5,372,224	5,367,183

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

[1]Table includes data available through May 12, 1987.

[2]In addition to the countries listed, Bulgaria is believed to have produced fluorspar and Uruguay has 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.

[6]Revised to zero.

TECHNOLOGY

An inorganic chemist for Rockwell International Corp. generated for the first time a significant amount of elemental fluorine by chemical synthesis. The discovery is not expected to supplant the process for electrochemical production of fluorine, discovered by Henri Moissan 100 years ago, but is significant because a chemical isolation had been sought for nearly two centuries and was thought impossible.[6]

Reagents that fluorinate aromatic rings at room temperature and in 80% to 95% yields have been developed at Clemson University. The present fluorination method requires the reaction to be made at low temperature and therefore at higher cost. The new method, by reducing the cost of these reagents, has potential for use in making drugs, pesticides, and plant growth regulators.[7]

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[1]Physical scientist, Division of Industrial Minerals.

[2]Centers for Disease Control. Fluorine Chemical Shortage Seminar, June 17, 1986, Summation of Comments. Sept. 29, 1986, 7 pp.; available from T. C. Reeves, Dental Disease Prevention Activity, Centers for Disease Control, Atlanta, GA.

[3]Chemical Marketing Reporter. V. 228, No. 10, 1985, p. 50.

[4]———. V. 229, No. 16, 1986, p. 3.

[5]Mining Journal (London). V. 306, No. 7862, 1986, p. 305.

[6]Chemical & Engineering News. V. 64, No. 37, 1986, pp. 23-24.

[7]———. V. 64, No. 4, 1986, p. 20.

Gallium

By Deborah A. Kramer[1]

Domestic gallium consumption increased dramatically from that of 1985. Although one company recovered a small quantity of gallium from a mine in Utah, the United States was heavily reliant on imports to meet its demand. Gallium imports more than doubled from those of 1985, and France replaced Switzerland as the largest supplier to the United States. Several companies announced plans to either construct new gallium extraction plants or increase existing capacity within the next 2 years. New gallium plants were planned in Australia, Canada, and Norway, and expansions were scheduled in the Federal Republic of Germany and Hungary.

Most gallium consumed in the United States was manufactured into advanced materials, such as gallium arsenide, for electronic and other applications. Developments in gallium arsenide-based semiconductors were concentrated on new fabrication techniques to improve the electrical and optical properties of the resulting integrated circuits. These integrated circuits could be used in a wide variety of advanced technology applications including lasers, fiber-optic communications systems, satellite communications, solar cells, and optical computers.

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 50 operations to which a survey request was sent, 78% responded, representing 34% of the consumption shown in tables 1, 2, and 3. Consumption for the 11 nonrespondents was estimated using import data and information on domestic consumption trends.

Table 1.—Salient U.S. gallium statistics

(Kilograms unless otherwise specified)

	1982	1983	1984	1985	1986
Production[e]	1,560	--	--	--	[1]750
Imports for consumption	5,199	7,294	9,669	7,961	17,202
Consumption	6,660	6,425	7,060	7,396	16,043
Price per kilogram	$630	$525	$525	$525	$525

[e]Estimated.
[1]Reported figure.

DOMESTIC PRODUCTION

Only one company recovered crude gallium domestically in 1986. Musto Explorations Ltd.'s subsidiary company, St. George Mining Corp., reportedly made its first shipment of a small quantity of gallium recovered from its mine and processing plant in St. George, UT, on April 14. Because of technical problems and delays in equipment delivery, the plant did not produce at its full 9,000-kilogram-per-year capacity. By June, the plant reportedly was operating at a rate of 48 kilograms per month. In July, the purification section of the gallium refinery was modified, and the purity of the gallium product had improved from 99.9% to 99.99% (sometimes referred to as "4 nines" or "4N"). Musto also announced that it made its first shipment of germanium dioxide in August. Recovery rates for both gallium and germanium were well below the projected recovery rates, and sales of the products reportedly were not generating enough working capital for the plant. A pressure-leaching system was proposed to improve recovery rates. Musto's mine was the only operation in the world to recover gallium and germanium as principal products.

Eagle-Picher Industries Inc. recovered and refined gallium from primary and secondary materials at its plant in Quapaw, OK.

CONSUMPTION

Consumption of gallium increased dramatically, and most of this increase was in electronic uses. About 93% of domestic gallium consumption was in the form of compounds, mainly gallium arsenide, for semiconductors, light-emitting diodes, and laser diodes.

Rhône-Poulenc S.A. announced plans to construct a gallium refinery in Freeport, TX. Completion of the plant was scheduled for the second half of 1988. This plant reportedly will have an annual capacity greater than current world demand, which is estimated to be about 45,000 to 50,000 kilograms, and crude gallium feed would be supplied by Rhône-Poulenc's new gallium extraction plant in Australia.

Alcan Aluminum Corp. announced plans to sell Cryscon Technologies Inc., its wholly owned subsidiary in Phoenix, AZ, which manufactured gallium arsenide substrates. Alcan stated that despite increasing sales, Cryscon did not meet the company's goals for developing business in the electronics market. However, Alcan reportedly planned to expand Epitronics Corp., its epitaxial gallium arsenide wafer facility in Phoenix, AZ, by purchasing additional reactors and increasing production facilities.

In May, Hughes Aircraft Co. reportedly began construction of a new facility to process gallium arsenide monolithic microwave integrated circuits in Torrance, CA. The cost of the new plant was projected to be greater than $10 million, and the facility will have the capability to process 100 3-inch-diameter wafers per week.

Martin Marietta Corp. and Alpha Industries Co. announced their intent to form a joint venture to develop reliable gallium arsenide integrated circuits for millimeter-wave radar applications. Millimeter-wave radar uses higher frequencies than those found in conventional radar, enabling guidance systems to pinpoint objects with a high degree of accuracy. The companies expected that the joint venture would shorten the time required to develop marketable products for use in military search systems and communications systems. Alpha was a manufacturer of microwave and millimeter-wave components for defense electronics, and Martin Marietta designed and manufactured communications, defense, electronics, and space systems.

A new firm, GAIN Electronics Inc., reportedly was formed to design, develop, and manufacture gallium arsenide integrated circuits that use a special device structure—a selectively doped heterostructure transistor—to provide ultrafast switching speeds. These devices also reportedly were radiation hard, stable over a wide temperature range, and used very little power. Commercial chip production was scheduled to begin in 1987 at a new facility in Branchburg, NJ.

Grumman Aerospace Co. and Ethyl Corp. planned to start a research and development project to produce gallium arsenide crystals in space. The companies believed that gallium arsenide crystals with improved properties could be manufactured in the reduced-gravity conditions that exist in space. The first test flight was proposed for 1988, and properties such as crystal uniformity and electronic performance characteristics of the space-grown crystals would be compared with those of crystals grown on the Earth.

Table 2.—U.S. consumption of gallium, by end use

(Kilograms)

End use	1984	1985	1986
Electronics[1]	6,320	7,071	14,920
Research and development	641	260	1,048
Specialty alloys	42	65	75
Unspecified	57	--	--
Total	7,060	7,396	16,043

[1]Lasers, light-emitting diodes, semiconductors, and other electronic devices.

Table 3.—Stocks, receipts, and consumption of gallium[1]

(Kilograms)

Purity	Beginning stocks	Receipts	Consumption	Ending stocks
1985:				
97.0% to 99.9%	105	65	65	105
99.99%	57	r386	419	r24
99.999%r	252	588	729	111
99.9999% to 99.99999%	760	r6,389	r6,183	r966
Total	r1,174	r7,428	7,396	r1,206
1986:				
97.0% to 99.9%	105	75	75	105
99.99%	24	64	86	2
99.999%	111	1,297	1,313	95
99.9999% to 99.99999%	966	14,214	14,569	611
Total	1,206	15,650	16,043	813

rRevised.
1Consumers only.

PRICES

The price of 99.99999%-pure (7N) gallium metal, quoted in American Metal Market (AMM), remained at $525 per kilogram in 100-kilogram lots throughout the year. At yearend, prices for the following gallium materials were published by AMM, in dollars per kilogram: gallium metal, 4N, in 100-kilogram lots, $435; gallium metal, 99.9999% pure (6N), imported, $460 to $490; gallium oxide, 4N, imported, $400 to $420; and gallium oxide, 99.999% pure (5N), $435.

Quoted prices for 6N metal and 4N and 5N gallium oxide increased from those at yearend 1985. The metal price increased by $30 per kilogram, and both oxide prices increased by $20 per kilogram.

FOREIGN TRADE

Export data for gallium metal and compounds were combined with data for other metal exports by the Bureau of the Census and could not be separately identified. Through the Journal of Commerce Trade Information Service-PIERS, a computer data base service, some exports of gallium could be identified; however, this service only contains information on materials that are transported by ship and may not reflect the total quantity of gallium exported. According to the information obtained from PIERS, 2,302 kilograms of gallium was exported, mainly as scrap metal. Small quantities of gallium were exported in the form of gallium arsenide scrap and gallium compounds such as trimethylgallium and triethylgallium. Primary destinations were the Federal Republic of Germany and the Netherlands.

Imports of gallium metal and waste and scrap more than doubled from those of 1985. France, Switzerland, and the Federal Republic of Germany, in decreasing order, accounted for almost 97% of U.S. imports. The average declared value of imported gallium decreased to $404 per kilogram in 1986 from $433 per kilogram in 1985.

Beginning January 1, 1986, import duties for gallium compounds and gallium metal (TSUS 423.00 and TSUS 632.24, respectively) were 3.9% ad valorem for most favored nations (MFN) and 25% ad valorem for non-MFN.

Table 4.—U.S. imports for consumption of gallium (unwrought, waste and scrap), by country

Country	1985		1986	
	Kilograms	Value	Kilograms	Value
Belgium-Luxembourg	55	$19,800	--	--
Canada	3	4,191	98	$52,095
France	1,563	711,496	8,231	3,114,144
Germany, Federal Republic of	1,423	587,876	2,740	1,176,562
Hungary	--	--	17	2,580
Japan	105	29,351	123	45,328
Malaysia	40	14,400	--	--
Netherlands	50	19,725	--	--
Suriname	30	15,100	--	--
Sweden	201	112,302	5	4,390
Switzerland	4,268	1,847,744	5,640	2,490,483
Taiwan	50	17,000	--	--
United Kingdom	163	49,017	348	68,769
Other	10	19,080	--	--
Total	7,961	3,447,082	17,202	6,954,351

Source: Bureau of the Census.

WORLD REVIEW

World production data for gallium were unavailable, but world production of primary gallium was estimated to be about 35,000 kilograms.

Australia.—Rhône-Poulenc announced that it planned to construct a primary gallium extraction plant in Pinjarra, Western Australia, with a capacity greater than current world consumption, which is estimated to be 45,000 to 50,000 kilograms. Gallium reportedly will be extracted from sodium aluminate liquors generated by Alcoa of Australia Ltd.'s alumina refinery at the same location by a proprietary liquid-liquid extraction process, which was used at Rhône-Poulenc's primary gallium plant in Salindres, France. Operations were scheduled to begin in the second half of 1988. Crude gallium produced in Australia reportedly will supply Rhône-Poulenc's gallium refinery in Freeport, TX, which will produce 6N and 7N gallium for U.S. markets.

West Coast Holdings Ltd. reportedly completed a preliminary feasibility study on construction of a plant in Kimberley, Western Australia, to process ore containing significant quantities of columbium, gallium, hafnium, rare earths, tantalum, yttrium, and zirconium. The plant, which will process 1,000 metric tons per day of ore, reportedly will use a hydrometallurgical leaching technique to recover the metals and could produce 37,000 kilograms of gallium annually. Exploration of the deposit has delineated a proven reserve of 4.29 million tons of ore. West Coast Holdings owned 50% interest in the property, and Greater Pacific Investment Ltd. held the remaining 50% interest and was a substantial shareholder of West Coast Holdings.[2]

Canada.—Alcan Aluminium Ltd. announced plans to construct a gallium extraction plant at its Jonquière, Quebec, alumina refinery with an annual capacity of 4,000 kilograms of 4N gallium metal. This facility was scheduled to be completed in 1988, and capacity could be expanded to 15,000 kilograms per year by 1989. Alcan reportedly will ship the 4N gallium to its refinery in Rorschach, Switzerland, where it will be purified to 6N and 7N gallium. Alcan also announced the completion of a gallium recycling plant in Kingston, Ontario, to recover between 4,000 and 5,000 kilograms per year of gallium from gallium arsenide scrap.

Germany, Federal Republic of.—Ingal International Gallium GmbH reportedly completed an expansion at its Schwandorf refinery to increase capacity by 50%. Total annual capacity, including secondary recovery, was estimated to be 12,000 kilograms at yearend. Ingal also was conducting an engineering feasibility study for a new primary gallium extraction plant to replace an existing facility in Lünen. The Lünen plant was scheduled to close in 1988 when the Vereinigte Aluminium Werke AG alumina refinery, which supplied the feed material, was scheduled to close.

Hungary.—The Hungarian Aluminium Corp. reportedly planned to construct a new plant to double its primary gallium extraction capacity to 8,000 kilograms per year by 1988. The cost of the new plant, to be built at Ajka, was estimated to be $2.2 million, and gallium reportedly will be recovered by a cementation process rather than the current process that uses mercury. Most of the gallium production was exported to Japan and the United States.

Japan.—Total gallium demand was estimated to be 25,000 kilograms in 1986, a drop of 32% from that of 1985. This steep decline was attributed to lower gallium consumption for semiconductors and adjustments in stocks, which were high because of excessive purchases in 1985. Imports for January through July 1986 totaled 7,250 kilograms and were received from China, Czechoslovakia, France, and the Federal Republic of Germany.[3]

Because of closures of aluminum smelters in Japan, alumina production also has declined. Sumitomo Chemical Co. Ltd., the country's largest gallium producer, reportedly closed its last operating alumina refinery in October; consequently, the company had no Bayer liquor from its alumina refinery to use as feed for its gallium extraction circuit.[4]

Norway.—Elkem A/S announced that it will construct a 5,000-kilogram-per-year gallium extraction facility at its aluminum smelter in Bremanger. The $2.3 million plant was scheduled to be on-stream in 1987 and reportedly will use waste materials from Elkem's aluminum smelters as feed for the gallium plant.

TECHNOLOGY

A method to make crystals for electronic devices in a single chamber reportedly was developed by researchers at Illinois' Northwestern University. Unlike the currently used liquid-phase epitaxy method that required physically moving the crystals from one reaction chamber to another as various layers were applied, the new technique, called flow-modulation vapor phase epitaxy, built layers in a single reactor, eliminating contamination and damage that might occur during transfer between reactors. The new method reportedly produced crystals that had uniform thicknesses and few defects. Although this method was initially tested on indium phosphide, it could be applied to gallium arsenide and silicon.

Researchers at American Telephone & Telegraph Co.'s (AT&T) Bell Laboratories reportedly developed an optical transistor capable of controlling light beams in essentially the same way a transistor controls electrical current. Each chip was constructed by alternating thousands of layers of gallium arsenide and aluminum gallium arsenide, each 40 atoms thick. The resulting material had properties different from either of the two raw materials. When a voltage was applied, the optical transistor became transparent, allowing a laser beam to shine through. A second, less powerful beam directed at the transistor had the effect of concentrating the electrical voltage in certain layers that then became opaque. Thus, the weaker beam controlled the transmission of the stronger signal beam. The outgoing light beam may be used as an input for the next device, and this could be important in developing optical computing devices that use the output of one transaction as the input to the next. One application for this type of transistor may be in AT&T's central office telephone switching machines. As more and more transmission lines were converted to fiber-optic systems, which transmitted energy in the form of light, the need to avoid converting from optical to electrical energy and back again would become important.

Toshiba Corp. reportedly produced highly uniform 3-inch-diameter gallium arsenide ingots by a new method using a superconductive magnet. Application of a magnetic field while growing crystals by the conventional Czochralski method limited temperature fluctuations to 1° C and resulted in uniform carbon distribution throughout the ingot. Gallium arsenide wafer production from each ingot reportedly could be increased from 10 to 50 wafers per ingot.[5]

In an improved design for a gallium arsenide integrated circuit, researchers at the National Aeronautics and Space Administration's Jet Propulsion Laboratory reportedly have replaced the customary silica insulating layer with a gallium arsenide layer. Because of the difference between the thermal expansions of silica and gallium arsenide, the device may be damaged when cooled from room temperature to a cryogenic operating temperature when silica is used for the insulating layer. With small variations caused by doping, the crystal lattice and thermal expansion of the two gallium arsenide layers matched closely at all temperatures.[6]

The U.S. Department of Defense reportedly planned to begin a $135 million program to develop usable gallium arsenide chips in 1988 because of increased demand for gallium arsenide-based integrated circuits for electronic applications in aircraft, missiles, and satellites. In the program, known as Mimic, private companies already engaged in gallium arsenide research and development will use the funds to accelerate their development activities.[7]

Scientists at Varian Associates Inc.'s Research Center reportedly developed a solar cell that converted more than 21% of available sunlight into electricity. The previously verified record was 19%, held by researchers in Japan. The new solar cells were composed of layers of aluminum gallium arsenide and gallium arsenide, fabricated by metal organic chemical vapor deposition (MOCVD). An increase of two percentage points reportedly would increase the power available for a satellite payload by 10%, permitting it to carry more instrumentation and perform more tasks. Gallium arsenide-based solar cells were twice as resistant to heat as those made of silicon, so they could operate in higher orbits, and they were more resistant to radiation in space.

A review of developments made in technology for fabricating gallium arsenide integrated circuits was published. New fabrication techniques have created a variety of crystals through alternating layers of gallium arsenide and aluminum gallium arsenide. By controlling the thickness and composition of each layer through methods such as MOCVD and molecular beam epitaxy, materials with specific electrical and optical properties may be produced. These crystals, called heterostructures may have applications in laser technology and optical computers.[8]

An overview of progress in developing cost-efficient photovoltaic cells was published. Various types of cell construction were described, and cells fabricated from four materials—amorphous silicon, copper indium diselenide, cadmium telluride, and gallium arsenide—were discussed.[9]

Researchers at GTE Laboratories Inc. reportedly produced pure, thin-film polymeric organic crystals of diacetylene that could be used in prototype high-speed optical switchers at a speed 1,000 times faster than that of gallium arsenide. In preparing the polydiacetylene crystals, a purified acetylene monomer was pressed between two flat hydrophilic surfaces at elevated pressure and heated to its melting point. As the melt spread, one surface was moved with respect to the other to create a shear, which aligned the molecules in nearly defect-free thin films. The melt was cooled as polydiacetylene crystal growth occurred. Process and material costs for these crystals were claimed to be low.[10]

NEC Corp. of Japan reportedly selected indium phosphide instead of gallium arsenide technology in developing new fiber-optics systems. The company claimed that by using indium phosphide circuits, the communication distance can be increased by 12 times over that using gallium arsenide circuits.

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Gem Stones

By Gordon T. Austin[1]

The value of natural gem stones, mineral specimens, and freshwater pearls, natural and cultured, produced in the United States was estimated to be $9.3 million, an increase of 26% over that of 1985. Small mine owners and amateur collectors accounted for most of the production. Small mines produced tourmaline, jade, opal, sapphire, turquoise, agates, lapis lazuli, garnet, beryl, and quartz.

The combined value of synthetic and simulant gem stones was reported to be $10.3 million. This was the first year that the domestic production of synthetic and simulant gem stones was reported by the Bureau of Mines. 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 stones produced in the United States include ruby, sapphire, garnet, spinel, alexandrite, quartz, emerald, and diamond. Simulants are manmade gem stones that have an appearance similar to that of a natural gem stone but have different optical, chemical, and physical properties. The major gem stone simulant produced in the United States was cubic zirconia.

The gem stone materials are sold to wholesale and retail outlets, in gem and mineral shops, at gem and mineral shows, and to jewelry manufacturers.

Domestic Data Coverage.—Domestic production statistics for gem stones were developed by the Bureau of Mines from the "Gem Stones" survey, a voluntary survey of U.S. operations, and from Bureau estimates of amateur collectors' production. Of the 105 operations to which a survey request was sent, 93% responded, accounting for 78% of the total production.

The 105 operations surveyed in 1986 were an increase of about 144% compared with operations surveyed in 1985, and the response rate represents an increase of 182%. Production by the nonresponding operations and by amateur collectors was estimated based on information from published data, gem and mineral dealers, gem and mineral shows, and collectors.

DOMESTIC PRODUCTION

Mines and collectors in all 50 States produced natural gem stones and/or freshwater pearls with an estimated value of $1,000 or more in each State. Ten States supplied 84% of the total value of the natural gem material. The States, in order of declining value of production, were Arizona, Tennessee, North Carolina, Arkansas, Montana, California, Oregon, Idaho, Texas, and Wyoming. Production of synthetic and simulant gem stone materials was valued at $10.3 million. Seven firms, four in California and one each in three other States, accounted for the production. The States, in order of declining value of production, were California, Massachusetts, New Jersey, and Michigan.

Vortex Mining Co. of Utica, MT, completed construction of a sapphire washing plant situated on the continuation of the Yogo sapphire dike in central Montana. Most of the sapphires found by Vortex were the highly prized cornflower-blue color and less than 1 carat in size. The sapphires found to date have been cut either by Vortex or in Thailand. No rough material was offered for sale.[2]

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.); conducted exploration for diamond on approximately 60,000 acres of land in Iron and Dickinson Counties, MI. The same three firms continued to explore for diamond in Wisconsin, and Exmin leased land for diamond exploration in Minnesota.

The joint venture between Lac Minerals Ltd. and Mobil Oil Co. for diamond exploration has not discovered any economically recoverable diamond deposits. However, exploration continued during 1986 in the State line district on the Colorado-Wyoming border. One kimberlite project was explored and evaluated to the extent that it was determined that the grade of the deposit, diamonds per ton of kimberlite, was sufficient to be of interest. However, it was determined that the quality of the diamonds recovered would not make the project profitable. Hanvey-Boulle Ltd., a mining company from Dallas, TX, submitted a plan to the State of Arkansas in October 1985 to sample the Crater of Diamonds State Park at Murfreesboro to determine the feasibility of constructing a diamond mining operation. A special committee, appointed by the Governor, completed a study of the proposed plan in late 1986. The committee recommended that the Governor appoint an "expert" committee of engineers and other mining experts to study the technical aspects of the proposed project. A committee of experts was appointed at yearend.[3] In June, a milestone was reached at the Crater of Diamonds State Park, when the 10,000th diamond was found since the park was established in 1972.[4]

In 1986, the world's largest diamond gem stone was cut and polished in the United States. The stone, known as the Zales Diamond and owned by Zales Corp., is a 535-carat, nontraditional shaped stone, which was cut from an 890-carat rough. In addition, 22 satellite stones, some as large as 20 carats, were cut from the same piece of rough, the origin of which was unclear. The world's largest star sapphire, 1,154 carats, was cut in the United States from a 1,905-carat rough reportedly found in the State of Idaho.[5] The world's largest cut gem stone, a smoky quartz that measures 10.0 by 5.6 by 4.0 inches, was cut in the United States from Brazilian rough. The stone was named the "Eye of the Idol" after the cut of the same name. The finished gem stone was valued at approximately $20,000. The world's largest gem stone by weight is the Brazilian Princess, a blue topaz, 5.7 by 5.7 by 4.7 inches, that weighs 21,005 carats. It was cut in the United States in 1976. A Miami Beach, FL, resident discovered an apple-sized pink sapphire at a dig-for-fee gem mine in North Carolina.

CONSUMPTION

Domestic gem and gem stone production was consumed in commercial and amateur gem and mineral collections, the production of objects of art, and the manufacture of jewelry. Value of U.S. apparent consumption increased 10% to $3,296 million.

U.S. imports for consumption of colored gem stones, led by emerald, ruby, and sapphire, increased 16% over those of 1985. The value of annual imports of emerald continued as the largest of any single colored gem stone. However, the combined value of imported ruby and sapphire exceeded that of emerald by 17%. The value of pearls imported into the United States continued to decline, decreasing 15% compared with that of 1985. The value of all imported gem stones, other than diamond, increased 7%.

According to data reported by the U.S. Department of Commerce, the sales value of all jewelry, costume jewelry, gold, and precious and semiprecious stones was about $24 billion, an increase of 11% over that of 1985. The same source reported that sales in jewelry stores increased 12% over that of 1985 to $12.4 billion.

PRICES

The U.S. price of a 1-carat, D-flawless diamond fluctuated between $9,500 and $16,500, and at yearend was $16,000. However, only a few hundred of these high-quality, 1-carat stones have been available each year, and their value has accounted for less than 0.2% of the total U.S. market. Prices of ruby, blue sapphire, and emerald experienced slight increases, while other colored stones experienced little change during the year. The average price of choker-length strands of 6.0- to 6.5-millimeter imported pearls increased approximately 10% compared with that of 1985. The price of American freshwater pearls increased 15% over that of 1985.

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] in 1986	Average price per carat[4] June 1985	Average price per carat[4] June 1986
0.04-0.07	H-I	VS	$440- $420	$420	$420
.04- .07	H-I	SI_1	420- 380	380	380
.08- .14	H-I	VS	470- 460	460	460
.08- .14	H-I	SI_1	440- 420	420	420
.18- .22	H-I	VS	850- 680	750	750
.18- .22	H-I	SI_1	700- 600	700	700
.23- .29	H-I	VS	1,200- 900	900	11,750
.23- .29	H-I	SI_1	900- 750	750	900
.30- .37	H-I	VS	1,400- 1,000	1,175	1,475
.30- .37	H-I	SI_1	1,000- 800	900	1,250
.46- .49	H-I	VS	1,700- 1,300	1,475	--
.46- .49	H-I	SI_1	1,400- 1,100	1,250	--
.70- .89	H-I	VS	2,200- 1,800	2,000	2,175
.70- .89	H-I	SI_1	2,000- 1,400	1,600	1,800
1.00[5]	D	IF	16,500- 9,500	[6]11,500	[6]12,000
1.00	E	VVS_1	9,450- 4,100	[6]4,550	[6]5,000
1.00	G	VS	3,700- 2,500	[6]3,000	[6]3,150
1.00	H	VS_2	3,100- 2,000	[6]2,400	[6]2,525

[1]Gemological Institute of America (GIA) color grades: D—colorless; E—rare white; and HG-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. 9, No. 1, Jan. 10, 1986; and v. 9, No. 45, Dec. 26, 1986. These figures represent Rapaport Diamond Report opinion of New York wholesale asking price.
[4]Rapaport Diamond Report. V. 8, No. 26, July 12, 1985; and v. 9, No. 22, July 11, 1986.
[5]The Diamond Registry Bulletin. V. 17, No. 1, Dec. 1985, p. 8; and v. 17, No. 11, Dec. 1986, p. 8.
[6]The Diamond Registry Bulletin. V. 16, No. 7, July 1985, p. 8; and v. 17, No. 7, July 1986, p. 8.

Table 2.—Prices of U.S. cut colored gem stones, by size[1]

Gem stone	Carat weight	Price range per carat in 1986[2]	Average price per carat,[3] June 1986
Amethyst	1	$6- $10	$8
Aquamarine	1	100- 250	175
Emerald	1	1,350-3,000	1,775
Garnet, tsavorite	1	700-1,200	950
Ruby	1	1,800-3,300	2,150
Sapphire	1	450-1,300	725
Tanzanite	1	275- 450	354
Topaz	1	6- 9	7.50
Tourmaline, green[4]	1	40- 250	145
Tourmaline, pink[4]	1	50- 300	175

[1]Fine quality.
[2]Jewelers' Circular-Keystone. V. 157, No. 5, May 1986, p. 166; and v. 158, No. 2, Feb. 1987, p. 340. 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. 157, No. 8, Aug. 1986, p. 430.
[4]The Gemstone Registry Bulletin. V. 3, No. 11, Dec. 30, 1985, p. 8; and v. 4, No. 11, Dec. 31, 1986, p. 8.

FOREIGN TRADE

Export value of all gem materials was $584.9 million. Export value of all gem materials other than diamond decreased slightly to $59.3 million. Of this total, other precious and semiprecious stones, cut but unset, were valued at $31.5 million; other precious and semiprecious stones, not set or cut, $16.5 million; synthetic gem stones and materials for jewelry, cut, $4.7 million; pearls, natural, cultured, and imitation, not strung or set, $2.6 million; and other, $3.9 million. Reexports of all gem materials was $317.1 million. Reexports of all gem materials other than diamond increased 38% to

$55 million. Reexport categories were synthetic gem stones and materials for jewelry, cut, $0.5 million; precious and semiprecious stones, cut but not set, $44.5 million; and other precious and semiprecious stones, natural, not cut or set, $10 million.

The customs value of U.S. imports of rough and polished natural diamond, excluding industrial diamond, was up 15% to about $3.5 billion. Total imports of polished diamond, principally from Israel, 32%; Belgium, 28%; and India, 21%; were valued at $3.0 billion, an 11% increase over those of 1985. Imports of diamond greater than 0.5 carat, mostly from Israel, 34%; Belgium, 30%; and Switzerland, 14%; increased 10% in value to $1.3 billion. The value of imports in the less-than-0.5-carat category, mostly from India, 35%; Israel, 31%; and Belgium, 27%; increased 15% to $1.8 billion. The imports of rough diamond, 52% in value from the Republic of South Africa, decreased 19% in caratage and increased 19% in value. A 46% increase in South African carat value, from $341 to $499, was indicated by custom values.

The total customs value of imported emerald increased 10% to $152.4 million. The total value of ruby imports increased 20% to $83.5 million, and sapphire imports increased 34% to $95.1 million. Average carat values increased 8% for emerald to $55, 16% for ruby to $22, and 16% for sapphire to $22.

Table 3.—U.S. exports and reexports of diamond (exclusive of industrial diamond), by country

Country	1985		1986	
	Quantity (carats)	Value[1] (millions)	Quantity (carats)	Value[1] (millions)
Exports:				
Belgium-Luxembourg	179,829	$82.3	205,565	$108.9
Canada	23,012	12.2	19,176	13.7
France	1,763	8.3	3,148	6.9
Germany, Federal Republic of	2,937	2.5	2,286	3.1
Hong Kong	42,302	61.7	67,393	97.1
Israel	109,842	56.7	156,819	87.2
Japan	31,218	46.5	48,266	93.6
Singapore	2,039	4.4	5,810	7.5
Sweden	21	([2])	--	--
Switzerland	29,025	95.6	19,318	85.4
Thailand	5,226	2.8	16,958	6.4
United Kingdom	3,966	4.0	6,405	7.8
Other	6,865	8.3	9,915	8.0
Total	438,045	385.3	561,059	525.6
Reexports:[3]				
Belgium-Luxembourg	839,257	56.7	806,945	89.5
Canada	4,243	.3	6,516	.5
China	8,120	.4	10,392	.6
Germany, Federal Republic of	53,318	1.6	39,479	2.7
Hong Kong	42,021	14.0	59,969	20.3
India	153,323	3.9	127,221	3.3
Israel	196,743	31.4	210,333	59.2
Japan	114,713	8.5	105,827	8.8
Netherlands	106,819	5.2	68,079	5.1
Switzerland	41,953	41.2	30,797	35.1
United Kingdom	297,044	12.2	398,044	27.6
Other	82,324	10.6	102,348	9.4
Total	1,939,878	186.0	1,965,950	262.1

[1]Customs value.
[2]Less than 1/10 unit.
[3]Artificially inflated in 1985 and 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, weight, and country of origin	1985 Quantity (carats)	1985 Value[1] (millions)	1986 Quantity (carats)	1986 Value[1] (millions)
Rough or uncut, natural:[2]				
Belgium-Luxembourg	130,996	$32.9	418,782	$73.8
Brazil	90,280	6.6	29,444	3.4
Cape Verde	21	(3)	940	1.0
Congo	80	.2	--	--
Guyana	636	(3)	2,122	.3
Israel	27,198	8.3	45,240	12.2
Netherlands	9,643	8.0	7,318	3.7
South Africa, Republic of	555,907	189.4	452,973	225.9
Switzerland	15,106	10.4	22,629	8.1
United Kingdom	116,601	52.0	135,099	66.0
Venezuela	21,036	.8	37,096	1.0
Other	75,309	8.9	155,618	39.7
Total	1,042,813	317.5	1,307,261	435.1
Cut but unset, not over 0.5 carat:				
Belgium-Luxembourg	1,466,325	444.8	1,540,601	471.9
Brazil	22,790	2.5	23,013	7.5
Canada	19,607	6.6	30,485	4.0
Hong Kong	146,416	39.4	131,717	25.0
India	2,667,906	486.8	2,886,722	629.0
Israel	1,237,123	448.2	1,555,742	542.7
Malaysia	17,772	6.0	2,151	.7
Netherlands	85,811	26.9	28,296	11.0
South Africa, Republic of	48,074	16.9	139,692	19.1
Switzerland	153,329	38.7	75,629	28.7
United Kingdom	35,138	13.4	36,714	17.9
Other	68,754	22.2	172,873	21.9
Total	5,969,045	1,552.4	6,623,635	1,779.4
Cut but unset, over 0.5 carat:				
Belgium-Luxembourg	369,838	314.7	412,645	371.1
Hong Kong	24,259	37.0	34,236	45.4
India	47,709	16.1	50,098	13.2
Israel	439,038	340.9	529,226	429.0
Netherlands	34,951	35.5	24,673	23.8
South Africa, Republic of	76,025	77.4	65,180	73.7
Switzerland	46,098	148.5	48,898	169.6
United Kingdom	46,832	75.1	35,303	63.8
Other	54,397	91.5	60,871	55.9
Total	1,139,147	1,136.7	1,261,130	1,245.5

[1]Customs value.
[2]Includes some natural advanced diamond.
[3]Less than 1/10 unit.

Table 5.—U.S. imports for consumption of natural precious and semiprecious gem stones, other than diamond, by kind and country

Kind and country	1985 Quantity (carats)	1985 Value[1] (millions)	1986 Quantity (carats)	1986 Value[1] (millions)
Emerald:				
Argentina	122	(2)	437	(2)
Belgium-Luxembourg	106,895	$3.4	16,262	$3.1
Brazil	219,068	6.0	144,899	6.4
Colombia	197,249	56.1	199,935	52.3
France	20,928	3.8	10,674	3.0
Germany, Federal Republic of	26,176	1.7	60,471	3.2
Hong Kong	317,142	10.8	187,525	12.0
India	1,413,167	11.0	1,267,481	14.5
Israel	101,683	11.5	59,724	14.1
Japan	12,661	1.4	3,816	.8
South Africa, Republic of	2,436	.4	37,795	1.8
Switzerland	163,048	23.9	448,580	27.4
Taiwan	1	(2)	5,056	.3
Thailand	74,418	1.1	138,284	2.6
United Kingdom	20,403	2.8	20,461	6.1
Other	65,916	5.1	155,735	4.8
Total	2,741,313	139.0	2,757,135	152.4

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	1985 Quantity (carats)	1985 Value[1] (millions)	1986 Quantity (carats)	1986 Value[1] (millions)
Ruby:				
Belgium-Luxembourg	11,381	$1.7	16,528	$4.3
Brazil	18,993	(2)	579	(2)
Colombia	4,701	.1	1,558	.1
France	9,712	1.9	4,563	1.9
Germany, Federal Republic of	35,204	1.6	14,412	.9
Hong Kong	110,033	3.7	85,954	3.4
India	221,923	1.3	247,687	2.1
Israel	42,921	1.2	35,433	1.3
Japan	21,242	.5	82,786	.4
Switzerland	296,877	15.6	256,921	16.5
Thailand	2,770,136	31.2	3,020,440	44.4
United Kingdom	33,713	6.4	19,496	5.8
Other	r103,861	4.5	82,677	2.4
Total	3,680,697	69.7	3,869,034	83.5
Sapphire:				
Australia	1,070	(2)	2,219	.2
Austria	122	(2)	--	--
Belgium-Luxembourg	32,047	.9	19,152	3.0
Brazil	1,424	(2)	28,604	(2)
Canada	2,717	.5	4,643	.7
Colombia	2,057	.1	1,769	(2)
France	18,973	1.9	26,764	1.9
Germany, Federal Republic of	32,028	1.2	20,699	1.2
Hong Kong	166,329	4.8	132,201	4.9
India	92,456	1.0	127,121	1.0
Israel	56,909	1.2	40,322	1.2
Japan	50,770	.8	29,157	.5
Korea, Republic of	2,664	(2)	7,527	.1
Singapore	5,910	.4	946	(2)
Sri Lanka	32,464	1.5	22,149	2.2
Switzerland	431,909	17.0	370,520	21.0
Thailand	2,765,371	32.4	3,394,602	50.3
United Kingdom	60,549	6.1	60,736	5.5
Other	72,000	1.0	71,587	1.4
Total	3,827,769	70.8	4,360,718	95.1
Other:				
Rough, uncut:				
Australia	NA	1.5	NA	.6
Brazil		14.0		15.9
Colombia		9.8		7.5
Hong Kong		.9		1.1
Nigeria		.3		.3
Pakistan		.4		.6
South Africa, Republic of		.2		.7
Switzerland		.1		.4
United Kingdom		.8		.4
Zambia		.3		.7
Other		4.8		3.0
Total	NA	33.1	NA	31.2
Cut, set and unset:				
Australia	NA	4.1	NA	4.6
Brazil		10.5		11.0
Canada		1.0		.8
China		4.5		5.1
Germany, Federal Republic of		12.3		11.4
Hong Kong		29.5		29.3
India		5.2		4.8
Japan		200.9		161.9
Switzerland		4.7		2.9
Taiwan		6.2		12.1
Thailand		3.4		6.1
United Kingdom		1.7		2.5
Other		12.6		19.3
Total	NA	296.6	NA	271.8

rRevised. 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	1985	1986
Synthetic, cut but unset:		
Austria	0.4	0.5
France	.9	.9
Germany, Federal Republic of	5.5	6.4
Korea, Republic of	7.1	9.0
Switzerland	2.2	2.8
Thailand	.8	1.5
Other	r.7	1.0
Total	17.6	22.1
Imitation:		
Austria	23.0	34.4
Czechoslovakia	1.7	2.0
Germany, Federal Republic of	8.9	12.0
Japan	6.3	7.2
Other	3.6	7.0
Total	43.5	62.6

rRevised.
[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	1985 Quantity	1985 Value[1]	1986 Quantity	1986 Value[1]
Diamonds:				
Rough or uncut[2]	1,043	317,584	1,307	435,029
Cut but unset	7,108	2,689,178	7,885	3,024,902
Emeralds: Cut but unset	2,741	139,045	2,757	152,396
Coral: Cut but unset, and cameos suitable for use in jewelry	NA	2,224	NA	2,291
Rubies and sapphires: Cut but unset	7,509	140,618	8,230	178,655
Marcasites	NA	256	NA	139
Pearls:				
Natural	NA	2,997	NA	3,406
Cultured	NA	228,004	NA	190,497
Imitation	NA	8,396	NA	9,655
Other precious and semiprecious stones:				
Rough, uncut	NA	33,168	NA	30,589
Cut, set and unset	NA	63,070	NA	65,392
Other	NA	NA	NA	8,102
Synthetic:				
Cut but unset[3]	52,164	17,590	63,532	22,074
Other	NA	2,457	NA	2,586
Imitation gem stones	NA	35,333	NA	52,939
Total	XX	3,679,920	XX	4,178,652

NA Not available. XX Not applicable.
[1]Customs value.
[2]Includes 630 carats of other natural diamond, advanced, valued at $1,062,100 in 1985, and 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 1986 were reported to be $2.56 billion compared with $1.83 billion in 1985, an increase of 40%. Sales of colored gem stones also increased.

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, Kenya, Sri Lanka, Tanzania, Thailand, and the United States. Aquamarine was produced in Afghanistan, Brazil, China, India, Nigeria, Pakistan, Tanzania, and the United States.

Angola.—The Government of Angola liquidated Companhia de Diamantes de Angola, the state-owned diamond mining company, and stopped mining diamonds. The Government formed a new corporation called Empresa Nacional de Diamantes de Angola to oversee Angolan diamond operations. Under the new system, Angola's diamond-bearing areas would be parceled into concessions and allocated to foreign companies. The Angolan Civil War totally disrupted the production of diamonds. Production fell from 1.5 million carats in 1979 to approximately 0.3 million carats in 1986. The average price fell from $158 per carat in 1980 to $45 per carat in 1986. Production costs increased greatly because the mining areas were not secured, and all equipment, supplies, and personnel had to be airlifted to the mines.[6]

Australia.—Argyle Diamond Mines Joint Venture completed the first year of production from the AK-1 lamproite pipe. The production of 29.2 million carats exceeded the planned production of 25 million carats. Argyle Diamond Sales Ltd. held the first sale of the rare pink diamond. The 56 cut stones sold for $1.54 million.[7]

Freeport Bow River Properties Inc. and Gem Exploration and Minerals Ltd. completed trial mining and feasibility studies on the Bow River alluvial diamond deposit. Plans were announced for construction of a mine and processing plant.

Australian Ores & Minerals Ltd. Div. and De Beers, Afro West Mining Ltd. and Aracca Petroleum Corp., and Ashton Mining Ltd. all continued exploration and testing of their diamond projects.

Australia accounted for about 70% of world sapphire production and 80% of the world opal production.[8]

China.—The Chinese Corp. of the People's Republic of China opened overseas offices of the China National Arts and Crafts Import and Export Corp. in the Federal Republic of Germany and the United States. The offices were established to improve the marketing of freshwater pearls.

Exports of rough and polished diamonds greatly increased the first half of 1986. Diamond exports from China were valued at $12 million during the period of January through June 1986, compared with $10 million for all of 1985.[9]

Ruby and sapphire deposits of record size were discovered in Wemchange County on Hainan Island off the southern coast of China. The largest find was an oriental sapphire deposit with reserves calculated at over 820 kilograms (4.1 million carats).

The Government of China and Chicester Diamonds Services, a firm associated with De Beers, signed a diamond prospecting agreement to explore for diamond in Shandong Province.

China also produced aquamarine, rock crystal, citrine, turquoise, peridot, sapphire, jet, and jade.

Ghana.—Ghana Consolidated Diamonds Ltd. began mining operations in January in the Birim Valley. The operations were established as the main source of gravel for milling, replacing the almost depleted Akwatia deposits. The continued use of obsolete, inefficient machinery resulted in a decrease in the number of carats produced. Gold was recovered as a byproduct of the diamond production.

The Government of Ghana published the Minerals and Mining Law of 1986, modifying existing laws. It ruled that all minerals in Ghana in their natural state would be vested in the Provisions National Defense Council for and on behalf of the people of Ghana. The Government shall also have the right of preemption of all minerals recovered in Ghana or any waters controlled by Ghana.

Guinea.—Bridge Oil Ltd. reported that Aredor diamond production was 203,788 carats, an increase of 54% compared with 1985 production. A single 100.2-carat, high-quality gem diamond from the project was sold for $3.62 million.[10] This was the most valuable diamond mined from Aredor to date. A second stone of 121.1 carats also was found but was not sold. Feasibility studies and design work were completed for a system to recover gold from the diamondiferous gravel.

Indonesia.—Australian-based Pelsart Resources NL, part of the Parry Corp., negotiated a joint venture with Ashton Mining NL to explore for diamond in the Pujon area of central Kalimantan. Alluvial diamonds have been found in this area for many years. The source of the diamonds and the delineation of the extent of the diamond-bearing alluvials are the primary objectives of the exploration.

Acorn Securities Ltd. of Australia reported that the joint venture of Acorn, 65%; P.T. Aneka Tambang, 20%; and Keymead Ltd. of London, 15%, the Indonesian state-owned mining company, was exploring allu-

Table 8.—Diamond (natural): World production, by country[1]

(Thousand carats)

Country	1982 Gem	1982 Indus-trial	1982 Total	1983 Gem	1983 Indus-trial	1983 Total	1984 Gem[2]	1984 Indus-trial	1984 Total	1985[p] Gem[2]	1985[p] Indus-trial	1985[p] Total	1986[e] Gem[2]	1986[e] Indus-trial	1986[e] Total
Angola	915	310	1,225	775	259	1,034	652	250	902	464	250	714	240	10	250
Australia	274	183	457	3,720	2,480	6,200	3,415	2,277	5,692	4,242	2,828	7,070	[3]13,145	[3]16,066	[3]29,211
Botswana	1,165	6,604	7,769	4,829	5,902	10,731	5,810	7,104	12,914	6,318	6,317	12,635	[3]9,610	3,500	13,110
Brazil	80	450	530	80	450	530	200	550	750	233	217	450	300	250	550
Central African Republic	186	91	277	230	65	295	236	101	337	245	105	350	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	68	616	684	34	306	340	35	311	346	65	585	650	60	540	600
Guinea	13	27	[e]40	23	17	[e]40	44	3	47	123	9	132	[3]190	[3]14	[3]204
Guyana[e]	4	7	11	5	5	10	6	8	14	4	7	11	3	6	[3]9
India	11	2	13	12	2	14	13	2	15	14	2	16	14	2	16
Indonesia[e]	3	12	15	5	22	27	5	22	27	5	22	27	5	22	27
Ivory Coast	--	--	--	--	--	--	--	--	--	--	--	--	4	6	10
Lesotho	39	3	42	--	--	--	--	--	--	--	--	--	--	--	--
Liberia	170	263	433	132	198	330	108	132	240	66	72	138	[3]63	[3]189	[3]252
Namibia	963	51	1,014	915	48	963	884	46	930	865	45	910	900	50	950
Sierra Leone	203	87	290	242	103	345	240	105	[e]345	243	106	349	215	100	315
South Africa, Republic of:															
Finsch Mine	847	3,003	3,850	1,765	3,278	5,043	1,714	3,184	4,898	1,770	3,184	4,954	1,800	3,172	4,972
Premier Mine	615	1,845	2,460	800	1,844	2,644	765	1,785	2,550	820	1,864	2,684	834	1,869	2,703
Other De Beers' properties[4]	1,359	906	2,265	1,400	569	1,969	1,452	593	2,045	1,500	569	2,069	1,529	567	2,096
Other	521	58	579	589	66	655	585	65	650	460	35	495	472	57	529
Total	3,342	5,812	9,154	4,554	5,757	10,311	4,516	5,627	10,143	4,550	5,652	10,202	4,635	5,665	10,300
Swaziland	--	--	--	--	--	--	7	10	17	9	12	21	17	23	40
Tanzania	100	120	[e]220	183	78	261	193	84	277	207	89	[r] [e]296	210	90	300
U.S.S.R.[e]	2,100	8,500	10,600	3,700	7,000	10,700	4,300	6,400	10,700	4,400	6,400	10,800	4,400	6,400	10,800
Venezuela	99	394	[e]493	45	234	279	40	232	272	35	180	215	40	195	235
Zaire	308	5,856	6,164	3,355	8,627	11,982	5,169	13,290	18,459	5,493	14,124	19,617	4,661	18,643	[3]23,304
World total	10,243	30,188	40,431	23,039	32,353	55,392	26,073	37,354	63,427	27,781	37,822	65,603	39,157	52,676	91,833

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

[1]Table includes data available through June 2, 1987. 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 (1982-86), Central African Republic (1983-85), Guinea (1984-86), 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]Other De Beers Group output from the Republic of South Africa includes Kimberley Pool, Koffiefontein Mine, and the Namaqualand Mines.

vial diamond claims in the Danan Seran area of southern Kalimantan and had completed a successful sampling program. Results to date yielded 992 stones weighing 144.76 carats. The stones ranged in size from 0.01 to 2.31 carats, and 19 of the stones exceeded 1.0 carat. The stones appeared to be 95% gem quality.

South Africa, Republic of.—De Beers made the decision to deepen its operations and switch from the long-established block-caving system to sublevel caving in the Dutoitspan and Bultfontein Mines. The project would extend the economic life of both mines and would reduce labor costs. The two mines share a common shaft system. Both mines were developed about 100 years ago.

The Gravelotte emerald mine continued to produce a limited number of very-high-quality emeralds in 1986. The mine accumulated an inventory of 1.5 million carats because of the weakness of the market. The Republic of South Africa also produced aquamarine and tourmaline.

Syria.—The Ministry of Syrian Oil and Minerals Resources confirmed the existence of a project to exploit diamond deposits discovered in the Homs area.[11]

Zaire.—Diamond production set a record high for the second consecutive year. Production was reported to be 23,303,739 carats, an increase of about 19%. The average price per carat was $8.26, well above the $7.90-per-carat floor price established by the agreement entered into with De Beers in 1985.

TECHNOLOGY

The Gemological Institute of America perfected a new set of testing procedures to determine whether an amethyst is natural or synthetic. Polarized light is used to determine if Brazil law twinning is present. If Brazil law twinning is present, the stone is natural amethyst. In the absence of any twinning, a synthetic origin is probable, but further testing is needed to correctly identify the stone as synthetic. Angular or straight color zoning with colorless or violetish zones next to purple areas identify natural amethyst. The presence of only light and dark purple zoning or the complete absence of zoning indicates a synthetic stone. These procedures have made it possible for the first time for the average dealer to determine if stones represented as natural amethyst are truly natural.[12]

[1]Physical scientist, Division of Industrial Minerals.
[2]Jewelers' Circular-Keystone. Gemstones. V. 158, No. 2, Feb. 1987, p. 337.
[3]Arkansas Gazette. Gem of a Plan Awaits Study. Feb. 8, 1987, p. 2.
[4]Murfreesboro Diamond. Nashville Man Finds Crater's 10,000th Gem. June 18, 1986, p. 1.
[5]Jewelers' Circular-Keystone. Gemstones. V. 157, No. 11, Nov. 1986, p. 159.
[6]———. V. 157, No. 9, Sept. 1986, p. 118.
[7]Where necessary, values have been converted from Australian dollars ($A) to U.S. dollars at the Dec. 3, 1986, rate of $A1.00=US$1.54.
[8]Australian Bureau of Mineral Resources. Australian Mineral Industry Annual Review. Preliminary Summary 1986. Gemstones, Feb. 1987.
[9]Page 158 of work cited in footnote 5.
[10]Where necessary, values have been converted from Australian dollars ($A) to U.S. dollars at the Dec. 3, 1986, rate of $A1.00=US$1.54.
[11]Mining Journal (London). Development. V. 308, No. 7903, Feb. 6, 1987, p. 95.
[12]Crowningshield, R., H. Cornelius, and C. W. Fryer. A Simple Procedure To Separate Natural From Synthetic Amethyst on the Basis of Twinning. Gems & Gemology, v. 22, No. 3, 1986, pp. 130-139.

Gold

By John M. Lucas[1]

Responding to continued favorable prices for gold, relative to those for some other mineral commodities, domestic and international mining companies continued to focus their exploration and development efforts on gold. The success of these efforts in recent years is reflected in the 31% increase in world gold production between 1979 and 1986 and the nearly 300% increase in U.S. production during the same period. With over 3.7 million ounces[2] produced during 1986, the United States was the third largest gold producing country in the world.

Table 1.—Salient gold statistics

	1982	1983	1984	1985	1986
United States:					
Mine production thousand troy ounces	1,466	2,003	2,085	r2,427	3,733
Value thousands	$550,968	$849,071	$751,833	r$771,032	$1,374,710
Percentage derived from:					
Precious metals ores	80	83	87	r92	96
Base-metal ores	17	14	11	5	2
Placers	3	3	2	r3	2
Refinery production:					
Domestic and foreign ores thousand troy ounces	r1,308	r1,972	r2,101	r2,076	2,431
Secondary (old scrap) do	r1,785	r1,772	r1,759	r1,597	1,522
Exports:					
Refined do	1,637	1,881	3,482	2,888	3,172
Other do	1,333	1,258	1,499	1,078	1,441
Imports for consumption:					
Refined do	4,238	3,599	6,032	6,361	13,800
Other do	r683	994	1,837	1,865	1,949
Gold contained in imported coins do	2,908	1,948	2,769	2,064	1,101
Net deliveries from foreign stocks in Federal Reserve Bank do	1,330	-220	381	484	4,692
Stocks, Dec. 31:					
Industry[1] do	776	623	765	r619	865
Futures exchange do	2,303	2,530	2,359	[2]2,110	[2]2,809
Department of the Treasury:					
American Eagle gold coin sales do	--	--	--	--	[3]1,788
Gold medallion sales[4] do	63	634	419	48	([5])
Olympic gold coin sales do	--	--	[6]156	24	([7])
Statue of Liberty gold coin sales do	--	--	--	[7]121	([8])
Consumption in industry and the arts do	r3,463	r3,101	3,164	r2,999	2,976
Price:[9] Average per troy ounce	$375.91	$424.00	$360.66	$317.66	$368.24
Employment[10]	6,800	6,500	6,900	6,900	8,200
World:					
Mine production thousand troy ounces	r43,105	44,996	46,475	p48,673	e50,937
Official reserves[11] million troy ounces	1,145.1	1,143.0	r1,142.0	r1,144.7	1,145.2

eEstimated. pPreliminary. rRevised.
[1]Unfabricated refined gold held by refiners, fabricators, dealers, and U.S. Department of Defense.
[2]Commodity Exchange Inc. only.
[3]Sales program began on Oct. 20, 1986.
[4]Sales program began July 15, 1980.
[5]No sales. No action was taken on the reauthorization bill by the 99th Congress.
[6]Includes coins sold in 1982 and 1983 for delivery in 1984.
[7]Authorization sales program fulfilled in 1985.
[8]Sales completed by yearend 1985 for delivery in early 1986.
[9]Engelhard Industries quotation.
[10]Mine Safety and Health Administration.
[11]Held by market economy country central banks and governments and international monetary organizations. Source: International Monetary Fund.

Consumption of gold in the market economy countries, increased about 14%. A number of countries, including Australia, Japan, and the United States, brought new official coins to the market, thus consuming the greatest quantity of gold ever recorded in this category. Gold has been employed in high technology applications for many years, especially in aerospace-defense and electronic applications where its properties of malleability, ductility, extreme resistance to corrosion, and electrical conductivity, make it especially useful in electronic contacts, connectors, hookup wire, and as reflective foils and coatings on space vehicles to reduce solar radiation damage.

Table 2.—Volume of U.S. gold futures trading

(Million troy ounces)

Exchange	Location	1982	1983	1984	1985	1986
Chicago Board of Trade	Chicago	1.96	10.15	9.73	5.42	4.00
Commodity Exchange Inc	New York	1,212.40	1,038.28	911.55	788.40	842.96
International Monetary Market[1]	Chicago	153.35	99.40	.88	(2)	(2)
MidAmerica Commodity Exchange	do	12.73	11.59	2.02	1.04	.70
Total		1,380.44	1,159.42	924.18	794.86	847.66

[1]A division of the Chicago Mercantile Exchange.
[2]Less than 1,000 ounces traded. Trading ceased July 10, 1985.

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 gold, silver, copper, lead, and zinc mines. Of the 337 lode gold producers in operation to which a survey request was sent, 73% responded, representing 88% 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.—On September 8, at the U.S. Bullion Depository, West Point, NY, the Secretary of the Treasury struck the first 1-ounce $50 American Eagle gold coin thereby initiating the gold bullion coin program authorized by Public Law 99-195, enacted in December 1985. The coins, the first noncommemorative legal tender coins to be minted in the United States since 1933, range in gold content from 0.10 to 1 troy ounce. Sales to the public, through 25 primary dealers worldwide, began on October 20, and by yearend, nearly 1.8 million ounces of 91.6%-pure gold had been sold. Legislation to mint 1 million gold coins and up to 10 million silver coins to commemorate the United States Constitution's bicentennial became Public Law 99-582 on October 29. Both coins issued are to be legal tender. By law, a surcharge will be added to the price of each coin, and the proceeds shall be directed solely toward reducing the national debt. On September 4, the President renewed for 1 year Executive Order 12532, imposing limited sanctions against the Republic of South Africa, including a ban on the importation of gold Krugerrand coins.[3]

DOMESTIC PRODUCTION

The gold mining industry in the United States continued to flourish during 1986, bringing into production nearly 40 gold mines during the year, mostly in California, Colorado, Idaho, and Nevada. Many of the new deposits are lower grade remnants or halos surrounding deposits that have been worked on and off for over a century. The vast majority of new operations brought into production over the last several years utilize open pit, bulk haulage methods, and heap leaching, a precious metals recovery technique for low-grade ores developed by the Bureau of Mines.

Of the 3.7 million ounces of gold produced in the nation, 85% was attributed to the 25 leading producers. The average recoverable content of precious metals ores processed from lode mines was 0.05 ounce per short ton, while placer gravels yielded an average of 0.02 ounce per cubic yard washed.

The revisions in domestic refinery production data for 1982 through 1986 shown in table 10 reflect the inclusion of newly reported data and account more accurately for the contribution of several new domestic refineries that began production during the 5-year period, plus the addition of some previously unreported metal of both primary and secondary origin. During 1986, domestic refiners reportedly continued to be burdened with excess production capacity, some of which represented capacity constructed during the early 1980's to handle the large volume of material attracted to the market by rising prices for precious metals.

Table 3.—Mine production of gold in the United States, by State

(Troy ounces)

State	1982	1983	1984	1985	1986
Alaska	30,513	39,523	19,433	44,733	48,271
Arizona	61,050	61,991	54,897	52,053	W
California	10,547	38,443	85,858	[r]187,813	425,617
Colorado	64,584	63,063	60,010	43,301	120,347
Idaho	W	W	W	44,306	70,440
Michigan	--	--	--	W	W
Montana	75,171	161,436	181,190	160,262	W
Nevada	757,099	960,657	1,020,546	1,276,114	2,098,929
New Mexico	W	W	W	45,045	39,856
North Carolina	--	--	--	--	12
Oregon	W	322	W	W	W
South Carolina	--	--	--	W	W
South Dakota	185,038	309,784	310,527	356,103	W
Utah	174,940	238,459	W	135,489	W
Washington	W	W	W	W	W
Total	1,465,686	2,002,526	2,084,615	[r]2,427,232	3,733,190

[r]Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."

Alaska.—The quantity of gold produced in Alaska in 1986 and reported to the Bureau of Mines increased to 48,271 ounces, compared with 44,733 ounces reported for 1985. 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, about 160,000 ounces, had actually been produced. This figure compares with similarly derived figures for 1982 through 1985 of 174,900, 169,000 175,000, and 190,000 ounces, respectively. The value of 1986 production was estimated by the State at nearly $61 million. The DGGS in its annual review of mining activity in the State noted a substantial decline from previous years in overall mineral industry activity in 1986.[4] Expenditures for exploration, development, and production together declined about 14%. Separately, expenditures for exploration, including exploration for gold, were only slightly less than those of 1985, but development expenditures dropped 29%. The number of mechanized gold placer mining operations in 1985 amounted to 266; by the end of 1986, the number had diminished to 195. The number of placer mining operations in the Circle mining district of the eastern interior region reportedly had dropped by nearly 75% since 1984. The eastern interior region alone suffered a nearly 50% drop in employment in 1986.

The State's turbidity requirement for mine discharge water continued to be a source of concern for placer miners; according to the DGGS, few miners have been prosecuted, but most are not in compliance with State law and may face court action. Efforts to improve the quality of water discharged from placering operations were continued by the industry as well as by both the Federal and State governments. For example, Alaska continued its 1984 Placer Mining Innovative Demonstration Grant program, whereby individual placer miners with innovative proposals and possible solutions to the water quality problem could receive grants from the State to test their unproven technology. The focus of the program continued to be on improving fine gold recovery, reducing water usage and/or pollution, and solving waste disposal problems. On the Federal level, a wastewater treatment process developed by the Bureau of Mines was tested at four Alaskan placer mines; initial results reportedly were encouraging (see "Technology" section).

In the Kantishna Hills area of Alaska's

eastern interior region and within the Denali National Park and Preserve, the Bureau of Mines conducted geological and engineering studies of the types and abundance of gold mineralization, mineral development potential, and acquisition costs of mineral claims. Between 1983 and 1986, evaluation and sampling of placer deposits along 27 drainages found that 10 streams had high mineral development potential and that 5 of these lacked mining activity during the year of investigation, 1983.[5] In another study published in 1986, gold placer deposits along the upper Yukon River, in the region between Circle and Eagle, were also investigated by the Bureau. Geological studies and a survey of 162 panned concentrates indicated previously unreported sites of placer gold. A potential for the discovery of additional placer and lode gold deposits was noted.[6] East of Anchorage, in south-central Alaska, the Bureau and the U.S. Geological Survey completed a 4-year mineral appraisal of the Chugach National Forest. The studies in the Chugach National Forest identified five types of placer gold deposits and identified both previously mined and unmined drainages having a potential for future production. Investigations in drainage with anomalous placer sample values also identified previously unknown lode mineralization.[7]

Also in south-central Alaska, the Bureau and the DGGS in 1985 completed an evaluation of the placer resources of the Porcupine mining area, near Haines. Each of three identified types of deposits was sampled to estimate resources, identify gold fineness, determine mineral development potential ratings for streams, and calculate optimum screen sizes for use in recovery plants. Identified resources included 932,000 cubic yards of gravel rated as having moderate or high mineral development potential.[8]

Alaska's largest gold producer for the third consecutive year was the Valdez Creek Mining Co. Inc. (formerly Denali Mines Inc.). According to published data, the company produced 30,000 ounces of gold from its properties east of Cantwell on the south flank of the central Alaska Range.

Following resolution of some technical problems encountered in 1985 and despite the limited working season, La Teko Resources Ltd., an affiliate of Citigold Mining Co. Ltd. of Vancouver, British Columbia, Canada, began test heap leaching of ore from its Ryan Lode deposit on Ester Dome, 8 miles northeast of Fairbanks. Despite the availability of only about 60 days of favorable weather per year, La Teko was reportedly proceeding with construction of a full-scale leaching facility capable of recovering about 13,000 ounces of gold per year.

In the Ester Dome area, Tri-Con Mining Inc., the contract operator, in concert with the owner, Silverado Mines Ltd., reportedly reopened the underground Grant Mine. The mine operated for a short time during 1985; however, following withdrawal of one of the three partners involved then, work was suspended until the mid-1986 reopening. The mine is a conventional, shaft-serviced, underground lode gold mine, reportedly the only one operating in Alaska during 1986.

In August, off the coast of Alaska, about 12 miles west of Nome, Inspiration Gold Inc. began mining gold-bearing sediments on one of several of its State offshore mining leases with a 525-foot-long offshore mining vessel, the *BIMA*. The 15,000-ton bucket dredge, capable of digging more than 1,000 cubic yards of gravel per hour to a depth of 40 feet, is expected to produce about 30,000 ounces of gold per year when fully operational. On northern Admiralty Island, in the southeastern region of the State, the Greens Creek gold-silver-base metals project moved toward its scheduled late 1988 opening. The project is a joint venture between Amselco Minerals Inc. (79%), and CSX Oil and Gas Corp. and Exalas Resources Corp. (21% combined). Amselco, a wholly owned subsidiary of British Petroleum Co. PLC (BP), purchased the property in February 1986, from Noranda Mining Inc. Amselco's wholly owned subsidiary, Greens Creek Mining Co. will be the manager and operator of the 1,000-ton-per-day trackless underground operation. Developments at Greens Creek during 1986 include a 6.8-mile access road that was constructed from Hawk inlet to the site of a planned 6,000-foot-long adit that will be the main haulage way for the mine.

At Juneau, Echo Bay Mines Ltd., of Edmonton, Alberta, Canada, continued evaluation of the old Alaska-Juneau Mine, once the largest gold mine in the Nation. Operated from 1893 to April 1944, the Alaska-Juneau Mine produced nearly 2.9 million ounces of gold. Echo Bay does not expect production to resume before 1991. A report prepared by the Bureau of Mines chronicles the history of the Juneau Gold Belt from the discovery of the first placer gold in 1869 to the reevaluation of the economic potential of the Alaska-Juneau Mine in 1985.[9]

At the Chichagof Joint Venture project, at Klag Bay on Chichagof Island north of Sitka, Queenstake Resources U.S.A. Inc. and its partners, Exploration Ventures Co. and Ventures Trident L.P., Vector Mining Co., continued to explore and evaluate the old Chichagof gold mine. In early 1986, the partners acquired the adjoining Hirst-Chichagof property and proceeded to reopen the early workings and thus gain access to areas suitable for launching further exploration.

Arizona.—Production of newly mined gold in Arizona declined for the third consecutive year. Gold mine development activity in the State was maintained at about the same level as in 1985; exploration, development, and construction programs begun in previous years continued, and rising gold prices toward yearend served to spur this activity.

In Yavapai County, at the McCabe property, in the Big Bug District, 20 miles east-southeast of Prescott, Stan West Mining Corp.'s partner Santa Fe Mining Inc. terminated work at the mine in late March, then returned its 50% interest to Stan West. Santa Fe had invested $5 million in the property. Immediately afterwards, Stan West announced that it was proceeding with development of the underground mine and expected to begin operation, following a year or so of further development, at an annual production rate of about 60,000 ounces of gold and 200,000 ounces of silver. Development was to include the construction of a 500-ton-per-day mill.

Also in Yavapai County, near Crown King, about 35 miles south of Prescott, Nor-Quest Arizona Inc., a subsidiary of Nor-Quest Resources Ltd. of Nanaimo, British Columbia, maintained intermittent gold and silver production at its underground Gladiator War Eagle Mine and 100-ton-per-day mill.

In the Bighorn Mountains of western Maricopa County, Roddy Resources Inc., of Vernon, British Columbia, Canada, and J. Devins Resource Group, its partner and mine operator, began heap-leaching operations at the U.S. Mine. Leaching at the surface mine, also known as the Bighorn Mine, began in late 1986 and was limited to one leach pad. The company reportedly planned to construct another leach pad in the near future. At the El Tigre, or Big Horn property, in the same district but several miles to the northwest of the U.S. Mine, Can-Ex Resources Ltd. of Vancouver, British Columbia, Canada, continued exploration and evaluation of five old mines. Can-Ex was focusing efforts on examining the property's potential as an open pit and heap-leaching facility.

Between Parker and Quartzite in La Paz County in western Arizona, Cyprus Minerals Co. moved forward on its plans to bring the Copperstone property into production during the third quarter of 1987 at a rate of about 60,000 ounces of gold per year. Estimated recoverable reserves of metal in the Copperstone deposit are 317,000 ounces, deemed to be sufficient to support at least 5 years of mining at what will reportedly be the largest open pit gold mine in the State.

California.—Production of gold in California rose substantially in 1986. For the fourth consecutive year, the State's reported gold production increased more than 100%. A number of new mines began producing gold while many other potential producers entered the final stages of exploration or preproduction development and were expected to begin producing in 1987 or 1988. The State's largest gold mine, Homestake Mining Co.'s McLaughlin Mine, near the town of Lower Lake, 60 miles north of San Francisco, completed its first full year of operation, producing 173,000 ounces of gold from slightly over 1 million tons of milled ore. The mine had originally been scheduled to produce over 200,000 ounces annually, but during 1986, ore grades were lower than expected. Reexamination of the original ore grade data led to a recalculation and reduction in the mine's ore reserves of about 6%. To offset the effect of lower ore grades, Homestake began studies aimed at reducing costs and enhancing the efficiency of the recovery process.

The largest new gold mine to come onstream in California during 1986 was the Mesquite Mine, developed by Gold Fields Mining Corp., a wholly owned subsidiary of Consolidated Gold Fields PLC, of the United Kingdom. Following the pouring of its first gold during the new plant testing period in mid-February and the commencement of leaching operations in March, the mine, six miles north of Glamis, in Imperial County, attained its targeted gold recovery rate during the first week in April. The open pit heap-leaching operation is expected to yield 130,000 to 160,000 ounces of gold per year.

East of the Mesquite Mine and near the Colorado River, Chemgold Inc., a subsidiary of Glamis Gold Ltd. of Vancouver, British Columbia, Canada, reported that its Picacho Mine produced 26,378 ounces of gold by heap leaching during the fiscal year ended June 30, 1986, compared with nearly 25,000 ounces in fiscal year 1985. Chemgold's direct cost, including depreciation, to produce an ounce of gold was $126, nearly identical to the cost in 1985. In addition to producing ore from two open pits and preparing a third for production, the company conducted a drilling program on a nearby mineralized zone designated the "Dulcina Deep." An open pit plan and a cost estimate indicating a viable project at $350 per ounce of gold was prepared. Also in Imperial County, near Ogilby, Eastmague Gold Mines Ltd. of Toronto, Canada, through its subsidiary, American Girl Mining Corp., reportedly continued construction and development work on its Cargo Muchacho open pit and heap-leaching facility. Mining and metal production from the test heap was expected to begin in early 1987.

To the north in Kern County at Chemgold's other California gold property, the Yellow Aster Mine, near Randsburg, 125 miles northeast of Los Angeles, the company announced in October that heap leaching had begun and that it expected to extract about 4,000 ounces of gold from the LaMonte discovery zone over the ensuing 6-month period. The company also completed exploration drilling of the main Yellow Aster pit area and applied for the permits necessary to screen and leach 2.6 million tons of dump material from earlier mining operations. Near the city of Mojave in Kern County, CoCa Mines Inc. and its partner, Ventures Trident, which together constitute Cactus Gold Mines Co., brought its Cactus gold mine, a 1,000-ton-per-day open pit and heap-leaching facility, on-stream in the fall. Gold production by yearend had reportedly amounted to nearly 11,000 ounces.

In adjoining San Bernardino County, Beaver Resources Inc., of Vancouver, Canada, completed a shallow drilling program at its Kramer Hills gold property that reportedly doubled its minable ore reserves to over 1 million tons bearing about 40,000 ounces of gold. The drilling also intersected several high-grade areas outside of the main pit area. Toward the end of March, Beaver and its partner Agean Resources Inc, a subsidiary of Glamis Gold, reportedly began leaching at Kramer Hills, and a third leaching pad was to be constructed to enhance the mine's capacity. At the Argus gold project of Queenstake Resources, of Vancouver, Canada, the firm performed feasibility studies to determine if the property could be developed as a viable heap-leaching project. Ore was to be mined from three potential open pit areas identified by an earlier exploration program.

Near Nipton on the California-Nevada border in San Bernardino County, Vanderbilt Gold Corp. reportedly attained full-scale ore production in the fall at its open pit Morningstar Mine. Initial heap-leaching production yielded about 4,000 ounces of gold during 1986 with full-year leaching in 1987 expected to result in 32,000 ounces being produced. About 15 miles to the north, Colosseum Gold Mines Ltd. and several partners, new owners of the Colosseum project in the Clark Mountains near the Nevada border, reportedly moved toward a planned mid-1987 startup. The mine was forecast to produce about 70,000 ounces of gold per year.

In the several central California counties hosting the famous Mother Lode and associated gold producing districts, gold mining activity was undiminished from the previous year. Increased erosion resulting from heavy rains in the Sierra Nevada foothills in early 1986 and the possibility that greater than usual amounts of gold may have thus been uncovered, reportedly brought scores of gold seekers into the area during the spring and summer. In Mariposa County, Goldenbell Resources Inc. decided at yearend to place its Pine Tree gold project near Coulterville into production in 1988. The mine will start as an open pit operation utilizing flotation, roasting, and leaching to recover about 130,000 ounces of gold per year. About 15 miles to the north in Tuolumne County, Sonora Gold Corp. announced near yearend that it had begun the startup phase at its new Jamestown mining and milling complex at Jamestown. The mine is projected to produce about 130,000 ounces of gold per year from ore bodies centered around the old Harvard Mine. The first shipment of gold-bearing concentrate left the new 10,000-ton-per-day flotation plant in early January. Until construction of the plant at Jamestown is completed, reduction of the concentrate will be performed out-of-State. Sonora's minority partner in the Jamestown venture is Pathfinder Gold Corp, a wholly owned subsidiary of Cogema Inc., a French firm. Both Sonora and Goldenbell Resources are members of the ABM Mining Group Inc. of Vancouver, Canada.

Near Angels Camp in Calaveras County,

Grandview Resources Inc., of Vancouver, through its subsidiary, Carson Hill Gold Mining Corp., poured its first bar of production gold at the new 5,000-ton-per-day Carson Hill Mine. The open pit heap-leaching facility, developed on the site of the historic Carson Hill Mine, is expected to add 60,000 ounces of gold per year to California production.

In Nevada County, north of Grass Valley, Coastal Mining Co., a subsidiary of M.A. Hanna Co., and its partner Centurion Minerals Ltd., of Vancouver, Canada, was reportedly examining the gold potential at the San Juan Ridge property near North Columbia. Placer Service Corp., after spending a number of years exploring the old hydraulically worked property, released it in 1984 owing to low gold prices and regulatory restrictions. In Plumas County near La Porte, Brush Creek Mining & Development Co. Inc. opened its placer mine, the Gardner Point gold mine, in July; however, owing to logistical problems and the onset of winter weather, the production rate did not reach the company's goal of 12,000 to 15,000 ounces per year.

Near Happy Camp in Siskiyou County, mining operations were terminated at the Grey Eagle Mine of Noranda Grey Eagle Mines Inc. Exhaustion of the ore body, opened in 1982, was the reason for the closure. Following the closure in March, the company began its scheduled reclamation phase.

Near Marysville, the placer gold dredging operations of Yuba Placer Gold Co., a joint venture between Yuba Natural Resources Inc. and St. Joe Gold Co.'s Placer Service, were severely impacted by the same winter rains and flooding that attracted prospectors to placer fields elsewhere in the State. Again, as in years past, numerous small intermittent placering operations were active throughout the State during 1986, and exploration for new gold deposits and of existing undeveloped properties continued at a brisk pace.

Colorado.—Gold mining in Colorado was substantially advanced by the April 1 reopening of the Sunnyside Mine, the State's largest underground gold mine, followed by the April 16 opening of Galactic Resources Ltd.'s new open pit Summitville Mine in Rio Grande County.

Slightly more than a year after Standard Metals Corp. of New York ceased operations at the Sunnyside Mine, mining was resumed at the rehabilitated Silverton facility by its new owners, Echo Bay. August 1 marked the resumption of commercial metal production. In October, a joint venture agreement was concluded between the mine operator, Sunnyside Gold Corp., and Gerber Minerals Corp. to explore and develop the gold potential of the presently closed Gold King Mine claims immediately west of the Sunnyside property.

Heap leaching at Galactic's new open pit mine, in the San Juan Mountains, at an altitude of about 12,000 feet, began on June 5, and by yearend, the mine had reportedly produced about 55,000 ounces of gold. To accommodate the two ore types present in the deposit, hard leachable silica ore and soft clayey leach-resistant ore, Galactic employs a dual 30,000-ton-per-day processing system. Under the system, silica ore is crushed and goes directly to a heap for leaching. Clayey ore, following a separate path, is agglomerated with portland cement prior to placement on a separate heap. To partially overcome the effects of the severe winter weather in the area, expendable leach solution delivery pipes are buried permanently in the heaps, and in winter, the leach solution is preheated prior to injection. When winter weather arrives, mining and ore haulage to the heaps ceases but solution injection continues. The so-called valley-fill-type heaps employed are unique in that the pregnant solution, rather than flowing to an exposed collection pond, is collected for processing from a sump at the protected base of the heap. Using this combination of features, Galactic hoped to maintain its leaching circuits in operation for better than the 7-month-minimum season planned during preproduction feasibility studies. During the year, Galactic also announced that exploration efforts had resulted in the discovery of additional ore zones nearby, reportedly capable of doubling the mine's known reserves.

In central Colorado around the historic old Cripple Creek mining district, Nerco Minerals Co. reportedly halted work at its Victor Gold Mine in late January owing to design and construction problems related to an earlier expansion program. The mine is one of the State's largest gold producers and was among the first to successfully employ an all-weather vat leaching process. Nearby, Cripple Creek and Victor Gold Mining Co., a partnership between Texasgulf Minerals and Metals Inc. and Golden Cycle Gold Corp., completed construction and seasonal loading of two new heap-leaching pads. The pads, presently holding about 800,000 tons, were designed to hold more than 1.5 million tons of dump material collected from old local mines. The two pads are in addition to one commissioned in August 1985. The venture reportedly recovered about 26,000 ounces during the 1986 leaching season and anticipated recovering more than 31,000 ounces during 1987.

Near Ouray, in Ouray County, Camp Bird Colorado Inc., a subsidiary of Federal Resources Corp., extended a 2-year lease to three companies known collectively as the Camp Bird Venture, and made up of Chipeta Mining Corp. (76%), Royal Gold Inc. (19%), and Ouray Ventures Inc. (5%). Chipeta is a wholly owned subsidiary of Western Mining Corp. Holdings Ltd. of Australia. The main objective of the group at Camp Bird is to locate new high-grade ore reserves at the former lead, zinc, silver, and gold producer. The mine, closed since 1981, had been one of the nation's largest gold producers, with cumulative production of more than 1.4 million ounces. In recent years, however, work has been confined to exploration and development, with only limited production. To the south, at Red Mountain, along the Ouray-San Juan County line, Cornucopia Resources Ltd., of Vancouver, Canada, moved to accelerate development of its Red Mountain open pit gold and silver heap-leaching project. Plans called for seasonally limited mining to begin at the 12.4-million-ton deposit in 1988.

Idaho.—Gold production in Idaho, at 70,440 ounces in 1986, has nearly trebled since 1979. At the end of July, Coeur d'Alene Mines Corp. began mining and crushing operations at its new Thunder Mountain gold mine, in eastern Valley County. The open pit heap-leaching facility, at the site of the old Sunnyside Mine, yielded 11,000 ounces of gold before it was closed for the winter at the end of October. The property's elevation at nearly 9,000 feet limits the productive season to only 6 or 7 months per year. The company expects to recover about 25,000 ounces of gold during its first full season of operation in 1987.

Fifteen miles southeast of Yellow Pine in Valley County, three Canadian firms (Pioneer Metals Corp., the operator, and its affiliates, MFC Mining Finance Corp. and TRV Minerals Corp.) restarted seasonal mining operations at the Stibnite-West End gold mine following a 1-year hiatus during which Superior Oil Co., a subsidiary of Mobil Oil Corp., sold its 75% interest in the property to Pioneer. The mine, at an elevation of 7,000 feet, is a seasonal open pit heap-leaching operation, which operates from early spring to late fall because of weather restraints. Five leach pads are employed at the property, and the total cycle time required to load, leach, recover, and unload the pads is 50 days. The consortium expected to produce nearly 30,000 ounces during 1986, with production forecast to rise to 42,000 ounces per year by 1988.

In Custer County's Yankee Fork mining district, U.S. Antimony Corp. (USAC) entered into a joint venture agreement on the Valley Creek Mine, an open pit gold and silver mine developed by Golden Maple Mining and Leaching Co., of Kellogg. Under the agreement, USAC will operate the mine, trucking the ore 35 miles from the year-round operation to USAC's flotation and cyanide leach plant at Yankee Fork. USAC also continued seasonal mining on its properties at the higher elevation of Estes Mountain and initiated a program of mine development at the base of the mountain where mining on a year-round basis is possible. The company's mill also continued to process gold- and silver-bearing ores from other mines in the district.

Exploration activity in Idaho continued to be focused on the search for gold deposits that were mineralogically compatible with the heap-leaching process. In Washington County, Ican Resources Ltd. and Canu Resources Ltd., both of Vancouver, Canada, continued exploration and feasibility studies on their Almaden property, 75 miles northwest of Boise. Open pit mining and heap-leaching methods are planned. Another former producer, the Atlanta Property, in the Atlanta mining district of Elmore County, was undergoing examination as a potential heap-leaching operation by another Vancouver company, Atlanta Gold Corp. Initial plans included beginning the mine as an open pit project by late 1988, then moving underground at a later date.

In Idaho County, Nevex Gold Inc. continued exploration at its Robinson-Dike claims and entered into a joint venture agreement with Mines Management Inc. of Spokane to acquire an interest in an adjoining property known as the Majestic Project. Nevex was reportedly planning to have the Robinson-Dike property in production as an open pit heap-leaching operation in 1987. Near Elk City, Normine Resources Ltd. and Amir Mines Ltd. entered into a joint venture agreement with Glamis Gold in May to further pursue their interests in the Buffalo Gulch-Friday-Deadwood Mountain gold belt. Pursuant to the agreement, Glamis Gold was to proceed in the spring of 1987 with a test production program at the Buffalo Gulch claims and bulk-leaching tests at the Friday gold zone to the south. All three companies are from Vancouver. In Shoshone County, Golden Chest Inc., of Tempe, AZ, announced that examination of its historic Golden Chest property near Murray revealed the presence of an ore body with open pit mining potential. Additional exploration, drilling, and evaluation was to be done during 1987.

Interest in the State's placer mining potential remained high during 1986, with applications and plans to placer mine in various drainages increasing over similar applications submitted the year before. Opposition to placer mining based on environmental concerns was similarly greater.

Montana.—In an annual review and summary of mining and mineral developments in Montana in 1986,[10] the Montana State Bureau of Mines and Geology noted that exploration for gold was widespread over much of the western half of the State and that preliminary data on the number of new mining claims recorded from January through the end of September indicated an increase over the number of claims recorded during the previous year.

In Southern Park County, the Jardine Joint Venture, a partnership between Homestake Mining and American Copper & Nickel Co. Inc., reportedly received the necessary State permits to begin underground mining operations. At yearend, no decision to proceed had yet been released; in the meantime, surface and underground exploration and drilling continued. In the Judith Mountains, in Fergus County, Cimarron Exploration Inc. and its partner Chelsea Resources Ltd., of Vancouver, Canada, continued development and construction of a 50-ton-per-day mill at the Spotted Horse gold mine. The mill was scheduled to begin processing stockpiled high-grade ore from the rehabilitated underground working during the first quarter of 1987.

To the north in Phillips County, Pegasus Gold Inc. produced 86,300 ounces of gold and 214,700 ounces of silver at its Zortman-Landusky Mine in the Little Rocky Mountains. Despite a torrential rain, in late September, which caused abnormally high volumes and dilution of the leach solutions, no leach solution escaped from the leaching circuit or from the containment ponds.

At Whitehall, in Jefferson County, the State's largest gold mine, Placer U.S. Inc.'s Golden Sunlight Mine, produced 92,404 ounces of gold in 1986, compared with 96,205 ounces produced in 1985. The small decline in production reflected a lower grade of ore and reduced recovery. At yearend, the company started its new sand tailing retreatment plant and added a preaeration step in the milling process to reduce reagent consumption and costs. The company completed underground drilling at the adjacent West Mineral Hill ore body, and studies were under way at yearend to determine the future use of the property. Also in Jefferson County, U.S. Minerals Exploration Co. and Pegasus moved toward an early 1987 startup of their Montana Tunnels open pit gold, silver, zinc, and lead mine. Following a short startup period, the flotation mill was expected to process 12,500 tons of ore per day and produce 106,000 ounces of gold, 1.7 million ounces of silver, 26,000 tons of zinc, and 5,700 tons of lead annually from 4.3 million tons of ore; gold production during 1987 was expected to be about 50,000 ounces. The recovery plant was designed as a zero discharge facility and utilizes a unique tailings disposal process that allows for the maximum recovery and reuse of process wastewater.

Several placer mines were active in Montana during the summer season. In western Missoula County, USAC, of Thompson Falls, MT, continued placer mining operations on Nine Mile Creek. Southwest of Dillon, in Beaverhead County, Channel Mining Co. ran an 800- to 1,000-yard-per-day washing plant near Grant.

Exploration and development work was conducted at a number of properties throughout the State. One of the most active areas was around the town of Elkhorn in Jefferson County. Near there, but in Broadwater County, Western Energy Co., a subsidiary of Montana Power Co., continued to explore its Chartam property south of Winston; the company also investigated its Keep Cool Project east of Lincoln in Lewis and Clark County. Near Helena, Mountain West Resources and Homestake Mining joined forces to conduct further exploration at the Elkhorn property. Also near Helena, Moruya Gold Mines of North America Inc. and several partners were reportedly studying the Pauper's Dream, a former producer once held by Anaconda Minerals Co. Gold Pan Resources Inc. continued to explore its Bullion and Crystal Tunnels properties, about 5 miles west of the developing Montana Tunnels project. At Marysville, in Lewis and Clark County, AMAX Exploration Inc. and Gulf Titanium Ltd. continued to explore the Cruse Belmont and adjoining Empire Mine properties. To the south in Deer Lodge County and near Georgetown Lake, Gold Coin Mining Inc. of Spokane, reportedly continued development work at the Gold Coin Mine, a former producer closed since 1962. In Liberty County in north-central Montana, Santa Fe Mining began exploration for gold in the Sweet Grass Hills near the Canadian border.

Nevada.—A dozen or so new mines or expansions at existing operations combined to push the State's share of national gold production even higher than in 1985. The increased activity also provided about 2,000 new jobs and thereby helped to boost the economy of many rural Nevada counties.

Fifty miles north of Gerlach in Washoe County, Western Goldfields Co., of Sparks, and several corporate partners opened the new Hog Ranch gold mine, breaking ground for the open pit in April, commencing heap leaching in August, and pouring the first bar of production gold in mid-September. The mine property, reportedly covering about 12,000 acres of continuous lode-mine claims is the first major gold mine to be developed in Washoe County. Output is expected to be 50,000 to 55,000 ounces per year. In Pershing County, 40 miles northeast of Lovelock and adjacent to Interstate Highway 80 (I-80), Pegasus brought its new Florida Canyon Mine on-stream in September. In early October, Pegasus began heap leaching agglomerated ore mined from both Florida Canyon and from its recently acquired Relief Canyon property, 40 miles to the south. The Relief Canyon Mine was brought into production in 1985 by Lacana Mining Corp. Following a brief production period during which suitable gold recovery was not realized, Lacana terminated the operation. Pegasus subsequently determined that crushing and agglomeration were necessary to effect a suitable recovery from Relief Canyon ore. Following purchase of the mine from Lacana in mid-1986, Pegasus resumed mining at the property, transporting the ore via I-80 to the Florida Canyon site for processing and leaching. One unique feature at Florida Canyon is the development and use of a conveyor-loaded circular 200-acre leach pad.

Agglomerated ore is fed by conveyor to a mobile ore stacker conveyor system, anchored in the center of the circular pad. The ore is then distributed in uniform layers by the mobile stacker as it traverses the pad. Reportedly, this is the first heap leach gold mine to utilize this system. The Florida Canyon Mine is expected to yield about 53,000 ounces of gold per year. Also in Pershing County, about 25 miles northeast of Lovelock, Coeur d'Alene's new Rochester silver-gold mine completed, near yearend, its first full quarter of operation. During this startup period, 4,200 ounces of gold and 544,000 ounces of silver were produced at the open pit heap-leaching facility. At full production, Rochester was expected to yield 43,000 ounces of gold and 3.7 million ounces of silver per year.

In the Slumbering Hills of northwestern Nevada, near Winnemucca, AMAX Inc. poured the first bar of production gold at its Sleeper gold mine in late March. The Humboldt County deposit was discovered by AMAX's geologists in 1982. As a result of an earlier than anticipated startup date and higher than originally planned output by the new 500-ton-per-day mill, production during 1986, at 128,000 ounces of gold and 94,000 ounces of silver, substantially exceeded earlier first-year projections. Both conventional milling and heap leaching were employed at the mine. Northeast of Winnemucca, FRM Minerals Inc., a wholly owned subsidiary of First Mississippi Corp., completed the first full year of heap leaching both open pit ore and old dump material at its Getchell property.

In late April, Tenneco Minerals Co. poured the first gold at its 75,000-ounce-per-year McCoy project, 27 miles southwest of Battle Mountain, in Lander County. The new open pit and heap-leaching facility was formally dedicated in September. Before yearend, Tenneco announced that it had sold its Nevada gold mining interests to Echo Bay. Included with McCoy in the sale to Echo Bay were Tenneco's Manhattan Mine in Nye County and the Borealis Project, near Hawthorne, in western Mineral County. The Manhattan Mine has two open pits, and uses conventional milling. The Borealis Mine is an open pit heap-leaching operation; at Borealis, production from the company's new Freedom Flats ore body was to begin in early 1987. Also in Lander County, gold was poured to mark the opening near yearend of a 1,000-ton-per-day flotation mill at the Austin Gold Venture, several miles south of Austin. The open pit mine project is a joint venture between Inspiration Gold (a subsidiary of Inspiration Resources Corp.) and FMC Corp. Combined annual gold production in flotation concentrates and bullion is expected to be about 50,000 ounces. In southern Lander County, Nevada Goldfields Corp. moved toward an early 1987 restart at its surface and underground Kingston mining project. The operation, formerly known as the Sumich Mine, began operation in 1985 but was forced to close in midyear because of technical problems.

At Battle Mountain Gold Co.'s operations in northern Lander County, the company completed the second full year of production from the Fortitude ore body. Gold production in 1986 amounted to 259,000 ounces, compared with 222,000 ounces in 1985. Both gold recovery, averaging 96%, and gold ore grades, averaging 0.24 ounce of gold per ton, improved during 1986 compared with that of 1985. Production costs were $172 per ounce in 1986, compared with $206 per ounce in 1985. Evaluation of the Surprise deposit, found in 1985 at Copper Canyon about 7 miles north of Fortitude, continued during 1986. Premining stripping was scheduled to begin in mid-1987, with gold production at a rate of 15,000 to 18,000 ounces per year, using heap leaching, to begin in 1988. In Crescent Valley to the southeast, along the Lander County-Eureka County line, Cortez Gold Mines reportedly boosted its annual gold production rate by 10%, to over 62,000 ounces, most of which was extracted from reserves at the Horse Canyon deposit.

In mid-1986, Newmont Mining Corp.'s wholly owned subsidiary Carlin Gold Mining Co. changed its name and ownership status to Newmont Gold Co., a publicly owned business. Reflecting improvements completed in 1985 at its gold mining and milling facilities in the Carlin area of Elko and northern Eureka Counties, Newmont more than doubled the tonnage of ore treated during 1986 to 7.7 million tons; gold sales also were increased from 223,000 ounces in 1985 to 474,000 ounces in 1986, and gold sales during 1987 were expected to rise 22% over those of 1986. Production costs were reduced from $261 per ounce in 1985 to $233 per ounce in 1986. Metal contained in ore reserves at Newmont's eight principal deposits was increased during 1986 by 3.6 million ounces, to 12.3 million ounces of gold. A number of properties showing significant gold mineralization were examined by Newmont during the year.

In Elko County, and north of Newmont's Carlin operations, Freeport-McMoRan Gold Co.'s (FMG) 70%-owned Jerritt Canyon operations processed over 1.3 million tons of ore, up 4% from that of 1985, for a record-high gold production of 269,000 ounces. Construction of FMG's new heap-leaching facility was completed during the year, and leaching was begun on about 200,000 tons of ore in August. At the end of 1986, the company's Big Springs project north of the Jerritt Canyon area was deemed to be of commercial quality, thus adding nearly 250,000 ounces of gold to FMG's proved reserves; combined reserves at Jerritt Canyon and Big Springs at yearend amounted to nearly 2.2 million ounces.

On October 18, Silver King Mines Inc. and Pacific Silver Corp., both of Salt Lake City, dedicated their new 1,000-ton-per-day gold and silver mill at Ruth, in central White Pine County. The carbon-in-pulp mill, known as the Lone Tree Mill, was constructed to process ore mined from surface deposits on 12,000 acres of eastern Nevada claims leased in 1985 from Kennecott. Annual gold and silver production from deposits such as the Star Pointer, at the site of Kennecott's old Nevada Mines Div. porphyry copper operations, was expected to be about 48,000 ounces and 96,000 ounces, respectively. Also in October, Pacific Silver reportedly closed its underground Buckskin Mine, 16 miles west of Yerington in Lyon County, owing to depletion of reserves. In the northwestern part of White Pine County, Northern Dynasty Explorations Ltd., following depletion of available surface reserves at its Little Bald Mountain property, reportedly began work on the first of two underground mining phases aimed at developing the remaining potential of the property. Production in 1986 amounted to 4,300 ounces of gold and 670 ounces of silver. In the same area of White Pine County, Placer U.S. completed conversion of its Bald Mountain Mine's heap-leaching and carbon-recovery facility from a pilot-scale plant to a full-scale operation capable of producing about 4,000 ounces of gold per month. The design throughput rate of about 2,000 tons of ore per day was achieved by April, and mining was expanded to include the Top ore body. Gold production for the year was reported to be nearly 35,000 ounces.

Southeast of Bald Mountain at the Alligator Ridge Mine, Amselco and Nerco Minerals continued to explore for additional ore to bolster the mine's nearly depleted reserve.

In western Nye County, on April 24, nearly 3 months ahead of schedule and $13 million under budget, the Minerals Div. of FMC poured its first bars of gold and silver at the Paradise Peak Mine, 8 miles south of Gabbs. By the end of 1986, the 4,000-ton-per-day open pit and milling facility had produced 143,000 ounces of gold and about 1.1 million ounces of silver. The average annual production in future years was expected to be about 100,000 ounces of gold and 3.5 million ounces of silver.

Sunshine Mining Co.'s new Weepah gold mine was opened in October near Silver Peak in Esmeralda County. Sunshine began mining gold ore from the open pit at a rate of about 1,000 tons per day. Earlier in the year, owing to depressed silver prices, Sunshine closed its Sixteen-to-One silver mine at Silver Peak and converted the existing mill there to process Weepah ore. Gold production at the Weepah is expected to be about 30,000 ounces per year.

New Mexico.—In December, after nearly 7 years of mining and producing gold at its Ortiz open pit heap-leaching operation near Cerrillos, Gold Fields Mining closed the mine following exhaustion of reserves.

A map of silver and gold occurrences in New Mexico was published by the New Mexico Bureau of Mines and Mineral Resources. The map and accompanying brochure describe the types and locations of deposits, districts of occurrence, and estimated production of each district.[11]

South Dakota.—Again, as in years past, South Dakota gold developments continued to be centered around the town of Lead, in Lawrence County. At Homestake Mining's Homestake Mine, at Lead, where gold has been the principal product for over 100 years, nearly 342,000 ounces of gold were produced during 1986. Ore milled from underground operations totaled about 1.9 million tons while surface ore milled amounted to nearly 432,000 tons. In 1986, the average grade of ore from the underground operations remained unchanged at 0.174 ounce per ton. Overall grade of ore milled improved, and mill recovery increased slightly to 94.7%. Homestake Mining's average cost of production increased to $298 per ounce from $294 in 1985. Mining and exploration work was focused below the 6,800-foot level while long-range exploration drilling continued from below 8,000 feet. Stripping work on the Open Cut project, site of the original gold strike, was proceeding. Ore and waste rock removed from the project totaled 13.1 million tons, from which nearly 32,000 ounces of gold was recovered. The main ore body will be exposed for mining in March 1987, when the project becomes fully operational.

In the Bald Mountain mining district west of Lead and 1 mile northwest of Terry Peak, Wharf Resources (USA) Inc. of Deadwood maintained heap-leaching operations and ore production at its Annie Creek and adjoining Foley Ridge Mines. Combined production for the year was expected to be about 26,000 ounces. Early in the year, Wharf completed the purchase of Homestake Mining's 25% interest in the Foley Ridge property. Improvements planned by Wharf were anticipated to increase production significantly.

North of Annie Creek near Carbonate, St. Joe Gold continued exploration drilling and environmental studies aimed at determining the feasibility of an open pit gold mining operation on its 3,000-acre Richmond Hill property.

Southwest of Lead, in the Ruby Basin District, Golden Reward Mining Co. (a joint venture between Moruya Gold Mines (1983) NL of Australia, Coin Lake Gold Mines Ltd. of Toronto, Canada, and Ventures Trident of Denver) moved ahead with plans to construct a 1.5-million-ton-per-year surface mine in Terry Gulch. Full-scale mining at the Golden Reward Mine was expected to begin in 1988 at an annual rate of about 30,000 ounces of gold. In February, Brohm Resources Inc., of Vancouver, Canada, acquired a 100% interest in the Gilt Edge property, at Galena, 4 miles southeast of Lead. Brohm reportedly plans a heap-leaching operation based on two adjacent open pit mines. Ore mining at an initial rate of about 750,000 tons per year was expected to begin in 1987, with production in 1988 forecast at 50,000 ounces of gold.

Utah.—Developments in Utah during 1986 included a midyear announcement by Kennecott that operations at its Bingham Canyon Mine, near Salt Lake City, would resume in early October. The company agreed to reopen the facility, closed since early 1985, as part of a labor contract settlement reached during July. Metals production was expected to restart in early 1987. When the ongoing modernization work is completed in 1988, the mine will be able to produce 260,000 ounces of gold and 2 million ounces of silver as part of the byproduct values recovered in the large copper mine. Bingham Canyon had been one of the Nation's leading byproduct gold producers for many years.

Utah's largest gold producer during the year was the Mercur Mine, operated by Barrick Mercur Gold Mines Inc. and owned by American Barrick Resources Co., of Toronto, Canada. The mine, near Tooele, in Utah's old Camp Floyd mining district, reportedly produced about 111,000 ounces of gold at an estimated production cost of about $190 per ounce.

Washington.—A record high 154,000 ounces of gold was reportedly produced in the State in 1986, with production at the new Cannon Mine, brought on-stream in early 1985, accounting for nearly 112,000 ounces. The Cannon Mine, at Wenatchee in Chelan County, owned by Asamera Minerals (U.S.) Inc. and Breakwater Resources Ltd., consists of a trackless underground facility supported by a new 2,000-ton-per-day flotation mill. Problems with a trunion bearing on the ball mill forced a temporary shutdown of the milling operation at midyear. Milling was resumed in late August. Within the mine and along its surface trend, the company maintained an aggressive exploration program aimed at maintaining existing ore reserves and locating new targets for later development. In November, Echo Bay acquired the North American gold properties of Tenneco; the acquisition included Tenneco's royalty interest retained during an earlier land transaction with the Asamera joint venture. Also in the Wenatchee area, Teck Resources (U.S.) 1983 Inc. conducted exploration and drilling around the old Lovitt Mine.

In the Liberty-Blewett Pass area west of Wenatchee, Tillicum Gold Mines Ltd. and its partner, Montana de Oro Inc., conducted an exploration and drilling program on their 8,000-acre tract that includes a number of former producing mines. Gold exploration was reportedly conducted on the Sunset Gold property in Liberty by M.G.M. Resources Corp. of Vancouver, Canada, and M.G.M.'s partner, Gold Placers Inc., of nearby Ellensburg. North of Liberty along Peshastin Creek, J & S Mining reportedly investigated placer gold on its Grey Wolf claims; the company also mined placer gold along the Sultan River in Snohomish County. In the northern part of Chelan County, Sunshine Valley Minerals Inc. continued work on the gold tailings at the long-abandoned Holden Mine just south of Lake Chelan.

At Washington's second largest gold mine, the Knob Hill Mine, in Ferry County, Hecla Mining Co. completed work on its new $42.2 million Golden Promise Shaft. The shaft was constructed to gain access to two high-grade veins discovered in 1984, just prior to the mine's closure owing to exhaustion of reserves. A number of other Ferry County projects were active during the year in the Republic mining district, between Republic and Danville. Three miles north of Republic, Glamis Gold and Crown Resources Corp. continued leaching tests at their South Penn property. Farther north, High Country Mining was reportedly producing gold- and silver-bearing concentrates at its Valley Mine. At the beginning of the year, Echo Bay entered into a joint venture agreement for the Key and Granny properties, which are held by Crown Resources and Gold Texas Resources Ltd., of Vancouver, Canada. Subsequent drilling by the venture partners reportedly identified a potentially minable deposit at the Granny property, west of Curlew, and a smaller one at the Key property, about 15 miles to the southeast.

Elsewhere within the State, gold continued to be the priority target of many companies. In the Pacific Ocean, offshore from Ilwaco, Columbia Ocean Minerals Inc. explored for gold and accessory titanium and iron on an offshore bar near the mouth of the Columbia River. Exploration continued at many of the State's former producing gold and silver mines in King, Okanogan, Stevens, and Whatcom Counties, and grassroots exploration for precious metals, especially epithermal-type deposits, was conducted by numerous companies statewide. Mining and exploration activities in the State during 1986 were summarized by the Washington State Department of Natural Resources.[12]

Other States.—Interest in gold and gold mine development was not confined to the traditional gold producing Western States. Exploration for and production of gold continued in the Eastern States as well.

Near Ishpeming, MI, Callahan Mining Corp.'s 100%-owned Ropes gold mine completed its first full year of operation, reportedly producing, according to Callahan's annual report, about 46,000 ounces of gold and over 62,000 ounces of silver. Startup difficulties encountered and corrected during the first half of the year resulted in lower first year production than originally anticipated. Callahan expected that the newly operational underground mine will yield 55,000 to 60,000 ounces of gold in 1987.

Encouraged by the success of new mine developments such as the Ropes Mine on Michigan's Upper Peninsula and the recent opening of several substantial new mines at nearby Hemlo, Ontario, Canada, numerous individuals and corporations, including some of the Nation's major gold producers, pursued base and precious metals targets in Michigan, Minnesota, and Wisconsin.

Flurries of interest in local precious metals mining, history, lore, and occurrences were evident during 1986 in several New England States, including Connecticut and Maine.

In Fairfield County, SC, Amselco and its new partner, Galactic, moved ahead with the preproduction phase at their gold deposit, 4 miles east of Ridgeway and 25 miles northeast of Columbia. Preliminary plans called for mining, at a rate of 14,000 tons per day, beginning in late 1987 or early 1988. Production was anticipated to be about 160,000 ounces of gold per year. Northeast of the Ridgeway Mine, in adjoining Lancaster County, Piedmont Land and Exploration Co. completed its first full year of gold production at the old Haile Mine, 3 miles northeast of Kershaw. Piedmont began operations in January 1985, using open pit heap-leaching methods. Gold was first discovered at the Haile site in 1827, and both surface and underground mining was continued on an intermittent basis until 1942. About 15 miles farther to the northeast, in Chesterfield County, near Jefferson, another historic South Carolina gold mine, the Brewer Mine, was being investigated by Westmont Mining Inc., a subsidiary of the London-based Costain Group PLC. The Brewer Mine was discovered about 1828 and has a history similar to that of the Haile gold mine.

There were reports in 1986 of companies exploring for gold and/or fixing a land position in old gold producing areas from Alabama north through Virginia, especially around old abandoned gold mines in south-central North Carolina.

Table 4.—Mine production of gold in the United States, by month

(Troy ounces)

Month	1982	1983	1984	1985[r]	1986
January	106,956	134,435	140,586	174,916	285,981
February	109,407	131,636	144,945	175,486	287,923
March	138,066	153,808	174,242	204,492	295,480
April	136,674	162,224	166,908	182,938	315,064
May	143,212	179,950	183,068	193,338	309,520
June	116,925	178,929	195,337	191,202	325,416
July	114,845	179,521	186,620	199,189	316,898
August	114,538	192,095	183,123	200,682	327,152
September	109,024	189,237	178,483	235,618	327,154
October	127,928	183,524	186,413	220,586	323,199
November	127,843	165,903	174,313	226,005	309,606
December	120,268	151,264	170,577	222,780	309,797
Total	1,465,686	2,002,526	2,084,615	2,427,232	3,733,190

[r]Revised.

Table 5.—Twenty-five leading gold-producing mines in the United States in 1986, in order of output

Rank	Mine	County and State	Operator	Source of gold
1	Carlin Miner Complex	Eureka, NV	Newmont Gold Co	Gold ore.
2	Homestake	Lawrence, SD	Homestake Mining Co	Do.
3	Jerritt Canyon (Enfield Bell)	Elko, NV	Freeport Gold Co	Do.
4	Battle Mountain	Lander, NV	Battle Mountain Gold Co	Do.
5	McLaughlin	Napa, CA	Homestake Mining Co	Do.
6	Round Mountain	Nye, NV	Round Mountain Gold Corp	Do.
7	Mesquite	Imperial, CA	Goldfields Mining Co	Do.
8	Paradise Peak	Nye, NV	FMC Corp	Do.
9	Sleeper	Humboldt, NV	Nevada Gold Mining Inc	Do.
10	Cannon	Chelan, WA	Asamera Minerals (U.S.) Inc	Do.
11	Mercur	Tooele, UT	Barrick Mercur Gold Mines Inc	Do.
12	Golden Sunlight	Jefferson, MT	Golden Sunlight Mines Inc	Do.
13	Pinson	Humboldt, NV	Pinson Mining Co	Do.
14	Zortman-Landusky	Phillips, MT	Pegasus Gold Inc	Do.
15	Alligator Ridge	White Pine, NV	Amselco Minerals Inc	Do.
16	Horse Canyon (Cortez)	Lander, NV	Cortez Gold Mines	Do.
17	New Summitville	Rio Grande, CO	Summitville Consol Mining Co. Inc	Do.
18	Dee	Elko, NV	Dee Gold Mining Co	Do.
19	Gold Strike	Eureka, NV	Western States Minerals Corp	Do.
20	Ropes	Marquette, MI	Callahan Mining Corp	Do.
21	Grey Eagle	Siskiyou, CA	Noranda Grey Eagle Mines Inc	Do.
22	Republic Unit	Ferry, WA	Hecla Mining Co	Do.
23	McCoy	Lander, NV	CanAm Gold Corp	Do.
24	Borealis Project	Mineral, NV	do	Do.
25	Buckhorn	Eureka, NV	Cominco American Incorporated	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	Lode: Copper ore: Short tons	Lode: Copper ore: Troy ounces of gold
1982	38,466	17,918,046	1,124,225	1,213,247	37,697	5,318,490	13,539	150,095,844	233,093
1983	53,887	24,141,617	1,593,406	1,124,556	43,445	7,512,261	35,057	137,668,016	258,222
1984	37,597	30,497,262	1,736,998	1,587,850	55,382	4,380,945	25,785	132,899,873	198,729
1985	r73,299	35,908,918	r2,170,920	1,043,854	41,801	3,836,130	31,288	149,464,862	74,633
1986:									
Alaska	48,271	--	--	--	--	--	--	--	--
Arizona	W	W	W	--	--	--	--	95,266,294	36,951
California	22,469	6,421,705	403,148	--	--	--	--	--	--
Colorado	W	2,913,798	103,169	--	--	--	--	--	--
Idaho	W	748,327	41,326	W	W	W	W	--	--
Michigan	--	W	W	--	--	--	--	--	--
Montana	W	W	W	--	--	W	W	W	W
Nevada	W	34,005,354	2,079,137	W	W	W	W	--	--
New Mexico	--	W	W	W	W	--	--	W	W
North Carolina	--	300	12	--	--	--	--	--	--
Oregon	W	200	16	--	--	--	--	--	--
South Carolina	--	W	W	--	--	--	--	--	--
South Dakota	--	W	W	--	--	--	--	--	--
Utah	W	2,070,765	111,007	--	--	305,717	800	W	W
Washington	--	W	W	--	--	--	--	--	--
Total[1]	73,280	60,698,866	3,543,557	869,099	28,399	5,532,818	22,207	116,775,362	47,037
Percent of total gold	2	XX	95	XX	1	XX	1	XX	1

Year	Lode: Lead and zinc ores: Short tons	Lode: Lead and zinc ores: Troy ounces of gold	Lode: Copper-lead, lead-zinc, copper-zinc, and copper-lead-zinc ores: Short tons	Lode: Copper-lead, lead-zinc, copper-zinc, and copper-lead-zinc ores: Troy ounces of gold	Lode: Old tailings, etc.: Short tons	Lode: Old tailings, etc.: Troy ounces of gold	Total[1]: Short tons	Total[1]: Troy ounces of gold
1982	--	--	([2])	([2])	[3]646,084	[4]18,666	175,191,711	1,465,686
1983	--	--	([2])	([2])	[3]858,749	[5]18,509	171,305,199	2,002,526
1984	([2])	([2])	([2])	([2])	[6]472,359	[7]30,124	169,838,289	2,084,615
1985	--	--	([2])	([2])	[3]4,476,684	[4]35,291	194,730,448	r2,427,232

Table 6.—Gold produced in the United States, by State, type of mine, and class of ore —Continued

	Lode						Total[1]	
	Lead and zinc ores		Copper-lead, lead-zinc, copper-zinc, and copper-lead-zinc ores		Old tailings, etc.			
	Short tons	Troy ounces of gold	Short tons	Troy ounces of gold	Short tons	Troy ounces of gold	Short tons	Troy ounces of gold
1986:								
Alaska	--	--	--	--	--	--	--	48,271
Arizona	--	--	--	--	108,232	1,466	W	W
California	--	--	--	--	--	--	6,421,705	425,617
Colorado	W	W	--	--	W	W	3,134,352	120,347
Idaho	--	--	--	--	--	--	2,133,674	70,440
Michigan	--	--	--	--	--	--	W	W
Montana	--	--	--	--	--	--	W	W
Nevada	--	--	--	--	--	--	38,639,010	2,098,929
New Mexico	--	--	--	--	W	W	18,799,590	39,856
North Carolina	--	--	--	--	--	--	300	12
Oregon	--	--	--	--	--	--	W	W
South Carolina	--	--	--	--	--	--	W	W
South Dakota	--	--	--	--	--	--	W	W
Utah	--	--	--	--	--	--	W	W
Washington	--	--	--	--	--	--	W	W
Total[1]	(2)	(2)	--	--	[5]334,932	[5]18,710	184,211,077	3,733,190
Percent of total gold	XX	(2)	XX	--	XX	(8)	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]Included with "Old tailings, etc."
[3]Includes lead-zinc ores.
[4]Includes gold recovered from lead-zinc and molybdenum ores.
[5]Includes gold recovered from lead-zinc ores.
[6]Includes lead and lead-zinc ores.
[7]Includes gold recovered from lead ore, lead-zinc ores, and molybdenum ore.
[8]Less than 1/2 unit.

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)		
1982	140,196	25,416	19,901,354	1,101,721	154,933,339	3,245,464	290,023	216,822	10,060	175,191,711	1,427,220
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	[r]2,088,815	154,886,138	3,220,471	231,706	221,315	[2]34,179	194,730,448	[r] [2]2,358,441
1986:											
Arizona	--	--	W	W	W	W	W	110,947	2,191	W	W
California	1,600	92	6,419,005	402,900	1,100	10	156	--	--	3,072,180	403,148
Colorado	98,436	14,102	W	W	W	W	W	W	W	3,134,352	[2]120,347
Idaho	--	--	1,596,774	68,733	536,900	25,922	[2]1,707	--	--	2,133,674	[2]70,440
Michigan	--	--	W	W	--	--	--	--	--	W	W
Montana	--	--	W	W	W	W	W	W	W	W	W
Nevada	750,000	19,500	37,538,995	2,039,468	W	W	W	W	W	38,639,010	[2]2,098,929
New Mexico	--	--	W	W	W	W	W	W	W	18,799,590	39,856
North Carolina	--	--	300	12	--	--	--	--	--	300	12
Oregon	200	16	--	--	--	--	--	--	--	200	16
South Carolina	--	--	W	W	--	--	--	--	--	W	W
South Dakota	--	--	W	W	--	--	--	--	--	W	W
Utah	--	--	2,376,482	111,807	W	W	W	--	--	W	W
Washington	--	--	W	W	W	W	W	--	--	W	W
Total	850,236	33,710	64,682,782	3,357,244	118,529,487	2,838,702	[2]262,703	148,572	[2]6,455	184,211,077	3,660,112

[r]Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."
[1]Includes old tailings and some nongold-bearing ores not separable, in amounts ranging from 0.15% to 0.25% of the totals for the year listed.
[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)
1982	7,616,036	710,688	12,294,232	391,033
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	[r]1,555,835	19,059,466	532,980
1986	27,123,093	2,358,641	37,559,689	998,603

[r]Revised.
[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:						
1982	6	8	4,702	22	$8,130	$1.729
1983	3	4	4,785	30	12,512	2.615
1984	2	3	4,840	29	10,387	2.147
1985[r]	3	4	3,958	32	10,185	2.573
1986	3	4	4,081	30	11,227	2.751
Dragline dredging:						
1982	3	14	[2]29	[3]3	1,188	18.960
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
Hydraulicking:						
1982	4	4	17	([5])	139	8.026
1983	1	1	3	([5])	117	43.342
1984	1	1	28	([5])	90	3.220
1985	--	--	--	--	--	--
1986	1	1	100	([5])	17	.166
Nonfloating washing plants:						
1982	10	11	805	13	4,829	6.000
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
Underground placer, small-scale mechanical and hand methods, suction dredge:						
1982	15	15	30	([5])	174	5.848
1983	23	24	[2]167	[3]3	1,437	7.831
1984	10	11	197	1	454	2.304
1985	19	19	621	6	2,061	3.320
1986	24	24	896	14	5,156	5.755
Total placers:[6]						
1982	38	52	[2]5,584	[3]38	14,460	[4]2.475
1983	35	48	[2]6,026	[3]54	22,849	[4]3.792
1984	25	36	[2]5,501	[3]38	13,560	[4]2.242
1985[r]	31	43	[2]5,694	[3]73	23,284	[4]3.913
1986	35	47	[2]5,366	[3]73	26,985	[4]4.812

[r]Revised.
[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	1982[r]	1983[r]	1984[r]	1985[r]	1986
Concentrates and ores: Domestic and foreign	1,308	1,972	2,101	2,076	2,431
Old scrap	1,785	1,772	1,759	1,597	1,522
New scrap	1,372	1,357	1,543	1,510	1,576
Total[2]	4,466	5,102	5,403	5,184	5,529

[r]Revised.
[1]Data may include estimates.
[2]Data may not add to totals shown because of independent rounding.

CONSUMPTION AND USES

The total consumption of gold was essentially the same as that of 1985. The use of gold in various jewelry and artistic applications continued, as in most previous years, to be the dominant end-use sector, accounting in 1986 for about 54% of the total consumed. Electronic products, specialty alloys, and various aerospace applications constituted the principal industrial usages of gold, consuming nearly 1 million troy ounces in 1986. Gold's use in dental applications, although down somewhat from that of 1985, remained in-line with consumption levels reported during the 1982 through 1984 period.

Fabrication and sales of official gold coins and medallions by the U.S. Department of the Treasury changed substantially between 1985 and 1986. Owing to completion of authorized sales programs for the gold medallion, Olympic gold coin, and Statue of Liberty gold coin programs during the previous year, no sales of these coins were made during 1986. The popularity of the earlier programs notwithstanding, they could not match the immediate popularity of the American Eagle gold coin series launched by the U.S. Department of the Treasury in late 1986. Between October 20, and the end of the year, nearly 1.8 million ounces of gold in the form of Eagle gold coins was sold, an amount nearly equivalent to all the gold sold in earlier domestic coin programs from 1980 through 1985.

On November 20, the Commodity Exchange Inc. (COMEX), in New York, and the Sydney Futures Exchange, in Australia, launched a computerized gold futures trading link, thereby enabling market participants to initiate gold contract trades on one exchange and close them on the other. Contracts are for 100 troy ounces denominated in U.S. dollars.

Table 11.—U.S. consumption of gold,[1] by end-use sector[2]

(Thousand troy ounces)

End use	1982	1983	1984	1985[r]	1986
Jewelry and the arts:					
Karat gold	[r]1,676	[r]1,450	1,466	1,369	1,392
Fine gold for electroplating	17	18	18	18	17
Gold-filled and other	301	237	225	198	210
Total[3]	[r]1,994	[r]1,706	1,709	1,585	1,619
Dental	358	360	363	380	356
Industrial:					
Karat gold	64	44	42	34	37
Fine gold for electroplating	389	344	415	326	299
Gold-filled and other	649	644	628	667	657
Total[3]	1,102	1,032	1,084	1,027	994
Small items for investment[4]	9	3	8	7	6
Grand total[3]	[r]3,463	[r]3,101	3,164	2,999	2,976

[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

Official.—Stocks of gold bullion held by the U.S. Department of the Treasury (primarily at Fort Knox, KY; Denver, CO; and West Point, NY) continued to decline slowly, reflecting in part temporary withdrawals of bullion to initiate the American Eagle gold coin series.

Official stocks of market economy countries, including stocks held by the International Monetary Fund (IMF) and the Bank for International Settlements, totaled 1.145 billion ounces at yearend, essentially unchanged from stocks held at the close of 1985. IMF yearend stocks, 103.43 million ounces, were unchanged from stocks reported every year since 1980.

Commercial.—Stocks of refined bullion held by industrial users at yearend increased substantially from stock levels reported at the end of 1985. The 40% increase in inventories between yearend 1985 and yearend 1986 may reflect, in part, material obtained toward yearend to offset reduced levels of jewelry imports reportedly resulting from a weaker U.S. dollar. Stocks of gold certified for delivery by COMEX increased substantialy between yearends 1985 and 1986, and may reflect in part increased COMEX activity toward yearend. COMEX is the Nation's largest gold futures exchange.

Table 12.—Yearend stocks of gold in the United States

(Thousand troy ounces)

	1982	1983	1984	1985	1986
Industry	776	623	765	r619	865
Futures exchange	2,303	2,530	2,359	[1]2,110	[1]2,809
Department of the Treasury[2]	264,046	263,406	262,814	262,672	262,032
Earmarked gold[3]	348,555	341,402	r337,328	r337,399	332,733

rRevised.
[1]Commodity Exchange Inc. only.
[2]Includes gold in Exchange Stabilization Fund.
[3]Gold held for foreign and international official accounts at New York Federal Reserve Bank.

PRICES

The Engelhard Industries daily price for gold, which is based upon the London daily final price, averaged slightly more than $340 per ounce during the first half of 1986. Subsequent world economic and political developments favoring gold investment in some world markets converged at the beginning of the fourth quarter to drive the price to nearly $440, its highest level in over 3 years. The price remained near $400 throughout the remainder of the year, closing on December 31 at about $396. The Engelhard average for the year was about $368, an increase of $50 per ounce over the previous year's average. The increased value of gold in terms of U.S. dollars reflected, in part, augmentation of the supply of dollars—the result of domestic monetary policy directed toward lessening the problems related to trade imbalances. The price of gold, in terms of some stronger currencies such as the Japanese yen, the German mark, and the Swiss franc, declined overall in 1986.

Table 13.—U.S. gold prices[1]

(Dollars per troy ounce)

Period	Low Price	Low Date	High Price	High Date	Average
1982	r296.75	June 21	481.00	Sept. 7	375.91
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:					
January	326.70	Jan. 2	363.40	Jan. 16	345.78
February	331.75	Feb. 14	352.80	Feb. 25	339.60
March	336.00	Mar. 3	353.30	Mar. 21	345.74
April	333.50	Apr. 1	346.60	Apr. 23	340.84
May	339.10	May 20	345.75	May 9	342.80
June	337.15	June 17	348.75	June 12	343.12
July	342.70	July 2	357.90	July 31	349.17
August	358.90	Aug. 5	388.40	Aug. 11 and 13	377.24
September	393.65	Sept. 2	435.90	Sept. 22	419.37
October	401.40	Oct. 31	438.50	Oct. 8	423.91
November	381.15	Nov. 24	411.15	Nov. 10	398.74
December	388.30	Dec. 9	397.07	Dec. 1	392.58
Average and date	326.70	Jan. 2	438.50	Oct. 8	368.24

rRevised.
[1]Engelhard Industries daily quotation.

FOREIGN TRADE

Total net imports for consumption of gold increased for the third consecutive year. Net imports of refined bullion, over 13 million ounces, were three times greater than those of 1985. Following a trend begun in 1982, net exports of gold-bearing waste and scrap continued to fall. Net imports of gold-bearing ore and concentrate were little changed from those of 1985.

The import data shown in the accompanying tables is gold imported for consumption in the domestic market and does not include material intended for reexport. Thus, the refined bullion data shown in the tables does not fully reflect the 1986 activity associated with the large volume of gold assembled from the world markets by domestic traders for transhipment to Japan for use in that country's coin program. In part to satisfy demand for that program, Japan imported nearly 20 million ounces of refined gold during 1986; the United States, was the source of 7.5 million ounces. Gold contained in bullion coins imported into the United States was estimated to have declined for the third consecutive year to nearly 1.2 million ounces, compared with nearly 2.1 million ounces in 1985. Domestic investor interest in the new American Eagle coin program toward yearend may have depressed coin imports.

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

Year and country	Ore and concentrates: Quantity (troy ounces)	Ore and concentrates: 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[2]: Quantity (troy ounces)	Total[2]: Value (thousands)
1982	3,092	$1,028	1,149,821	$427,846	180,297	$69,264	1,637,184	$590,947	2,970,394	$1,089,086
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:										
Belgium-Luxembourg	--	--	44,748	16,665	44	11	1,161	385	45,953	17,060
Canada	1,212	304	333,161	115,243	304,692	103,522	2,436,727	904,472	3,075,792	1,123,541
Colombia	--	--	--	--	--	--	3,064	1,004	3,064	1,004
France	350	55	387,442	142,725	64,039	22,286	354	109	452,185	165,175
Germany, Federal Republic of	254	76	7,539	2,791	72,049	27,018	1,460	513	81,302	30,399
India	--	--	--	--	56	44	1,006	379	1,062	423
Israel	674	78	--	--	51	15	652	197	1,377	289
Italy	--	--	4,485	1,556	80	22	1,343	484	5,908	2,062
Japan	--	--	180	55	4,721	1,424	561,389	241,366	566,290	242,846
Mexico	47	14	63	27	--	--	6,068	2,050	6,178	2,091
Panama	--	--	--	--	--	--	4,952	1,790	4,952	1,790
Peru	--	--	--	--	474	187	23,594	8,817	24,068	9,003
Spain	--	--	1,662	584	--	--	--	--	1,662	584
Sweden	--	--	60,411	22,242	5,139	1,830	--	--	65,550	24,072
Switzerland	--	--	446	156	2,746	921	126,563	44,932	129,755	46,009
Turkey	273	82	88	28	878	323	--	--	1,239	433
United Kingdom	2,329	933	137,156	49,795	410	160	521	181	140,416	51,070
Yugoslavia	--	--	547	178	--	--	843	311	1,390	489
Other	205	47	1,141	427	888	242	2,542	793	4,776	1,510
Total[2]	5,344	1,589	979,069	352,471	456,267	158,005	3,172,239	1,207,783	4,612,919	1,719,848

[1]Bullion also moves in both directions between U.S. markets and foreign stocks on deposit in the Federal Reserve Bank. Monetary gold excluded.
[2]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

Table 15.—U.S. imports for consumption 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)
1982	202,410	$69,528	85,584	$27,786	394,667	$145,571	4,237,669	$1,650,719	4,920,330	$1,893,604
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:										
Australia	26	8	--	--	290	110	124,235	47,586	124,551	47,705
Belgium-Luxembourg	--	--	415	123	--	--	1,004,559	341,881	1,004,974	342,004
Bolivia	30	13	182,257	61,436	2,115	682	6,946	2,236	191,348	64,367
Brazil	--	--	318	102	--	--	245,576	89,320	245,894	89,422
Canada	11,644	4,007	67,222	17,740	1,133,210	409,835	5,392,748	2,012,434	6,604,824	2,444,016
Chile	485	57	--	--	17,653	6,035	214,502	76,864	232,640	82,957
Dominican Republic	11	4	10,816	2,789	184,632	68,379	101,740	34,595	297,199	105,767
Germany, Federal Republic of	62	19	--	--	3,635	1,494	297,060	105,475	300,757	106,988
Guyana	4,083	1,257	8,346	2,458	230	65	3,050	978	15,709	4,758
Italy	--	--	225	69	383	138	25,774	9,853	26,382	10,060
Mexico	12,048	4,518	18,771	5,556	361	54	5,300	2,123	36,480	12,252
Peru	--	--	16,212	5,527	3,789	1,190	8,832	2,890	28,833	9,608
South Africa, Republic of	1,107	371	38	13	--	--	217,845	78,769	218,990	79,153
Switzerland	47	10	--	--	13,011	4,646	3,830,664	1,338,463	3,843,722	1,343,119
U.S.S.R.	235	85	5	2	1,928	764	451,797	154,284	453,965	155,134
United Kingdom	--	--	1,281	431	16,722	5,943	1,071,682	377,284	1,089,685	383,658
Uruguay	--	--	--	--	748	202	760,973	328,147	761,721	328,349
Venezuela	--	--	174,682	50,973	704	181	4,821	1,585	180,207	52,740
Yugoslavia	--	--	528	185	6,048	2,574	11,724	4,193	18,300	6,952
Other	7,840	2,744	39,201	12,383	5,602	2,165	20,623	7,599	73,266	24,890
Total[3]	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

[1]Bullion also moves in both directions between U.S. markets and foreign stocks on deposit in the Federal Reserve Bank. Monetary gold excluded.
[2]Includes gold content of base metal ores, concentrates, and matte inported for refining.
[3]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

WORLD REVIEW

In 1986, for the seventh successive year, world gold mine production exceeded that of the previous year. The trend of production in all but a few of the producing countries has been upward for several years. On the other hand, production in the Republic of South Africa, the world's dominant producer, continued ratcheting slowly downward from levels reported during the early 1970's. These declines, however, do not necessarily reflect any structural change in South African gold mining. For example, South African mines are required by Federal law to mine the average value of their ore reserves. Thus, the declines reflect in part gold prices moving slowly upwards, greater volumes of lower grade ore processed, and the maintenance of an orderly scheme of mine development rather than simply concentrating on high-grade areas.

Consolidated Gold Fields, in its annual summary of world gold supply and demand, reported that the supply of gold available to commercial purchasers in market economy countries in 1986 was about 63.2 million ounces, or nearly 11.6 million ounces greater than that of 1985. For the first time, Gold Fields included gold scrap as a component of supply in its report. Following 1983 and 1984, when central banks and Government-controlled investment institutions, which together make up the "official" sector, were net sellers of gold to the market, the official sector made net purchases in 1985 and 1986 amounting to over 4.3 and 5.8 million ounces, respectively. According to Gold Fields, "Governments clearly remained convinced (during 1986) of the value of holding at least part of their reserves in gold, whether these were declared or hidden, and the official sector as a whole was a net buyer."

The report estimated that consumption of gold in market economy countries was about 53.6 million ounces, or about 14% greater than in 1985. Following roughly the same broad pattern of consumption as in the United States, but including the minting and sale of official coins, jewelry uses consumed 66% of the total; dental uses, 3%; industrial, electronics, and medallions and unofficial coins, 11%; and official coins, 20%. Fabrication and sales by Japan of an official coin to commemorate Emperor Hirohito's 60th year of reign accounted for about 56% of the total attributed to the official sector, an occurrence not expected to be repeated soon. In addition to the material consumed in fabricated products, about 7.1 million ounces were estimated to have been hoarded by individuals outside of Europe and North America. The remaining excess of gold supply, about 3.8 million ounces, was reportedly absorbed by investors in Europe and North America.[13]

A comprehensive look at the world's gold resources was detailed in a Bureau of Mines study released during 1986. The report examined the long-term availability of gold in terms of both demonstrated resources and the economic and technical factors that will affect future gold production. Long-term cost and availability of primary gold from 135 mines and deposits worldwide were presented. Collectively, the evaluated countries represent 93% of world gold production. Conclusions regarding the long-term outlook for gold production were presented.[14]

Australia.—Australia's 1986 gold production surpassed that of the previous year for the sixth successive time, reaching a preliminary total of nearly 2.5 million ounces, up 32% over production in 1985, and the highest since 1911. At least 29 new mine projects were commissioned during 1986 and about 40 additional prospects may be brought to production within the next 2 years. Western Australia was once again the principal gold producing State.

One of the factors responsible for stimulating the current boom in gold mining in Australia has been the longstanding income tax shelter, enjoyed, more or less exclusively, by gold mining companies. An attempt was initiated by the Government in 1986 to impose a 30% to 46% net income tax on Australian gold mining companies. Stiff opposition by mining interests as well as antitax advocates resulted in the Government announcing in December that it had decided not to proceed with the tax plan. The Government reportedly concluded that the importance of encouraging exports, exploration, and development, plus the income generated by the gold mining industry, outweighed arguments favoring the tax.

Following a trend established by a number of other countries, the Government of Australia minted its first bullion gold coins in August. The coins, of 99.99% purity and known as the Nugget series, comprise four coins commemorating the world's largest gold nuggets, all discovered in Australia. Produced by the Perth Mint in Western Australia and distributed by a special marketing company, Goldcorp Australia, the coins range in weight from 0.10 to 1.0 troy ounce. Each will bear the image of a famous Australian nugget. According to Goldcorp, the first proof issue of the series was launched on November 5 and sold out in just over two months. The coins were reported to be the world's first 99.99% pure coins ever struck in proof form.

Gold developments in Australia during 1986 were summarized by the Australian Bureau of Mineral Resources (BMR).[15] Australia's largest gold mine, the open pit Kidston Mine, 180 miles northwest of Townville, Queensland, completed its first full year of production, recovering nearly 240,000 ounces of gold from over 4.0 million tons of ore milled. The principal owner, Placer Development Ltd., of Canada, following an earlier Government order to reduce its ownership to 55%, completed the sale of the required 45% balance to Australian interests. Placer's 55% interest is vested in the Australian operator, Kidston Gold Mines Ltd. In northern Queensland, Elders Resources Ltd. began production at its large, low-grade Red Dome deposit in August. Production at the heap-leaching operation was expected to be nearly 50,000 ounces per year. In October, Pan Australian Mining Ltd. began open pit mining and heap leaching at its Mount Leyshon deposit in the Charters Towers District. Production was planned to average 46,000 ounces per year during the first 3 years of operation. Also near Charters Towers, Pajingo Gold Mines Pty. Ltd., a subsidiary of Battle Mountain Gold of Houston, TX, moved forward on the preproduction development of its Pajingo Prospect. A critical path timetable was established that would bring the Pajingo property into production by the end of 1987. Full production for 1988 was projected at 60,000 ounces per year. Cyprus Minerals Australia Co.-Arimco-Elder Resources expected to open their Selwyn (formerly Starra) Mine in western Queensland in late 1987. There was also considerable gold exploration activity in Queensland, with much of the activity centered in the Charters Towers-Townsville-Kidston area.

In the State of New South Wales, Paragon Resources N.L. moved toward an early 1987 startup of its open pit Temora Mine, at Gidginbung Hill near the town of Temora. The mine and its 500,000-ton-per-year carbon-in-leach plant was expected to produce about 41,000 ounces in 1987, rising to 45,000 ounces in 1988.

In the historic Ballarat and Bendigo goldfields of the State of Victoria, BP Minerals International Ltd., Balmoral Resources NL and Kinex Pty. Ltd., together forming the Standhurst Joint Venture, investigated the gold potential of placer and underground tailings remaining from earlier mining operations. BP Minerals also reportedly planned to construct a pilot plant to use a new gold recovery process under development and patented by BP Minerals. The process, known as the coal-oil agglomeration process, reportedly offers both environmental and cost benefits, when compared with cyanide processes. Western Mining Corp. Holdings Ltd. (WMCH) continued exploration and evaluation of the several properties it held in the Bendigo Goldfield and elsewhere in the State. WMCH's 75.2%-owned Stawell Joint Venture was Victoria's largest gold producer, with an estimated 24,000 ounces produced during 1986.

To the west, in the State of South Australia, WMCH and its partner, BP Australia Ltd., moved ahead with the development of its large Olympic Dam project at Roxby Downs. Production at a rate of 90,000 ounces of gold, plus copper and uranium values, was expected to begin in mid-1988. Total capital committed to the project's completion was about $400 million.

At least three new producing gold mines came on-stream during the year in the Northern Territory. Norseman Gold Mines N.L. and Preussag AG began production at their small, high-grade TC8 Mine at Tennant Creek in November. Also at Tennant Creek Peko-Wallsend Ltd., began production at its small, high-grade Argo Mine. In the Tanami Desert area about 300 miles northwest of Alice Springs, North Flinders Mines Ltd. commissioned its new Granites Mine in August. Initial production was expected to be about 65,000 ounces of gold per year from surface and underground workings. A number of other gold mines and gold exploration projects were active in the Northern Territory during the year. The Enterprise Mine, at Pine Creek, became the Northern Territory's leading gold producer. The new open pit mine, 60%-owned by Renison Goldfields Consolidated Ltd. and Enterprise Gold Mines NL (40%), produced an estimated 50,000 ounces during its first full year of production.

With about 2 million ounces of gold produced during 1986, Western Australia continued to be the country's leading gold producing State and, as in recent years, the focus of intense exploration activity. Nineteen new gold projects came on-stream in the State during the year. The Telfer Mine, east of Nullagine, owned by Newmont Holdings Pty. Ltd. (70%) and The Broken Hill Pty. Co. Ltd. (BHP) (30%), was the State's largest producer, yielding about 165,000 ounces. In December, Newmont Holdings 60%-owned New Celebration Mine, 21 miles south of Kalgoorlie, began production. The $7 million open pit project, including a new carbon-in-leach plant, was expected to produce 41,000 ounces of gold per year. Newmont Holdings partners in the mine were Hampton Australia Ltd. and Mount Martin Gold Mines N.L.

Australia Consolidated Minerals Ltd. (ACM) (60%) and Austamax Resources Ltd. (40%) poured their first gold in April from the Golden Crown Mine, near Cue, and from ACM's (100%) Westonia open pit 30 miles north of Merredin in Western Australia; annual production was planned for about 30,000 ounces and 51,000 ounces, respectively. Also in April, Austwhim Resources N.L. poured the first gold at its New Cork Tree Well Mine, near Laverton. The mine and its 330,000-ton-per-year carbon-in-pulp plant was expected to yield about 30,000 ounces per year. Austwhim began development at its nearby Mount Morgans deposit in December. At Brunswick Oil NL's New Galtee More Mine, the first gold was poured in February following completion of the new mill.

Near the old townsite of Agnew, north of Kalgoorlie, WMCH commissioned its new 620,000-ton-per-year treatment plant at the Emu Mine in August. Production during 1986-87 was expected to be 48,000 ounces. South of Agnew, at Lawlers, Forsayth Oil and Gas NL produced the first gold from its 240,000-tons-per-year, 30,000-ounce-per-year, Lawlers operation. Between Lawlers and Kalgoorlie, new mines included Julia Mine's developing Goongarrie open pit and farther south its Camperdown Prospect, followed by the recently opened Bardoc project belonging to Aberfoyle Ltd. and Hill Minerals NL. Next is WMCH's 50%-owned Lady Bountiful that began production in April, then Pancontinental Mining Ltd.'s new Paddington Mine, south of Broad Arrow, which completed its first full year of gold production in June.

WMCH is the dominant gold producing company in the area around Kalgoorlie and south to Norseman. During the fiscal year ending in June 1986, WMCH and its affiliated companies produced about 484,000 ounces of gold at their Kalgoorlie, Kambalda, and Norseman gold operations.

Included among the many other Western Australian properties due on-stream in 1987 was the Boddington gold project, about 70 miles southeast of Perth. The project is a joint venture between BHP Minerals Ltd. (20%), Shell Co. of Australia Ltd. (30%), and Reynolds Australia Alumina Ltd. through its Worseley Alumina Trust (40%). Annual production following a late 1987 startup was expected to be 165,000 ounces. The Boddington deposit is unusual in that the gold occurs mixed with bauxite and is concentrated in a highly lateritized zone within 30 feet of the surface. Geochemical work in the Boddington area during the 1970's by the Geological Survey of Western Australia reportedly led Reynolds Australia to the gold discovery. Recognition of this sort of gold occurrence at Boddington has led to a reexamination of similar environments elsewhere in Australia and may lead to careful reevaluation of deeply weathered terrain in other areas of the world such as the southeastern United States and certain areas of South America and Africa.

Brazil.—According to figures from the Departamento Nacional da Produção Mineral (DNPM), official gold production recorded by Government-owned or regulated gold mines amounted to about 500,000 ounces in 1986 compared with about 700,000 ounces in 1985. Estimates by DNPM and other sources for the contribution of unregulated, independent miners or "garimpeiros" vary so widely that, in the absence of more detailed reports regarding developments in Brazil, the figure for 1986 shown in the world production table was kept unchanged from that of 1985. The 1986 number includes an increase in production by garimpeiros offset by declines in the regulated sectors, resulting in no apparent change from the previous year. A large percentage of the unregistered production reportedly continued, as in past years, to be used as a medium of exchange in the frontier gold mining areas and ultimately smuggled out of the country.

In early 1986, the DNPM released data on investment and planned investment in mechanized Brazilian gold mining at nearly two dozen projects by Government and international companies, including Anglo American Corp. of South Africa Ltd. (AAC), General Mining Union Corp. Ltd. (Gencor), also of the Republic of South Africa, BP Mineração, Rio Tinto Zinc Corp. Ltd. (RTZ), Inco Ltd., and Kennecott. The DNPM forecast that cumulative investment from 1985, when it was estimated at $500 million, may triple by 1990.

Of the unregulated mining operations, or garimpos, the largest in recent previous years has been the huge hand-dug open pit at Serra Pelada, in the State of Pará, where production peaked in 1983 at nearly 400,000 ounces. Owing to a variety of factors including increasingly unstable pit walls, uncoordinated and haphazard mining methods employed by individual miners, and influxes of water, the mine is estimated to have produced less than 100,000 ounces during 1986. According to Consolidated Gold Field's annual publication, garimpos in the Tapajós, Cumarú, Alta Floresta, and Roraima areas all suffered declines in production during the year.[16]

In the State of Mato Grosso, Osborne & Chappel Goldfield Ltd. of Canada and its Canadian partner Treasure Valley Explorations Ltd. reportedly began a small dredging operation on the Teles Pires River in September. Annual gold production was expected to be on the order of about 10,000 ounces. BP Minerals, through its Brazilian subsidiary BP Mineração and Brazilian partners continued development of its 49%-owned Cabacal gold and copper mine in Mato Grosso. The mine was scheduled to open in 1987, producing at a rate of about 60,000 ounces per year.

At Paracatu, in the State of Minas Gerais, Rio Tinto Zinc do Brasil, a subsidiary of RTZ, and several partners reportedly continued to move toward a late 1987 startup of their 100,000-ounce-per-year open pit alluvial-type gold mine known as the Morro do Ouro. Drainages bearing gold of alluvial origin continued to hold the interest and attention of a number of domestic and international gold mining firms. For over a century and a half, lode mining, which accounts for a minor share of Brazilian production, has been concentrated largely in Minas Gerais. About 60 miles east of Belo Horizonte, Gencor moved closer to the 1987 startup of its new 58,000-ounce-per-year São Bento Mine. The $100 million underground mine and milling facility reportedly will employ a pressure oxidation recovery system to treat the mine's refractory ores. AAC, through its indirect Brazilian subsidiary, Mineração Morro Velho S.A. (MMV), and its partners reportedly produced over 160,000 ounces from its mines in Brazil, which include the old Morro Velho Mine near Nova Lima, where gold has been produced for over 150 years. The new 3,000-foot-deep-shaft at MMV's Raposos-Cuiaba Mine was completed in June and another was in progress at yearend.

In the State of Goiás, 150 miles northwest of Brasilia, underground exploration was begun by Inco and its partner at the Crixas property. The work was to confirm drill-indicated reserves of 7 million tons averaging 0.34 ounce of gold per ton. Kennecott, Inco's former 50-50 partner in the venture, sold its interest in the Crixas operation to a Brazilian subsidiary of AAC. WMCH of Australia had several gold prospects in the State of Goiás, one near Crixas and another, the Serra Dourada, about 150 miles to the south; WMCH also has a number of other prospects in the States of Pará, Ceará, and Minas Gerais.

Canada.—Canada ranked fourth in the world in mine gold production with nearly 3.4 million ounces produced in 1986, more than twice the quantity produced in 1980. The boom in exploration that began several years ago was maintained, if not increased, in tempo during 1986, and was stimulated in particular by a Government tax program introduced in 1983 and known as the Flow-through Share Program. The shares, issued for a specific exploration project, permit the issuing company to transfer tax benefits in the form of allowable Canadian exploration expenses on that project through to the investor, who in turn can deduct the expenses from taxable income earned from other sources. Many of the gold properties currently under development in Canada were reportedly financed at least in part by the flow-through share mechanism.

Gold production in Ontario, Canada's largest gold producing Province, increased 45% above production recorded in 1985. This increase reflected the first full-year contribution by the three major new mines opened in the Hemlo goldfield during 1985: the Golden Giant Mine of Noranda Mines Ltd.-Golden Sceptre Resources Ltd.-Goliath Gold Mines Ltd.; the Teck-Corona Mine belonging to Teck Corp. and Internationl Corona Resources Ltd.; and the Page-Williams Mine owned by Lac Minerals Ltd.

Combined production at the three mines was expected to amount to nearly 540,000 ounces during 1986. A legal dispute arose during the year between International Corona and Lac Minerals regarding an alleged breached trust involving the Page-Williams property. An Ontario Supreme Court ruling in favor of International Corona was being appealed at yearend by Lac Minerals.

At the Detour Lake Mine, 120 miles northeast of Timmins, Ontario, Campbell Red Lake Mines Ltd. and Amoco Canada Petroleum Co. Ltd., equal partners in the open pit mine, planned to proceed with the second phase of an underground mine plan to exploit the deep extension of the ore body. The underground operation was expected to be producing at a rate of about 1,800 tons per day by December 1987. Stockpiled ore was to be used as mill feed during the interim period. Near Timmins, Canamax Resources Inc. and Consolidated CSA Minerals Inc. neared an early 1987 startup at their underground Bell Creek Mine. In addition to the adjacent Marlhill property, Canamax also reportedly has several other developing gold projects in Ontario. Also at Timmins, Pamour Porcupine Mines Ltd. reportedly conducted the first successful heap-leaching tests to be performed in northern Ontario. A recovery of nearly 70% was reportedly realized in one test. The company expected to use heap leaching on a commercial basis in the near future. In the Harker-Holloway area north of Kirkland Lake, American Barrick Resources reportedly decided to proceed with the development of its $44 million Holt-McDermott project, and construction of an office and mill at the site. The mine was expected to begin production in mid-1988 at a rate of about 100,000 ounces per year. At Cameron Lake in southwestern Ontario, Echo Bay acquired up to a 49% interest in the Cameron Lake property from Nvinsco Resources Ltd. By early 1987, the partners were driving a decline ramp to examine the deposit from underground and to confirm a drill-indicated resource of 1.2 million tons containing 200,000 ounces of gold. Mining at Inco's McBean open pit mine in northern Ontario was completed during the year. The mill remained in operation on a custom basis.

In early 1986, St. Joe Gold announced the existence of a large gold reserve on its Golden Patricia property in northwestern Ontario.

Near Casa Berardi, in Estrades Township of northwestern Quebec Province, the exploration rush begun several years earlier continued. At one of the first discoveries made during the current rush, the three Golden Pond deposits, Inco and its partner Golden Knight Resources Ltd. outlined an additional 2 million tons of drill-indicated reserves during 1986, thus increasing the total to 10 million tons averaging 0.22 ounce per ton. A $7 million underground exploration program was completed at the east end of the 3.5-mile-long mineralized zone. Underground exploration of the west end of the zone was reportedly scheduled for 1987. Inco held a 60% interest in the property. Scores of companies were active in the Casa Berardi area throughout the year and claim staking and exploration activity by both major and junior corporations extended from the Ontario-Quebec border eastward for 60 or more miles. In Estrees Township, east of Inco's Golden Pond property, Teck Explorations, Golden Hope Resources Inc., and Golden Group Explorations Inc. reportedly struck a polymetallic deposit containing substantial tonnages of gold-silver-copper-zinc ore. In Quebec's Cadillac area near Val d'Or, Dumagami Mines Ltd. announced a decision to proceed with development of its gold property adjoining Lac Minerals' Bousquet Mine. Ore production was scheduled to begin in mid-1988 at a rate of about 2,200 tons per day. Lac Minerals reportedly encountered two new gold-bearing zones near the existing workings of the Bousquet Mine. With a gold production rate of nearly one million ounces per year, Quebec is Canada's second largest gold producing province.

For yet another year, there was much gold-related activity in Canada's Maritime Provinces. On the island of Newfoundland, BP Resources Canada Ltd., through its recently formed Hope Brook Mines Ltd., announced plans to proceed with the development of its recently discovered Hope Brook Mine, formerly known as the Chetwynd deposit, named after the nearest town. The Hope Brook Mine, the Province's first gold mine, was expected to begin operations in mid-1987 as a combined open pit and heap-leaching operation. By late 1988, production is to move underground and conventional milling is to be initiated. Production was expected to be about 128,000 ounces per year. A recent listing of gold occurrences in Newfoundland, prepared by the Provincial Department of Mines and Energy, indicated nearly three dozen localities where gold had been identified on the island. In the Province of New Brunswick, Gordex Minerals Ltd. shipped its first bar of production gold on June 26, and thereby officially opened Canada's only commercial gold heap-leaching operation. The Cape Spencer open pit operation was expected to recover about 10,000 ounces of gold per year during the limited leaching season. In Halifax County, Nova Scotia, Canada, Seabright Resources Inc. continued to examine its Beaver Dam gold property; at yearend, Seabright was reportedly considering the feasibility of installing a 1,000-ton-per-day production facility. The company reportedly had nearly a dozen prospects in Nova Scotia. There were about 10 other companies also exploring or participating in exploration in the Province. In Manitoba, Sherr-Gold Inc. poured its first gold in August from its new MacLellan Mine, near Lynn Lake. The 1,000-ton-per-day facility has an expected mine life of 5 to 6 years. Pioneer Metals was to announce in early 1987 its decision on whether to proceed with its Puffy Lake property near Flin Flon. In the La Rouge area of north-central Saskatchewan, the flurry of exploration activity over the past several years resulted in the discovery and development of several gold deposits. One, the Star Lake Mine of Saskatchewan Mining Development Corp. (SMDC) was to begin production in 1987. Other deposits under investigation in the Province included SMDC's Jojay and Tamar properties near the Star Lake Mine and Placer Development's Seabee property near Laonil Lake.

In British Columbia, Blackdome Mining Corp. began production at its Clinton Mine, 150 miles north of Vancouver; 45,000 ounces of gold and about 220,000 ounces of silver were to be produced per year. Near Hedley, Mascot Gold Mines Ltd. continued to work toward the 1988 startup date for its new, 130,000-ounce-per-year Nickel Plate Mine, and at Cassiar, Total Erickson Resources Ltd. conducted a successful exploration program to discover ore extensions at its Cassiar gold mine. Construction on a new 300-ton-per-day mill was also completed. Total Erickson and its partner also opened their Mount Skukum Mine in the Yukon Territory in mid-year; annual production from this mine, the Yukon's first major lode mine, was expected to be about 55,000 ounces per year. In the Northwest Territories, Echo Bay reportedly doubled ore reserves at its Lupin Mine, said to be the northernmost gold mine in a market economy country.

Developments in gold mining in Canada during the year were summarized by the Canadian Department of Energy, Mines, and Resources.[17]

China.—Estimated Chinese gold production continued to rise as the Government increased efforts to push production to new heights through the use of liberal policies aimed at encouraging prospecting and mining by individuals. Periodically, the Government emphasized increasing the price the Government pays miners for their production, sponsored expanded exploration for gold by Government geological teams, allocated greater funds for upgrading plant and equipment at existing operations and for providing basic equipment at developing sites, and strengthened ties with Western nations capable of providing new technology, such as heap leaching. To gain firsthand knowledge of Western technology and management skills, the Government-owned China Gold Co. reportedly entered into a joint venture with a small gold mining operation in Canada's Yukon Territory. China reportedly plans to increase gold production at an average rate of 14% to 16% during the seventh 5-year plan (1986-1990). The three major gold producing Provinces, Shandong, Hunan, and Heilungkiang, are expected to account for up to 51% of the nation's total production by the end of the decade. Gold deposits have been found in nearly 1,000 Chinese counties, and gold mining has been conducted in more than 400 of these. More than 200,000 Chinese reportedly were engaged in gold mining during 1986. Some newly developed gold producing areas include the western part of Guandong Province, Hainan Island, and Shaanxi Province.

In March, the Government announced the adoption of a new mineral resources law to be incorporated in the country's constitution. The new law, covering exploration, development, and protection of mineral resources became effective on October 1.

News media reports originating in Hong Kong indicated that exports of gold from China to Hong Kong rose sharply during the first 5 months of 1986, up 500% from the corresponding period in 1985. China was reportedly also very active in the London and Zurich gold markets during 1986.

Controlling the smuggling of gold continued to be a problem for the Government. Chinese miners are required to sell all their production to the State but despite the harsh penalties imposed for smuggling, many miners apparently consider the differential between the state price and that offered by smugglers and speculators to be worth the risks involved.

In late 1982, the Chinese Government relaxed restrictions on the holding and selling of gold jewelry products. Sales of gold jewelry in 1985 reportedly were more than 50 times greater than the sales volume recorded in 1983. Inexpensive, lightweight, gold alloy necklaces and rings with inlaid gems were reportedly the most popular jewelry items.

Chinese gold Panda coins continued to sell very well on world coin markets. Owing to their limited production and annual changes in design, the coins, once aimed at bullion coin collectors, captured the fancy of collectors of numismatic coins. Panda coins minted in 1982 were reportedly selling in 1986 for four times their value of contained gold.

Ireland.—Following several years of exploration in Northern Ireland, Dublin-based Ennex International PLC announced that it had outlined sufficient gold reserves at its Sperrin Mountains property in County Tyrone to support a viable gold mining operation. Ennex's partner in the project is Westfield Minerals Ltd. (37%) of Toronto, Canada. Westfield in turn is 25.6% owned by Whim Creek Consolidated N.L., based in Western Australia. Nearby, Jamex Resources Ltd., a Canadian company, reportedly was drilling several gold targets by earlier soil and stream sediment surveys. In County Wicklow, near Dublin, Toronto-based New Sabina Resources Ltd. reportedly planned to initiate a geochemical survey for gold and base metals.

Japan.—In 1986, the Government of Japan purchased 6.4 million ounces of gold bullion and 3.7 million ounces of silver bullion in overseas markets for use in minting commemorative gold and silver coins for the 60th anniversary of Emperor Hirohito's reign. The purchases were completed by June, and 10 million gold and 10 million silver coins were minted and placed on sale in mid-November. The bulk of the gold was imported from the United States, a considerable amount of the U.S. gold came from Switzerland and the United Kingdom and was then reexported to Japan. By employing this procedure, Japan reportedly was able to help reduce its large trade surplus with the United States. In launching its sales program, the Government used a form of lottery whereby banks were allotted a set number of tickets that were then distributed free to prospective buyers. One of four tickets was later designated as a winner. Winning ticket holders then purchased their coin through the bank. Although demand for the coins fell somewhat short of Government expectations, gold coin sales representing nearly 5.9 million ounces of gold eventually were registered.

July marked the first full year of production at Sumitomo Metal Mining Co. Ltd.'s rich Hishikari Mine, on Japan's southern island of Kyushu. The mine, reportedly a textbook example of an epithermal-type gold deposit, was mined using trackless, remote-controlled excavators that reportedly helped keep the production costs, in terms of U.S. dollars, at about $30 per ounce. Gold production for the full calendar year amounted to about 174,000 ounces, from ore containing about 2.3 ounces of gold per ton.

On the Japanese north island of Hokkaido, Chitose Mining Co. Ltd., a subsidiary of Mitsubishi Metal Corp., closed its Chitose Mine in February owing to the depletion of ore reserves.

Oceania.—The tempo of mineral exploration in the southwestern Pacific region, especially for gold, has quickened considerably over the past several years as more and more data are assembled and disseminated regarding the geological nature of the region's known gold occurrences. Many of the gold deposits in the region have been worked, mostly as placers, on and off for over a century. It is only within the last decade or so that theories of the development of epithermal deposits have been combined with the concepts of global plate tectonics and then applied with considerable success to the location of gold deposits, especially in those geographical areas comprising the so-called Pacific Rim. Epithermal gold deposits having more or less similar genetic characteristics have been recognized in the eastern rim in western North and South America and in the western rim in Japan, Taiwan, the Philippines, Indonesia and Papua New Guinea, the Bismarck Archipelago, the Solomon Islands, and New Zealand. Forty or more companies have rushed into the vast area that makes up the southwestern Pacific region to look for gold, and the results have been spectacular.

Results from tests conducted on Lihir Island, off the east coast of the Papua New Guinea island of New Ireland, reportedly indicated that a potential gold reserve of 12 million ounces or more may exist. In early 1987, the discovery of a new mineralized area, the Minifie Zone, near the main Lienitz ore body but much closer to the surface, was announced. The Lihir Island project is a joint venture between Kennecott Explorations (Australia) Ltd. (88%) and Niugini Mining Ltd. In the Tabar Islands, northwest of Lihir Island, Kennecott, Nuigini Mining, and Nord Resources Corp. continued exploration and drilling at four promising gold anomalies on Simberi Island. Nord reportedly also discovered anomalous gold values on New Hanover Island, off the northwest tip of New Ireland, as well as on Woodlark Island about 500 miles farther to the south, in the Solomon Sea.

To the southeast of Lihir Island, gold anomalies with geological characteristics similar to those found on Lihir and the Tabars have been found on the Tanga and Feni Islands by respective companies, Newmont Holdings and its partner Pacific Arc Exploration NL and Esso PNG Inc. and City Resources Ltd. Esso's and City Resources' other gold prospects include the Wild Dog Prospect, at Uramit about 30 miles south of Rabaul on the Gazelle Peninsula of East New Britain, and the Wapolu Prospect on Fergusson Island in the D'Entrecasteaux Islands, plus interests in several properties on the Papua New Guinea mainland.

On Misima Island, southeast of Fergusson Island, Placer Pacific Ltd., a subsidiary of Placer Development, proceeded with evaluation of its gold and silver property and continued negotiations with the Government of Papua New Guinea to obtain a mining development agreement before proceeding with a feasibility study for an open pit operation. In Enga Province on the New Guinea mainland, Placer Pacific and its partners, Mount Isa Mines Ltd. and Renison Goldfields Consolidated Ltd. (RGC), proceeded with testing and evaluation of its large Porgera gold property. Ore reserves at Porgera are estimated to contain about 11 million ounces of gold.

At the new townsite of Tabubil in the Star Mountains west of the Porgera property and near the border between Papua New Guinea and Indonesia, Ok Tedi Mining Ltd. continued gold production at the Ok Tedi copper-gold mine that began producing in mid-1984. The mine reached an annual production rate of over 700,000 ounces of gold in mid-1986. To take advantage of higher gold prices toward yearend, the company reportedly postponed the startup of the copper production phase, originally scheduled to start in October, to yearend. The mine is one of the largest gold producers outside of the Republic of South Africa. It is 80% owned by a consortium of international companies and 20% owned by the Papua New Guinea Government. Not an epithermal deposit, Ok Tedi is basically a gold-rich porphyry copper deposit genetically similar to Bougainville Copper Ltd.'s large copper and gold mine to the east at Panguna, on Bougainville Island. Gold production at Bougainville during 1986 amounted to over 527,000 ounces.

Elsewhere on the New Guinea mainland, New Guinea Goldfields Ltd., controlled by RGC, completed an expansion and modernization program during the year that trebled production at Wau to nearly 26,000 ounces of gold per year. There was a considerable increase in interest and activity in gold in neighboring Indonesia, where several epithermal deposits have been recognized or developed. In 1985, the Government of Indonesia reportedly had awarded only 9 gold mining and exploration contracts to interested companies, whereas in 1986, 34 such contracts were awarded to 12 companies. Twenty went to CRA Ltd., CSR Ltd., Jason Mining Ltd., and Pelsart Resources N.L., all of Australia. Companies from Asia and the United Kingdom reportedly received the remaining 14. Areas of interest were on the island of Sumatra, in the central Kalimantan region of the island of Borneo, on several islands east of Borneo, and in West Irian. Freeport Indonesia Inc., a subsidiary of Freeport-McMoRan Inc., has been producing byproduct gold from its copper mine in West Irian since 1972. In 1986, P.T. Lusang Mining Indonesia, 70% owned by CSR of Australia, began mining the new underground Lusang Mine at Lebong Tandai, in Bengkulu Province of southwest Sumatra. The company expected the mine to reach its full capacity of about 32,000 ounces per year by 1988.

Far to the east, on the Island of Viti Levu in the Fiji Islands, the Vatukoula Joint Venture, 80% owned by Emperor Gold Mining Co. Ltd. and 20% owned by WMCH, recovered 76,297 ounces of gold from the underground and surface working at its Emperor gold mine during the fiscal year ending in June 1986. WMCH was also involved in several separate exploration projects on the island.

From Bougainville Island southward through the Solomon Islands, Vanuatu (formerly the New Hebrides), and New Zealand, a variety of mostly small epithermal and alluvial deposits were under investigation, such as the recently announced discoveries by City Resources on Espiritu Santo and Malekula. In New Zealand, well-known international companies such as Homestake Mining, AMAX, Cyprus Minerals, and CRA pursued gold projects on both the North and South Islands. AMAX and its New Zealand partners applied for the permits and licenses required to reopen the old Martha Hill Mine at Waihi, 80 miles southeast of Auckland; opposition from environmental activists and delays in establishing new permitting steps reportedly slowed progress.

A comprehensive overview of mineral exploration and development activities in the southwestern Pacific region, including a discussion of regional mining history, current projects, geology and tectonic settings, plus exploration models and techniques was presented in late 1986.[18]

Philippines.—Overall gold production in the Philippines increased about 22% in 1986 compared with production in the previous year. Nearly 500,000 ounces was estimated to have come from small gold panning ventures scattered throughout the islands, including gold recovered by miners participating in the gold rush under way on Mindanao. Gold recovered as a byproduct of Philippine copper ore also reportedly increased as greater tonnages of copper ore underwent local, rather than foreign, processing.

As the southeastern Mindanao mines at Compostela, Pantukan, Dewalwal, and other sites ringing the Gulf of Davao entered their third year of operation, social and economic pressures as well as a decline in the amount of easily won gold reportedly resulted in a general decline in both gold production and in the number of people directly involved in production. Apex Mining Corp., a Mindanao-based copper and gold mining firm, and holder of the Government-granted mineral concessions affected by the Mindanao gold rush, was expected to try and regain control of its properties during 1987. At yearend, another rush had begun in the Diuata Mountains of northeastern Mindanao, and more than 40,000 persons reportedly had rushed in to seek their fortune.

To the north, on the island of Luzon, Benguet Corp., the country's largest gold producer, reported that its gold production had risen from 112,000 ounces in 1985 to 126,000 ounces in 1986. Benguet operated five adjacent underground gold mines at Itogon, Benguet Province, 10 miles east of Baguio City, and a centrally located 3,900-ton-per-day cyanidation plant. Of the five mines, the Acupan, Antamok, and Kelly Mines were owned by Benguet, and the Atok and Sierra Oro Mines were operated by Benguet. During 1986, the company was the contract operator of Philex Mining Corp.'s Tuding Gold property and Itogon-Suyoc Mines Inc.'s Itogon Mine, adjacent to Benguet's Acupan Mine, at Sangilo. Combined ore reserves at these Benguet operations amounted to 2.3 million tons, grading about 0.18 ounce of gold per ton. At Benguet's Dizon copper-gold operation, at San Marcelino, Zambales Province, the company reported that owing to slightly lower ore grades mined, gold production in 1986 declined 6%, to 120,383 ounces. Benguet also reported that a rockslide in the Dizon pit had covered the higher grade portion of the ore body and that it would require until mid-1987 to clear the slide and resume processing the richer ore. Benguet had a number of gold-bearing properties under investigation during the year in Albay, Davao del Norte, Zambales, and Pampanga Provinces plus its Paracale Gold Project in Camarines Norte Province, which it planned to bring into production in late 1987 at an annual rate of about 23,000 ounces.

At its operations on Cebu and Masbate Islands, including the 1,400-ton-per-day agglomeration heap-leaching operation at the Masbate gold mine, Atlas Consolidated Mining and Development Corp. reported producing about 140,000 ounces of gold in 1986. Masbate alone accounted for nearly 80,000 ounces. At Masbate, Atlas employs five asphalt leaching pads, each with a capacity of 7,000 tons. A complete leaching cycle, including loading and unloading, takes 26 days.

Recent interest in the concept of epithermal gold deposits around the Pacific Rim, reportedly has drawn attention to the Philippines, where similarities between some Philippine gold occurrences and known epithermal deposits in other western Pacific areas have encouraged exploration companies, especially Australian companies, to seek participation with Philippine interests.

South Africa, Republic of.—In 1986, South Africa's gold mining industry celebrated the passage of 100 years since the discovery of gold on the Witwatersrand in 1886. There, gold-bearing reefs or layers of sedimentary rocks have been mined and explored to a depth of over 2 miles over an arcuate area 200 miles long. To celebrate, the industry convened an international conference, "Gold 100," that covered a multitude of topics on gold ranging from mining and extractive metallurgy through the economics and marketing of gold. Experts on these subjects were attracted from many parts of the world to the September meeting held in Johannesburg.

Despite numerous obstacles, including economic sanctions that were imposed on the Republic of South Africa during the year by the United States and some other nations, disinvestment in South African business by some—mainly U.S.—companies, continuing labor strikes and unrest, and continuing currency inflation, the Republic of South Africa continued to dominate the world in terms of gold output, accounting for 40% of world mine production in 1986, compared with 44% in 1985. Rising U.S.-dollar-denominated gold prices helped to boost the earnings of the country's gold producers, and for some, to record highs.

Of the 20.5 million ounces of gold produced in the Republic of South Africa during the year, 19.5 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. The total ore milled by Chamber members, including ore milled by producers of byproduct and coproduct uranium, amounted to 118.7 million tons, averaging 0.16 ounce of gold per ton; in 1985, 115.3 million tons averaging 0.18 ounce per ton was milled. Working costs for South African gold mines in 1986 averaged $189.19 per ounce and ranged from $108.57 per ounce at the Kloof Mine to $411.66 per ounce at East Rand Proprietary.[19] Production by the six major mining groups was as follows, in million ounces: AAC, 7.6; Gold Fields of South Africa Ltd. (GFSA), 3.8; Gencor, 3.5; Rand Mines Ltd., 1.9; Johannesburg Consolidated Investment Co. Ltd. (JCI), 1.4; and Anglovaal Ltd., 1.3.

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 3.4, Vaal Reefs North and South lease areas with 2.5, Driefontein Consolidated with 1.9, Western Deeps with 1.2, Hartebeestfontein with nearly 1.0, and Kloof and Harmony with just under 1.0 each. Estimates of fully developed or blocked-out gold ore reserves reported by the Chamber of Mines at the end of 1986 amounted to nearly 540 million tons, containing, on average, about 0.28 ounce of gold per ton.

In January, Rand Mines' Harmony Gold Mining Co. commissioned the Republic's first major mine ice plant at its Merriespruit No. 1 shaft. The new ice plant, the largest facility of its type in the world, will be used to reduce the high temperatures prevalent in the deep underground workings.

The shareholders of AAC approved the merger of four major gold producing companies in the Republic to form Free State Consolidated Gold Mines Ltd. (Freegold), making it the largest gold mining company in the Republic of South Africa. The formation of Freegold, effective February 24, as a single contiguous mine, was expected to lower working costs and increase productivity. Of the Republic of South Africa's total annual gold production, Freegold's contribution from the combined Orange Free State operations was expected to be about 17%, or about 3.6 million ounces per year, and the company was expected to have a labor force of 105,000. In February, as part of an over $500 million expansion program, AAC completed the sinking of its $400 million No. 1 shaft at the Western Deep Levels Mine near Johannesburg. A new carbon-in-pulp gold plant and refrigeration plant, for cooling the deep underground workings, was completed in April.

In the Orange Free State, construction at JCI's new H. J. Joel Mine began in February, 5 months ahead of schedule. Production was expected to begin in 1988. The trackless mining methods being introduced at JCI mines, and planned for the Joel, were expected to reduce JCI's mine labor requirements by about 40% in 1986.

Boshoff Mines & General Investments Ltd. announced plans during March to increase the capacity of its Glencairn heap-leaching plant, commissioned in January 1985 and part of its Waverly Gold Mine operations, from 22,000 to 44,000 tons per month. Boshoff also planned to construct a new plant to treat old gold-bearing sand dumps at the minesite. Waverly resumed production in 1985 for the first time since its closure in 1963.

During May, sinking of one of the world's deepest shafts at AAC's Hartebeestfontein Mine in the Transvaal was completed. The shaft is over 7,900 feet deep.

A September 16 fire that spread toxic fumes through the workings of the Kinross gold mine, in the Evander area, resulted in the death of 177 miners and the hospitalization of many more. The accidental ignition of a foam material, applied to reduce degradation of the mine walls, reportedly was responsible for the fire, one of the worst in the history of South African mining. National gold production was not seriously affected.

On October 8, the Government announced an immediate ban on the recruitment of migrant mine workers from neighboring Mozambique. The action could ultimately affect about 52,000 Mozambicans working at South African gold and coal mines. The Government of Mozambique is heavily reliant on payments it receives for providing workers for South African mines. About 60% of the miners' earnings are paid directly to the Government of Mozambique by the South African Chamber of Mines. Mozambique then pays the miners in Mozambican currency.

Arson reportedly was ruled out as the cause of a fire that began on November 19 at the 7,500-foot level of GFSA's Kloof Gold Mine in Transvaal Province. Three weeks were required to bring the fire under control. Another fire in the same area of the mine, reportedly attributable to arson, had been extinguished shortly after it began on November 17.

Continuing high gold prices during the year again served to stimulate not only increased spending for capital improvements at existing or developing mines but to encourage the reexamination and reopening of a number of former producing mines. Exploration for new gold deposits or to expand the limits of known deposits continued at a high level, with most of the work being done by AAC, GFSA, and Gencor. Research and development directed toward improving the productivity, safety, and environmental impact of the nation's gold mines continued to be conducted by the South African Chamber of Mines as well as by individual companies.

Taiwan.—During the year, the Government of Taiwan passed legislation removing all barriers to the private ownership of gold; the new laws took effect on November 1.

U.S.S.R.—Estimated to be the world's second largest producer of newly mined gold, the U.S.S.R. continued to sell gold on international gold markets, usually through Zurich, Switzerland.

Some analysts estimated that in response to lower earnings from Soviet exports of oil during 1986 and the increased requirements for imported grain, sales of gold to the west by centrally planned economy countries, principally the U.S.S.R., increased sharply during 1986. As much as 12.9 million ounces was believed to have been exported during the year. Slightly less than 7 million ounces was estimated to have been sold during the previous year.

The history, geology, and mining of the huge Muruntau gold complex in Uzbek S.S.R. (Uzbekistan) was detailed in a brief report.[20]

Table 16.—Gold: World mine production, by country[1]

(Troy ounces)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Argentina	[r]22,248	[r]24,660	22,120	28,357	26,700
Australia	866,815	983,522	[3]1,295,963	[4]1,881,491	2,479,000
Bolivia	40,146	49,217	40,827	[e]30,000	30,000
Brazil[e 5]	1,500,000	1,750,000	1,750,000	2,000,000	2,000,000
Burundi	[e]100	272	1,115	829	900
Cameroon	136	261	[e]250	215	215
Canada	2,081,230	2,363,411	2,682,786	2,815,118	3,364,700
Central African Republic	1,000	2,492	6,953	6,033	6,000
Chile	543,569	570,971	541,051	554,281	[6]577,748
China[e]	1,800,000	1,850,000	1,900,000	1,950,000	2,100,000
Colombia	472,674	438,579	799,889	1,142,830	1,400,000
Congo	83	267	101	515	500
Costa Rica[e]	27,000	30,000	35,000	[6]15,997	11,600
Dominican Republic	386,309	354,023	338,272	328,046	282,990
Ecuador	1,601	608	[e]1,000	[e]1,000	2,000
El Salvador	3,300	650	285	(7)	--
Ethiopia[e]	12,000	14,000	15,000	15,000	15,000

See footnotes at end of table.

Table 16.—Gold: World mine production, by country[1] —Continued

(Troy ounces)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Fiji	45,750	40,124	48,515	59,961	82,300
Finland	36,780	25,206	28,067	[e]28,000	28,000
France	67,967	71,659	70,279	90,021	75,000
French Guiana	5,231	8,038	10,127	8,005	9,000
Gabon	[e]550	[e]550	1,325	1,608	2,000
Germany, Federal Republic of[e]	[6]1,813	1,900	1,500	1,200	1,200
Ghana	331,000	276,000	287,000	299,363	290,000
Guyana	7,347	4,607	11,131	10,323	24,000
Honduras	1,711	2,151	2,784	5,023	5,000
Hungary[e]	50,000	30,000	20,000	20,000	18,000
India[8]	71,935	70,158	65,234	58,771	60,000
Indonesia[9]	71,878	76,888	78,677	83,688	93,300
Japan	104,136	100,921	103,519	170,525	[6]332,020
Kenya	21	100	600	442	500
Korea, North[e]	160,000	160,000	160,000	160,000	160,000
Korea, Republic of[8]	55,750	72,083	79,156	77,258	80,000
Liberia[e 10]	12,656	15,400	10,500	[r]4,900	20,000
Madagascar[e]	110	110	130	130	130
Malaysia:					
Peninsular Malaysia	5,788	5,792	7,041	7,115	8,700
Sabah	[r]84,584	[r]78,543	82,012	78,818	80,000
Sarawak	23	161	474	4,371	4,500
Mali	[e]13,000	[e]13,000	16,075	16,075	16,100
Mexico	214,349	198,177	270,998	265,693	280,000
Namibia	7,395	7,459	6,302	6,237	6,100
New Zealand	7,775	9,667	21,605	45,011	46,000
Nicaragua	54,384	46,428	[e]35,000	24,491	24,000
Papua New Guinea	589,258	579,407	[e]835,000	1,186,618	1,157,400
Peru	[r]134,647	[r]168,534	187,406	212,870	185,380
Philippines	834,431	816,536	827,149	1,062,997	1,295,000
Portugal	6,783	9,603	[e]9,100	[r e]14,000	15,000
Romania[e]	65,000	65,000	65,000	65,000	60,000
Rwanda	286	623	240	238	240
Sierra Leone[11]	8,729	12,000	18,233	19,004	12,000
Solomon Islands	1,318	[e]1,100	2,572	[e]3,000	4,000
South Africa, Republic of	21,355,111	21,847,310	21,860,933	21,565,230	[6]20,513,665
Spain	109,858	162,296	123,330	185,542	150,000
Sudan[e]	400	500	1,500	1,500	1,600
Suriname	599	482	322	[e]500	600
Sweden	77,160	102,880	122,173	138,300	120,000
Taiwan[8]	71,770	52,361	37,794	30,633	29,300
Tanzania	[e]600	[e]800	2,680	1,776	1,800
U.S.S.R.[e]	8,550,000	8,600,000	8,650,000	8,700,000	8,850,000
United States	1,465,686	2,002,526	2,084,615	2,427,232	[6]3,733,190
Venezuela	27,993	[e]33,200	[e]50,885	74,180	82,800
Yugoslavia[8]	135,451	136,255	[e]140,000	[e]145,000	140,000
Zaire	60,733	192,930	117,115	63,022	60,000
Zambia	13,439	10,160	12,185	7,909	[6]1,865
Zimbabwe	426,000	453,373	478,306	472,000	480,000
Total	[r]43,105,396	[r]44,995,931	46,475,201	48,673,292	50,937,043

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through June 9, 1987.
[2]Gold is also produced in Bulgaria, Burkina Faso, 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: 1982—148,408; 1983—199,206; 1984—213,963; 1985—700,000 (estimated); and 1986—800,000 (estimated). Small mines (garimpos): 1982—671,982; 1983—1,526,775; 1984—982,623; 1985—1,300,000 (estimated); and 1986—1,500,000 (estimated).
[6]Reported figure.
[7]Revised to zero.
[8]Refinery output.
[9]Excludes production from so-called "people's mines," but includes gold recovered as byproduct of copper mining.
[10]These figures are based on gold taxed for export and include gold entering Liberia undocumented from Guinea and Sierra Leone.
[11]Excludes estimates of gold produced in Sierra Leone that is moved through undocumented channels for sale in Liberia.

TECHNOLOGY

In 1986 the Bureau of Mines continued research directed toward improving the recovery, utilization, and understanding of gold and associated precious metals. The Bureau investigated a hydrometallurgical procedure to recover gold, silver, and lead from complex lead-zinc sulfide ores that cannot be processed by conventional methods. The new environmentally safe technique, which works at atmospheric pressure and moderate temperatures, involves leaching concentrates from the complex sulfide ores sequentially with three solutions—ferric chloride, acidic thiourea, and brine. About 85% of the gold and silver in the test ore was recovered.[21]

The Bureau developed a polyethylene oxide (PEO) technology for clay wastes that consists of adding the PEO flocculant to effluent water, then screening to separate the flocculated solids from the water. During the 1986 Alaskan mining season, the Bureau, using a mobile waste treatment unit, conducted tests at Crooked Creek, Fairbanks Creek, Livengood, and the Kenai Peninsula, Alaska. A description of the PEO process was given.[22] In early 1986, the Bureau convened an open industry briefing session on precious metals recovery from low-grade resources. Topics discussed and subsequently published by the Bureau included cyanidation of carbonaceous gold ores to enhance gold recovery, a new method for precipitating mercury during cyanide leaching of gold ores, a staged heap-leaching process to generate suitable solutions for direct electrowinning of gold, the use of anion-exchange resins to recover gold from cyanide solutions, and precious metals recovery from electronic scrap.[23] The new method for mercury removal, as noted above, entails the addition of calcium sulfide to cyanide leach slurries. The chemical process and procedures employed were detailed in a separate report.[24]

Researchers at Japan's Osaka University, using a new high-resolution electron microscope system, were able to view the surface structure of gold atoms and thereby determine precisely how well gold and its alloys were being electrolytically deposited on submicron-size circuits destined for use in the next generation of very large-scale integrated circuit electronic devices.[25]

Scientists at AT&T Bell Laboratories demonstrated a new submicron electronic ring-oscillator switch, reportedly the fastest switch ever built. The new device, with gold bonding pads and gold metalized layers connecting 10 gallium arsenide transistors, can be integrated with larger electonic components to create ultrahigh-speed communications equipment, microprocessors, and computer memories.[26]

Bell Laboratories also demonstrated the feasibility of recovering gold from anion-exchange resins directly as pure potassium gold cyanide and suggested a new approach to recovering potassium gold cyanide from spent plating baths, dragout solutions, and rinse solutions. The process also provides one means to recover the gold from gold-plated scrap as potassium gold cyanide. Substantial cost reductions reportedly could be realized.[27]

Pilot-scale tests indicated that effective concentration of fine gold from Colorado River sands can be achieved by flotation, using an air-sparged hydrocyclone. Fine sands (55% minus 400 mesh, bearing 0.01 ounce of gold per ton) from gravity concentration operations were processed with a 5-centimeter air-sparged hydrocyclone; concentrate grades as high as 5 ounces per ton were produced in a single stage, at a recovery rate of 75%. The separation efficiency was reportedly better than that achieved in conventional batch flotation experiments.[28] The various criteria required for decision-making in selecting the appropriate excavation and processing plant technology for small-scale placer gold mining were assembled in a brief report.[29] The evaluation included data related to sampling, drilling saturation, feasibility studies, and equipment selection.

A 1-ounce 1908 U.S. gold coin lost decades earlier and found in a sluice box at an Alaskan placer operation in 1959 was, upon microscropic examination in 1986, found to have a number of subrounded and possibly faceted gold particles firmly attached to its surface. These particles may represent gold crystals that have nucleated in place upon the coin or may be simply microfine nuggets that have adhered to the coin during the apparently long time period between its loss and discovery or during the sluicing process. If these gold particles on the coin, known as the Parker Gold Piece, are indeed the result of naturally occurring gold nucleation, important implications concerning the formation of placer gold would be apparent. Recent theories suggesting that gold may become soluble under certain physical, chemical, and electrical conditions unique to regions of cold climate have been offered to explain the origin and/or the apparent in situ regeneration of some placer gold deposits.[30]

A guidebook traversing four major geologic provinces from western California to eastern Nevada was assembled for the Society of Economic Geologists field conference, September 1986. The principal focus of the conference was upon precious metals mineralization in hot-spring-type epithermal systems of both States. The guidebook contains articles on geology and mineralization at numerous representative deposits, including Homestake Mining's new McLaughlin Mine, near San Francisco, and the Round Mountain Mine, in Nye County, NV.[31]

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[2]Ounce refers to troy ounce.

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Graphite

By Harold A. Taylor, Jr.[1]

No domestic amorphous graphite material was mined in 1986. All natural graphites, including crystalline flake, were in more than adequate supply as demand by industrial users dropped substantially from the previous year. Prices of the major imported graphites generally increased from those of 1985, except for the price of Mexican amorphous graphite, which dropped slightly.

Production of manufactured graphite decreased 14% to 211,000 short tons valued at $539 million. Production of graphite fibers decreased 12% to 1,677 tons valued at $95 million.

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 37 operations to which a survey request was sent, 97% responded, representing 100% of the total production data shown in table 4 since the one nonrespondent was not included.

Table 1.—Salient natural graphite statistics

	1982	1983	1984	1985	1986
United States:					
Production short tons	W	W	W	--	--
Apparent consumption do	W	W	W	r44,380	35,036
Exports do	10,335	9,435	7,096	r8,357	7,754
Value thousands	$4,099	$3,455	$2,807	r$3,125	$3,416
Imports for consumption short tons	53,150	43,586	58,246	52,737	42,790
Value thousands	$15,676	$11,921	$14,579	$16,186	$15,758
World: Production short tons	619,928	664,029	682,260	p672,609	e672,837

eEstimated. pPreliminary. rRevised. 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 1986.

Table 2.—U.S. Government stockpile goals and yearend stocks of natural graphite in 1986, 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, 1986.

DOMESTIC PRODUCTION

United Minerals Co. began producing sizable amounts of low-grade amorphous graphitic material by open pit mining from the claims of National Minerals Corp. near Townsend, MT, in 1982. Production had been tapering off, before being suspended in 1985 and 1986. Other domestic deposits of graphite received little or no attention.

Output of manufactured graphite decreased 14% to about 211,000 tons, at 35 plants, with a likelihood of some unreported production for in-house use.

Production of all kinds of graphite fiber and cloth decreased 12% to 1,677 tons.

Superior Graphite Co. announced plans to expand its synthetic graphite plant at Hopkinsville, KY, by 10,000 tons per year to attain 35,000 tons per year. The expansion was expected to cost $2.2 million and was in response to increased demand for Desulco, a high-purity synthetic graphite product used to raise the carbon content of steel and iron. The expansion involved adding a third furnace.

There was one change in ownership in the graphite fiber industry in 1986. British Petroleum Co. Ltd. (BP) bought the HITCO Materials Group in December from Owens-Corning Fiberglas Corp. for $240 million in cash. The other advanced materials subsidiaries that were bought with HITCO in 1985 were not sold to BP.

BASF Structural Materials Inc. announced plans to build a graphite fiber precursor plant costing $20 million at Williamsburg, VA. BASF licensed the technology from Toyo Rayon Ltd. for making the polyacrylonitrile precursor, which will be used at its Rock Hill, SC, graphite fiber plant.

Table 3.—Principal producers of manufactured graphite in 1986

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	Ridgeville, SC	
Amoco Performance Products	Fostoria, OH	Cloth and high-modulus fibers.
Do	Greenville, SC	
Ashland Petroleum Co., Carbon Fibers Div	Ashland, KY	High-modulus fibers.
Avco Corp., Avco Specialty Materials Div	Lowell, MA	Do.
BASF Structural Materials Inc	Summit, NJ	Do.
Do	Rock Hill, SC	
Fiber Materials Inc	Biddeford, ME	Cloth and high-modulus fibers.
Fiber Technology Corp	Provo, UT	
BF Goodrich Co., Engineered Systems Div., Super Temp Operation.	Santa Fe Springs, CA	Other.
Great Lakes Carbon Corp	Rockwood, TN	Anodes, electrodes, high-modulus fibers, unmachined shapes, other.
Do	Morganton, NC	
Do	Niagara Falls, NY	
Do	Ozark, AR	
Hercules Inc	Salt Lake City, UT	High-modulus fibers.
HITCO Materials Group, Owens-Corning Fiberglas Corp.	Gardena, CA	Cloth and high-modulus fibers.
Hysol Grafil Co	Sacramento, CA	High-modulus fibers.
North American Carbon Inc	Punxsutawney, PA	Other.
Ohio Carbon Co	Cleveland, OH	Electric motor brushes, unmachined shapes.
Pfizer Minerals, Pigments & Metals Div	Easton, PA	Other.
Polycarbon Inc	North Hollywood, CA	Cloth.
Sigri Carbon Corp	Hickman, KY	Electrodes and other.
The Stackpole Corp., Carbon Div	Lowell, MA	High-modulus fibers, motor brushes, unmachined shapes, refractories, powder.
Do	St. Marys, PA	
Standard Oil Co., Specialty Graphite Metallics Div.	Sanborn, NY	Electrodes, crucibles, refractories, motor brushes, unmachined shapes, cloth.
Superior Graphite Co	Russellville, AR	Electrodes and other.
Do	Hopkinsville, KY	
Ultra Carbon	Bay City, MI	Powder and other.
Union Carbide Corp., Carbon Products Div	Clarksburg, WV	Anodes, electrodes, unmachined shapes, motor brushes, powder, other.
Do	Clarksville, TN	
Do	Columbia, TN	
Do	Fostoria, OH	
Do	Yabucoa, PR	

[1]Cloth includes low-modulus fibers; electric motor brushes include machined shapes; crucibles include vessels.

Table 4.—U.S. production of manufactured graphite, by use

Use	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)
Products:				
Anodes	7,021	$19,813	4,992	$14,463
Cloth and fibers (low-modulus)	316	27,235	164	17,895
Crucibles, vessels, refractories	W	W	W	W
Electric motor brushes and machined shapes	W	W	W	W
Electrodes	r164,598	r348,972	139,926	302,160
Graphite articles[1]	--	r35,167	--	32,351
High-modulus fibers	1,586	84,743	1,513	76,622
Unmachined graphite shapes	r11,795	66,069	11,086	49,545
Other	r39,210	r38,730	28,328	36,190
Total	r224,526	r [2]620,728	186,009	529,226
Powder and scrap	22,100	4,668	25,076	9,870
Grand total	r246,626	r625,396	211,085	539,096

rRevised. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Includes all items for which no quantity data is available.
[2]Data do not add to total shown because of independent rounding.

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)
1976	163	$11,376	37	$3,870	200	$15,246
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

CONSUMPTION AND USES

Reported consumption of natural graphite decreased 8% to about 31,700 tons. The three major uses of natural graphite—refractories, foundries, and lubricants—accounted for 54% of reported consumption.

Industrial Minerals (London) published its Refractory Supplement in May 1986, including in it articles describing how graphite (particularly crystalline flake) was used in plastic refractories, refractory brick, crucibles, stoppers, continuous casting powders, core and mold washes, and hot top compounds;[2] discussing carbon magnesite brick use in electric and basic oxygen furnaces;[3] and mentioning alumina-graphite use in shrouds for protection of the molten steel stream and in submerged nozzles and shrouds, the last refractory contacted by the molten steel before entering the continous casting mold.[4]

An important set of statistics on graphite fiber composite end use was released. Classified by aircraft engines, business aircraft, commercial aircraft, helicopters, military aircraft, missiles and space, and total aerospace, it indicated that the total market for all uses in 1985 was 3.5 million pounds of graphite fiber composites worth $165.0 million, 13.9 million pounds of fiberglass composites worth $82.0 million, and 1.8 million pounds of Kevlar composite worth $47.0 million. Of the total market for graphite fiber composites, 1.1 million pounds worth $51.8 million went into military aircraft, 0.5 million pounds worth $25.9 million went into missiles and space uses, 0.4 million pounds worth $23.9 million went into commercial aircraft, and the balance into other uses. Total aerospace use of graphite fiber composites was 2.5 million pounds worth $128.0 million.[5]

A new paintable silicon carbide coating to protect graphite from oxidation has been marketed by ZYP Coatings Co. The silicon carbide coating was said to protect against graphite burning and oxidation to above 1,000° C in air. The firm's tests showed that coated graphite samples were unaffected after eight heating cycles, while the uncoated graphite samples were half destroyed after one cycle and entirely gone at the end of the fourth cycle. If industry can apply this technology, graphite usage could be extended into new areas.

Table 6.—U.S. consumption of natural graphite, by use

Use	Crystalline		Amorphous[1]		Total[2]	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1985:						
Batteries	W	W	W	W	1,569	$2,602
Brake linings	1,023	$960	2,448	$2,297	3,472	3,257
Carbon products[3]	379	843	206	173	585	1,016
Crucibles, retorts, stoppers, sleeves, nozzles	4,213	3,529	1	15	4,215	3,544
Foundries[4]	514	612	6,006	1,953	6,520	2,565
Lubricants[5]	1,025	1,478	2,586	2,327	3,611	3,805
Pencils	1,829	2,737	339	231	2,168	2,968
Powdered metals	[r]471	[r]815	[r]103	[r]156	574	971
Refractories	W	W	W	W	6,503	3,257
Rubber	217	249	289	170	506	419
Steelmaking	131	81	1,836	691	1,967	772
Other[6]	227	295	2,741	2,815	2,968	3,110
Withheld uses	3,216	4,342	4,855	1,517	--	--
Total[2]	[r]13,246	[r]15,942	[r]21,411	[r]12,346	34,657	28,288
1986:						
Batteries	W	W	W	W	1,560	2,284
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	6,757	5,422	2,823	652	--	--
Total[2]	14,162	14,076	17,568	10,853	31,730	24,929

[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 coating.
[6]Includes paints 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 average prices of crystalline flake and other natural graphite imports mostly rose in 1986. The prices of crystalline flake increased by 21% to $648 per ton; Mexican amorphous graphite dropped slightly to $49 per ton; all types of Sri Lankan lump graphite rose by 18% to $932 per ton; and other natural graphite (mostly fine crystalline flake and dust) rose by 4% to $541 per ton from $521 (revised) in 1985.

Average prices for natural graphite at the point of consumption changed slightly in 1986. The price for crystalline graphite (mostly crystalline flake, some crystalline dust, and a little lump graphite) was $994 per ton, down 17% from $1,204 (revised) in 1985. The price for amorphous graphite (including small amounts of amorphous-synthetic graphite mixtures) was $618 per ton, up 7% from $577 (revised) in 1985.

Table 7.—Representative yearend graphite prices[1]

(Per short ton)

	1985	1986
Flake and crystalline graphite, bags:		
China	$54-$1,542	$54-$1,542
Germany, Federal Republic of	227- 3,357	NA
Madagascar	227- 816	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

NA Not available.
[1]F.o.b. foreign port or border.

Source: Engineering and Mining Journal. V. 186, No. 12, Dec. 1985, p. 11, and v. 187, No. 12, Dec. 1986, p. 19.

FOREIGN TRADE

Exports of both natural and artificial graphite increased by 50%. Exports of graphite electrodes totaled 59,551 tons worth $108.4 million, of which 10,998 tons ($16.8 million) went to Japan, 6,201 tons ($17.6 million) to Canada, 5,675 tons ($9.1 million) to Venezuela, 5,042 tons ($9.3 million) to the U.S.S.R., 4,099 tons ($7.8 million) to Brazil, and the balance to other destinations.

Imports for consumption of natural graphite decreased 19% to 42,790 tons. Imports of natural graphite from Brazil, China, and Mexico dropped substantially.

Imports of all kinds of graphite fiber, including tows, yarns, textiles, preox fiber, and carbon fiber, but not precursor, were estimated to be 640 tons, worth $34 million in 1986, compared with 760 tons, worth $40 million in 1985, and 705 tons, worth $34 million in 1984. Almost all of this was from Japan, but the United Kingdom, Taiwan, Belgium-Luxembourg, France, and Israel, in descending order, 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
1985:						
Brazil	49	$22,879	783	$992,413	832	$1,015,292
Canada	4,065	1,366,750	1,240	592,536	5,305	1,959,286
Germany, Federal Republic of	r200	r7,118	r2,509	r1,024,015	2,709	1,031,133
Italy	1,174	205,953	164	91,765	1,338	297,718
Japan	226	318,799	2,671	800,694	2,897	1,119,493
Mexico	1,115	395,995	1,964	194,699	3,079	590,694
United Kingdom	212	133,984	186	141,121	398	275,105
Venezuela	241	152,561	98	74,390	339	226,951
Other	1,075	520,838	1,339	898,868	2,414	1,419,706
Total	r8,357	r3,124,877	r10,954	r4,810,501	19,311	7,935,378
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

rRevised.
[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)
1984	10,720	$5,455	892	$950	14,823	$6,849	31,808	$1,329	58,246	$14,579
1985:										
Antigua	--	--	--	--	19	8	--	--	19	8
Belgium-Luxembourg	--	--	--	--	14	22	--	--	14	22
Brazil	1,775	1,081	--	--	5,092	2,002	--	--	6,867	3,083
Canada	114	58	--	--	340	140	--	--	454	198
China	2,480	1,054	--	--	[r]6,374	[r]2,716	[r]5,561	[r]785	14,415	4,555
France	--	--	--	--	110	103	--	--	110	103
Germany, Federal Republic of	48	25	--	--	907	934	--	--	955	959
Hong Kong	40	4	--	--	--	--	[r]1,144	[r]187	1,184	191
India	140	72	--	--	430	325	--	--	570	397
Japan	62	144	--	--	190	363	--	--	252	507
Liberia	--	--	--	--	33	42	--	--	33	42
Macao	19	12	--	--	--	--	--	--	19	12
Madagascar	1,169	675	--	--	1,819	1,405	--	--	2,988	2,080
Mexico	--	--	--	--	2,118	1,053	19,736	980	21,854	2,033
Netherlands	--	--	--	--	222	135	--	--	222	135
Norway	8	1	--	--	37	19	--	--	45	20
Sierra Leone	--	--	--	--	17	21	--	--	17	21
South Africa, Republic of	--	--	--	--	524	251	--	--	524	251
Sri Lanka	--	--	1,654	1,307	--	--	--	--	1,654	1,307
Sweden	4	8	--	--	--	--	--	--	4	8
Switzerland	--	--	--	--	38	11	--	--	38	11
Taiwan	--	--	--	--	282	93	--	--	282	93
United Kingdom	40	25	--	--	([2])	16	--	--	40	41
Zimbabwe	--	--	--	--	175	108	--	--	175	108
Total[1]	5,899	3,161	1,654	1,307	[r]18,743	[r]9,767	[r]26,441	[r]1,952	52,737	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	--	--	--	--	([2])	4	--	--	([2])	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	([2])	4	--	--	--	--	--	--	([2])	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	42,790	15,758

[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.

Table 10.—U.S. imports for consumption of artificial graphite and graphite electrodes, by country

Country	Artificial graphite		Graphite electrodes	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1985:				
Australia	3	$29	--	--
Austria	--	--	22	$50
Belgium	13	50	1,404	2,719
Cameroon	20	29	--	--
Canada	1,117	422	2,625	3,770
China	211	278	153	230
France	454	575	2,946	4,640
Germany, Federal Republic of	906	2,217	6,730	8,780
India	212	226	--	--
Israel	--	--	20	44
Italy	53	102	3,386	4,989
Jamaica	5	33	--	--
Japan	964	5,200	36,736	64,752
Korea, Republic of	--	--	11	46
Netherlands	23	113	1,642	2,167
Singapore	--	--	1,473	2,195
South Africa, Republic of	2	13	1	2
Spain	--	--	7	10
Sweden	4	12	(1)	68
Switzerland	3,137	4,007	4,144	1,231
Taiwan	2	7	65	120
United Kingdom	118	535	931	1,097
Total[2]	7,241	13,847	62,296	96,913
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

[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 and world supply of graphite were up slightly in 1986. Demand dropped significantly in such major markets as the United States and Japan.

Brazil.—Cia. Nacional de Grafite Ltda. was the largest Brazilian producer of crystalline flake graphite by far in both 1985 and 1986. It had two centers of production: Itapecerica in Minas Gerais near Belo Horizonte and Pedra Azul in Minas Gerais about 10 miles from the boundary with Bahia State. The remaining production, from very small producers, almost all came from nearby southern Bahia State.

Itapecerica was the location of the older mine and corporate headquarters. The ore averaged 20% carbon, occurring in numerous small pockets in an area of about 50 square miles. Six of these pockets were mined for 3 months in 1986 to yield 33,000 tons of ore. Such a short period of operation has been sufficient in the last few years to feed the plant for the entire year. The ore required no blasting before removal by front-end loader and transportation by dump truck to the plant. After concentration by flotation, sizing, and drying, a variety of products in different flake size ranges and carbon contents were produced. A 6,600-ton-per-year-capacity chemical leaching plant to produce high-purity (99.6%) carbon graphite from the flotation concentrate was due on-stream at yearend 1986.

Pedra Azul was the location of the newer and larger mine. The ore averaged 5% to 12% carbon, although the blend for the mill ranged from 6% to 7% carbon. The mine had six faces, which were operated 365 days per year to yield 660,000 tons of ore. The ore was not blasted before removal by shovel and front-end loader for transportation by dump truck to the plant. The firm estimated that there was at least 150 years' supply of ore. In addition to this source of ore, there was a newly discovered sizable deposit with a higher proportion of large flake that is about 30 miles to the southeast of present operations. As at Itapecerica, after flotation, sizing, and drying, a variety of products in different flake size ranges and carbon content were produced at Pedra Azul. The firm had a large new tailings pond built at a cost of $4 million. The pond was 3 miles long and was expected to last 30 years at present production rates, or only 15 years if some planned expansions are carried out.

About 95% of Brazilian production originated in Minas Gerais State. Of the graphite produced in Minas Gerais in 1982, the latest year published, about 48% was exported, 27% went to consumers in São Paulo State, 18% to consumers in Minas Gerais State, and the balance to Brazilian consumers in other States. Of the 52% consumed domestically, 32% went to the iron and steel industry, 8% to the refractory industry, 4% to the battery industry, 4% to the stone industry, and 4% to all other industries.

The balance of national production, from Bahia State, was almost all consumed without prior beneficiation as foundry facings. Brazil made some fairly sophisticated graphite containing products in 1986, such as carbon magnesite brick, expanded graphite, and continuous casting ware.

Canada.—The national and provincial governments continued to be interested in the discovery and development of Canadian graphite deposits. Government geologists performed an airborne survey and completed detailed cartography in four areas thought to contain graphite in Quebec. Government geologists performed field evaluation programs on graphite properties in Ontario. This activity coincided with and stimulated private sector exploration and activity.

Carbontec Industries Ltd. was founded in late 1985 to investigate a schistose body on Cape Breton Island, Nova Scotia, said to contain mostly amorphous graphite, plus some crystalline flake. The graphite content of the body was believed to be in the range of from 25% to 70% carbon, but probably averages 40% to 45% carbon. The firm estimated that substantial reserves existed, possibly even tens of millions of tons. The firm planned to upgrade to a micronized product containing 90% to 95% carbon.

Princeton Resources Corp. acquired 50 contiguous unpatented mining claims with graphite mineralization present near Bissett Creek, Ontario. The firm completed 106 drill holes with a total footage of 18,000 feet to outline the first 5.5 million tons of reserves, and later stated that the ore body contained 16.0 million tons of crystalline flake ore containing 2.7% carbon. Three mineralized zones have been found so far, at various depths down to 265 feet, and deeper zones might exit. Metallurgical test work showed that an 84% carbon product (with size distribution of 32% of the flake on a 35-mesh screen, 48% cumulative on a 65-mesh screen, and 97% on a 100-mesh screen) could be recovered by crushing, grinding, and flotation. The firm built a 200-ton-per-day pilot plant that will be used to produce a supply of crystalline flake graphite for test marketing; Klöckner Humboldt-Deutz AG was to provide technical assistance for it. Assuming satisfactory results, the firm plans to build a 15,000-ton-per-year plant.

On October 1, the firm granted an option for a 58% interest in this prospective graphite operation to a private individual.

Japan.—In 1986, Japan outdistanced the United States in graphite importation by over 20,000 tons. Imports of crystalline flake and Sri Lankan lump graphite dropped from 34,032 tons in 1985 to 33,168 tons in 1986, of which 29,668 tons originated from China, 1,584 tons from Madagascar, 1,336 tons from Sri Lanka, and the balance from other sources. Amorphous graphite imports dropped from 48,026 tons in 1985 to 26,763 tons in 1986, of which 21,398 tons came from the Republic of Korea, 4,712 tons from North Korea, and the balance from other sources. Imports of graphite, of which 75% or more, by weight, can pass through a 105-micrometer mesh sieve dropped from 4,866 tons in 1985 to 4,713 tons in 1986, of which 3,804 tons came from China, 616 tons from Sri Lanka, and the balance from other sources. Imports of graphite, particularly crystalline flake, have been increasing rapidly in the last 5 years because of the growing use of carbon-magnesite and new graphite containing refractories.

Exports of graphite electrodes rose from 118,264 tons in 1985 to 123,443 tons in 1986, of which 23,139 tons went to the United States, 17,144 tons to China, 11,451 tons to the U.S.S.R., 9,910 tons to the Republic of Korea, and the balance to other destinations.

Pakistan.—The Azad Kashmir Mineral and Industrial Development Corp. discovered large graphite deposits about 100 miles northeast of the city of Muzaffarabad, in Kashmir. Reserves were 1 million tons proven and over 8 million tons inferred. The ore was a graphite schist containing 10% to 12% carbon. Pilot plant studies indicated that an 84% carbon concentrate could be made by flotation.

Sweden.—Kema Nord Industrikemi AB, a subsidiary of Nobel Industries Sweden AB, bought out its former joint venture partner in its CarbonNord HB synthetic graphite plant at Sundsvaal. The partner, Superior Graphite, supplied the technology under license to the venture. The 13,200-ton-per-year-capacity plant had two furnaces, but capacity will be doubled by a third furnace being installed in 1987. The plant made Desulco by graphitizing pulverized petroleum coke, but might also be used to make silicon carbide. Because Kema Nord was already producing silicon and silicon nitride, this could add silicon carbide to its product line.

Turkey.—The Mining Department of Turkey recently collected information on graphite resources. One important graphite-in-schist deposit, at Domuzderesi, Province of Istanbul, was estimated to contain 165,000 tons of resources averaging 30% carbon. The Mugla-Milas-Yayladere occurrence was the largest mine, with resources of 660,000 tons averaging 82% carbon. The Mersin-Anamur Bozyazi deposit had 550,000 tons of resources averaging 35% carbon.

U.S.S.R.—The Soviet Union announced plans to build a new graphite electrode plant in Tashauz, Turkmenistan. Construction of this plant was scheduled to begin in the 1986-90 time period.

Table 11.—Graphite: World production, by country[1]

(Short tons)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Argentina	13	22	16	[e]20	17
Austria	26,953	44,553	48,269	33,911	38,600
Brazil (marketable)[3]	16,990	30,463	36,023	[r] [e]38,600	40,800
Burma[4]	308	220	258	258	220
China[e]	204,000	204,000	204,000	204,000	204,000
Czechoslovakia[e]	55,000	55,000	55,000	65,000	65,000
Germany, Federal Republic of	[5]12,845	11,023	9,392	14,107	11,000
India (mine)[6]	57,735	43,615	42,975	30,134	33,000
Italy	3,538	2,534	--	--	--
Korea, North[e]	28,000	28,000	28,000	28,000	28,000
Korea, Republic of:					
Amorphous	29,033	35,903	62,014	77,026	72,000
Crystalline flake	691	766	2,541	1,766	1,700
Madagascar	16,766	14,944	15,403	15,400	15,500
Mexico:					
Amorphous	37,886	47,034	43,923	36,892	39,000
Crystalline flake	1,989	1,828	1,855	2,105	2,100
Norway	8,213	8,888	11,097	[e]2,500	--
Romania[e]	13,800	13,900	13,700	13,200	13,200
Sri Lanka	9,704	6,094	6,198	8,171	7,700
Thailand	694	95	--	--	--
Turkey	3,704	5,297	NA	NA	NA
U.S.S.R.[e]	83,000	88,000	88,000	90,000	91,000
United States	W	W	W	--	--
Zimbabwe	9,066	21,850	13,596	11,519	10,000
Total	619,928	664,029	682,260	672,609	672,837

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

[1]Table includes data available through May 19, 1987.

[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: 1982—6,758; 1983—12,278; 1984—2,902; 1985—3,300 (revised); and 1986—4,400 (estimated).

[4]Data are for fiscal year beginning Apr. 1 of that stated.

[5]Data presented represent estimated marketable product derived from raw graphite mined indigenously, assuming that marketable output equals one-half of officially reported raw graphite production.

[6]Indian marketable production is about 10% to 20% of mine production.

TECHNOLOGY

Investigators for the Institute of Materials Processing of Michigan Technological University performed a preliminary evaluation of Michigan graphite resources. These resources were probably amorphous and were present in Michigan's Upper Peninsula. The graphite-rich rock occurs in a 30-mile-long belt near U.S. 41 in Baraga and Marquette Counties in the lower slate of the Precambrian Michigamme Formation. The resources totaled more than 3 billion tons with three field samples believed to be representative giving carbon contents ranging from 17% to 30%. Flotation and heavy liquid separations on -400-mesh samples were performed. The sample with the highest flotation recovery yielded a 47.5% carbon concentrate with a 55% recovery. The sample with the lowest recovery gave a 38% carbon concentrate with a 16% recovery from flotation. Heavy liquid separation tests on the sample with the highest flotation recovery gave a 62.4% carbon concentrate with a 53% recovery. The sample with the lowest flotation recovery gave only a 6% recovery from heavy liquid separation. The sample giving poorest recoveries was the most silicified; it contained 55% quartz compared with 30% to 35% for the other two samples. The liberation size for the graphite particles was very small, probably under 10 micrometers.[6]

The University of Delaware made plans to build a $5 million laboratory for research on fiber composites manufacturing, called the Center for Composite Materials. University officials hoped that it would help to establish a "composite valley" in the area. Other academic centers for research on graphite fiber, its composites, and other fibers included a laboratory at the School of Textile Engineering at Georgia Institute of Technology and the Materials Technology Center of Southern Illinois University.

The entire October 1986 issue of Scientific American highlighted advanced materials, including several articles relating to graphite fiber. One article pointed out that new materials are making and will make major changes in our economy. It is finally possible to start with a need and then develop a material to meet it rather than having the materials available dictate how or whether the need can be met. Graphite fiber has become cost competitive with many of the new engineered plastics. Tooling up to make a plastic or composite part has been found to be less expensive for a short production run than tooling up for the steel part.[7] Another paper pointed out that composites have a special role where there is a need for combinations of properties available from no single material, and that varying the weave, ordering, and length of the fibers has been found to result in different combinations of properties.[8] A third article pointed out the special need for materials with new properties for aerospace uses, particularly high-strength materials, lightweight materials, and heat-resistant materials, and that composites will grow in importance as this need is met, particularly for supersonic aircraft.[9]

Metal-matrix composites have begun to show the promise that plastic composites have already demonstrated. Most of the activity so far has involved manufacturing parts from composites of the easier-to-use fibers. An example of such parts are the alumina-fiber-reinforced or alumina-and-silica-fiber-reinforced pistons now being produced. Activity in the more difficult to manufacture fibers, such as graphite, has now begun, particularly in the area of producing objects to be used in outer space, where plastic composites would offgas and condense on optical instruments. Knowledgeable people in the field predicted that metal-matrix composites may become as common as plastic composites and gradually replace most unreinforced metals.[10]

A study of the strength variability of metal-matrix composites considered two components—the strength variability of the constituent fiber and the behavior of the metal-matrix coating process. The variability in the strength of the fiber was determined by testing a specimen of fiber at the beginning and at the end of each fiber containing spool. The graphite-aluminum wire produced by immersing a graphite fiber in molten aluminum was tested in tension. These two tests were found to give an accurate and sensitive indication of composite quality.[11]

A new fabrication technique for graphite-fiber reinforced magnesium composites looked promising. New developments of this sort were especially welcome because the lack of cheap and simple fabricating techniques has prevented the wide use of metal-matrix composites. First, an air stable silicon dioxide coating was deposited by hydrolysis or pyrolysis on the graphite fiber surface from an organometallic precursor solution. When the fibers were immersed in molten magnesium, the silicon dioxide coating facilitated wetting and bonding. This coating technique was modified to improve the adhesion between the graphite fibers and the silicon dioxide coating by coating the graphite fibers with amorphous carbon first before coating with silicon dioxide. Several kinds of graphite fiber were used with a couple of magnesium alloys.[12]

Carnegie Mellon University researchers developed a flexible graphite fiber than can be made into a lighter, less expensive, more impact-resistant composite. The new fiber was made by reacting commercial graphite fiber with halogenated inorganic reagent at high temperatures, producing a fiber that was much more flexible and one-half as dense as ordinary graphite fiber. Costs of composite production were reduced by 20%.

A clear and detailed description of the manufacturing processes involved in converting graphite fiber into metal-matrix and polymeric-matrix composites has been published. Techniques covered included hand layup, sprayup, autoclave, centrifugal casting, filament winding, pultrusion, compression molding, injection molding, resin-transfer molding, and cold stamping. Other fibers mentioned were silicon carbide fiber and boron fiber; also mentioned were coupling agents and a number of different kinds of matrices.[13]

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Gypsum

By Lawrence L. Davis[1]

Demand for gypsum products remained strong in 1986, fueled by 1.8 million new public and private housing unit starts. The gypsum industry set new record-high levels by mining 15.8 million short tons of crude gypsum, producing 17.1 million tons of calcined gypsum, and shipping 20.3 billion square feet of gypsum wallboard.

Sales of gypsum products increased slightly to 25 million tons valued at $2.5 billion. Imports for consumption of crude gypsum decreased 4% to 9.6 million tons. Total value of gypsum product exports increased 9% to $29 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 130 operations to which the annual survey request was sent, 100% responded, representing 100% of the total production shown in tables 1 and 2.

Table 1.—Salient gypsum statistics

(Thousand short tons and thousand dollars)

	1982	1983	1984	1985	1986
United States:					
Active mines and plants[1]	109	111	113	116	113
Crude:					
Mined	10,538	12,884	14,319	14,726	15,789
Value	$89,131	$101,361	$113,671	$114,229	$102,047
Imports for consumption	6,718	8,031	8,904	9,922	9,559
Byproduct gypsum sales	697	760	780	779	653
Calcined:					
Produced	11,243	13,902	15,450	15,982	17,061
Value	$196,488	$270,136	$320,518	$366,581	$310,353
Products sold (value)	$1,121,775	$1,605,605	$2,274,261	$2,418,296	$2,514,432
Exports (value)	$29,550	$32,088	$29,852	$26,419	$28,805
Imports for consumption (value)	$53,646	$87,880	$169,667	$155,422	$181,168
World: Production	r79,891	r86,515	89,008	p93,839	e96,556

eEstimated. pPreliminary. rRevised.

[1]Each mine, calcining plant, or combination mine and plant is counted as one establishment; includes plants that sold byproduct gypsum.

DOMESTIC PRODUCTION

The United States remained the world's leading producer of gypsum, accounting for 16% of the total world output.

Crude gypsum was mined by 35 companies at 63 mines in 20 States. Production increased 7%. Leading producing States, in descending order, were Texas, Michigan, Iowa, Oklahoma, California, and Nevada. These six States produced more than 1 million tons each and together accounted for 65% of total domestic production. Stocks of crude ore at mines and plants at yearend were 3.4 million tons.

Leading companies were USG Corp., 12 mines; National Gypsum Co., 7 mines; Georgia-Pacific Corp., 6 mines; Celotex Corp. (a subsidiary of Jim Walter Corp.) and Genstar Gypsum Products Co., 3 mines each; and Weyerhaeuser Co., 1 mine. These 6 companies, operating 32 mines, produced 79% of the total crude gypsum.

Leading individual mines, in descending

order of production, were USG's Plaster City Mine, Imperial County, CA; National Gypsum's Tawas Mine, Iosco County, MI; USG's Alabaster Mine, Iosco County, MI; USG's Sweetwater Mine, Nolan County, TX; USG's Shoals Mine, Martin County, IN; Weyerhaeuser's Briar Mine, Howard County, AR; National Gypsum's Sun City Mine, Barber County, KS; National Gypsum's Shoals Mine, Martin County, IN; Georgia-Pacific's Acme Mine, Hardeman County, TX; and USG's Southard Mine, Blaine County, OK. These 10 mines accounted for 41% of the national total. Average output per mine for the 63 U.S. mines increased 14% to 250,600 tons.

Gypsum was calcined by 14 companies at 72 plants in 30 States, principally for the manufacture of gypsum wallboard and plaster. Calcined output increased 7% in tonnage and decreased 15% in value. Leading States, in descending order, were California, Texas, Florida, Iowa, and New York. These 5 States, with 24 plants, accounted for 40% of the national output.

Leading companies were USG, 22 plants; National Gypsum, 18 plants; Georgia-Pacific, 9 plants; Genstar Gypsum, 5 plants; and Celotex, 4 plants. These 5 companies, operating 58 plants, accounted for 83% of the national output.

Leading individual plants were, in descending order of production, USG's Jacksonville plant, Duval County, FL; USG's Plaster City plant, Imperial County, CA; USG's Sweetwater plant, Nolan County, TX; Weyerhaeuser's Briar plant, Howard County, AR; National Gypsum's Tampa plant, Hillsborough County, FL; USG's Stony Point plant, Rockland County, NY; USG's Shoals plant, Martin County, IN; Republic Gypsum Co.'s Duke plant, Jackson County, OK; Georgia-Pacific's Acme plant, Hardeman County, TX; and National Gypsum's Medicine Lodge plant, Barber County, KS. These 10 plants accounted for 27% of the national production. Average calcine production for the 72 U.S. plants was 236,900 tons, a 5% increase.

The following companies sold a total of 653,000 tons of byproduct gypsum, valued at $4.6 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; and Texasgulf Inc. in North Carolina. Approximately 39% was of nonphosphogypsum origin, compared with 22% in 1985. Some byproduct gypsum was mixed with natural gypsum and commercially used in the manufacture of wallboard at USG's Baltimore, MD, plant using byproduct gypsum obtained from SCM Corp.'s SCM Pigments Div.'s plant in Baltimore.

Gypsum wallboard plant capacity increased 8% to 23.37 billion square feet. Temple-Eastex Inc. opened a new plant at Fletcher, OK, and several other companies expanded their plants. Total wallboard shipments were 20.3 billion square feet, indicating a 87% utilization of operating capacity. Shipments increased 4% to a record-high level.

Winn Rock Inc.'s Winnfield Mine in Winn Parish, LA, the only anhydrite mine in the United States, produced rock mainly for road construction. Several gypsum mines remained closed during the year, but shipped gypsum from their stockpiles. They were Fannin-Superior Gypsum Co.'s Lost Hill Mine in Kern County, CA; E. J. Wilson & Sons' Lidy Hot Springs Mine in Lemhi County, ID; and Southwestern Portland Cement Co.'s Finlay Mine in Hudspeth County, TX.

Genstar Corp., a major producer of gypsum and gypsum products, was purchased by Imasco Ltd., a Canadian firm. Imasco then agreed to sell Genstar's entire gypsum business, Genstar Gypsum, to Domtar Inc., also of Canada.[2] At yearend, the proposed $241 million sale to Domtar was under review by the U.S. Department of Justice.

Atlantic Gypsum Co. awarded a contract for construction of its $34 million gypsum importing facility and wallboard plant at Port Newark, NJ. The plant was expected to begin production in early 1988 using gypsum imported from Spain.[3]

Table 2.—Crude gypsum mined in the United States, by State

State	1985 Active mines	1985 Quantity (thousand short tons)	1985 Value (thousands)	1986 Active mines	1986 Quantity (thousand short tons)	1986 Value (thousands)
Arizona and New Mexico	7	600	$3,496	7	615	$3,246
Arkansas, Kansas, Louisiana[1]	5	1,365	7,740	4	1,474	8,166
California	8	1,332	12,201	7	1,378	10,777
Colorado, Montana, Washington, Wyoming	9	917	7,305	9	1,005	6,727
Indiana, New York, Ohio, Virginia	5	1,870	14,832	5	1,960	12,479
Iowa	6	1,639	13,682	6	1,826	12,602
Michigan	5	1,772	11,883	5	1,979	11,052
Nevada	4	1,207	8,942	4	1,236	8,221
Oklahoma	6	1,595	12,548	5	1,683	9,855
South Dakota	1	34	268	1	31	268
Texas	7	1,981	17,299	6	2,131	14,982
Utah	4	413	4,033	4	470	3,671
Total[2]	67	14,726	114,229	63	15,789	102,047

[1]1985 only.
[2]Data may not add to totals shown because of independent rounding.

Table 3.—Calcined gypsum produced in the United States, by State

State	1985 Active plants	1985 Quantity (thousand short tons)	1985 Value (thousands)	1986 Active plants	1986 Quantity (thousand short tons)	1986 Value (thousands)
Arizona and New Mexico	3	404	$10,016	3	426	$5,786
Arkansas, Louisiana, Oklahoma	6	1,664	34,905	7	1,831	29,209
California	6	1,606	41,325	6	1,695	33,495
Colorado and Utah	3	354	8,164	3	388	7,027
Delaware, Maryland, North Carolina, Virginia	6	1,404	32,841	6	1,543	28,980
Florida	3	1,185	27,974	3	1,309	25,158
Georgia	3	740	18,161	3	768	17,001
Illinois, Indiana, Kansas	6	1,445	28,862	6	1,533	25,664
Iowa	5	1,168	26,589	5	1,220	21,963
Massachusetts, New Hampshire, New Jersey, Pennsylvania	5	820	20,084	5	885	18,577
Michigan	4	571	12,217	4	618	10,923
Montana, Washington, Wyoming	5	705	19,951	5	778	16,451
Nevada	3	825	16,674	3	950	16,198
New York	4	1,046	24,408	4	1,047	18,940
Ohio	3	432	9,998	3	479	9,659
Texas	6	1,614	34,412	6	1,590	25,323
Total[1]	71	15,982	366,581	72	17,061	310,353

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

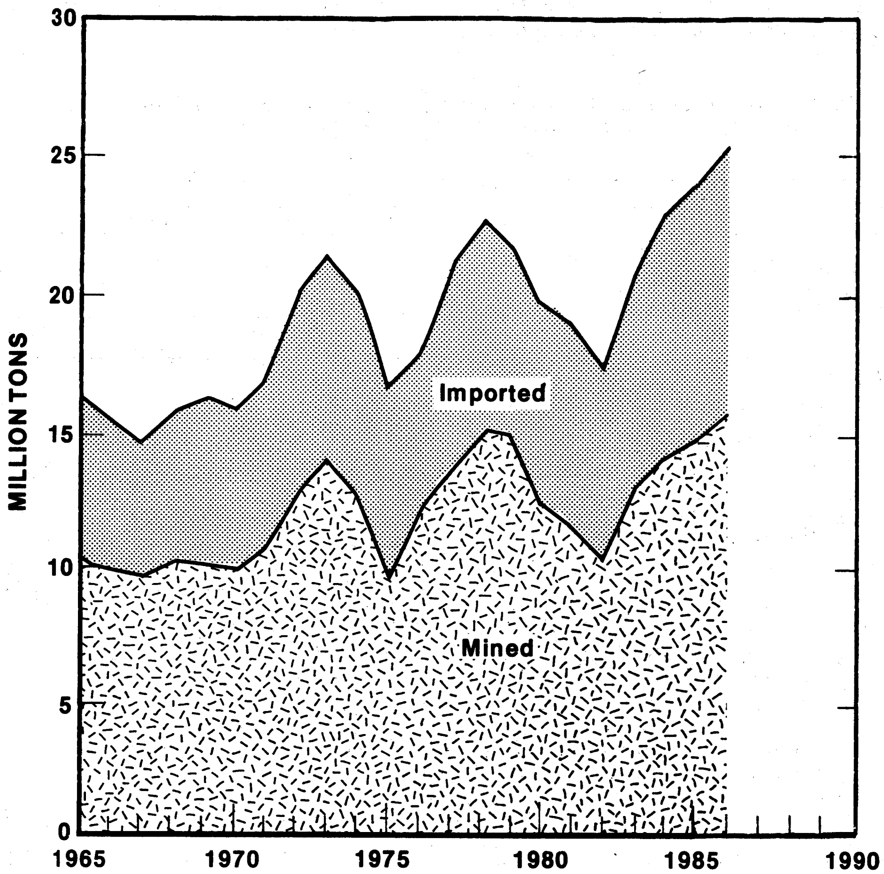

Figure 1.—Supply of crude gypsum in the United States.

CONSUMPTION AND USES

Apparent consumption, defined as production plus net imports plus industry stock changes, of crude gypsum, including byproduct gypsum, decreased slightly to 24.9 million tons. Net imports provided 38% of the crude gypsum consumed. Apparent consumption of calcined gypsum increased 6% to 16.9 million tons.

Yearend stocks of crude gypsum at mines and calcining plants were 3.4 million tons. Of this, 46% was at calcining plants in coastal States.

Of the total gypsum products sold or used, 5.3 million tons, 21%, was uncalcined. Of the total uncalcined gypsum, 81% was used for portland cement and 18% 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 upon surface square feet; 68% was regular wallboard; 21% was fire-resistant type X wallboard; 5% was lath, veneer base, sheathing, and predecorated wallboard; 3% was 5/16-inch mobile home board; and 3% was water- and/or moisture-resistant board. Of the regular wallboard, 83% 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 53% 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	1985 Quantity	1985 Value	1986 Quantity	1986 Value
Uncalcined:				
Portland cement	4,256	38,623	4,296	40,328
Agriculture[1]	1,180	16,377	943	13,517
Fillers and miscellaneous	132	6,448	93	7,868
Total[2]	5,567	61,448	5,331	61,712
Calcined:				
Building plaster:				
Regular base coat	149	15,027	133	14,888
Poured gypsum cement and concrete	2	192	2	139
Veneer plaster	102	15,190	107	16,412
Gauging plaster and Keene's cement	26	3,561	29	3,705
Other	8	1,105	7	1,224
Total[2]	288	35,075	278	36,367
Industrial plaster	510	55,426	476	54,126
Prefabricated products[3]	18,320	2,266,348	19,048	2,362,225
Total calcined[2]	19,117	2,356,849	19,802	2,452,719
Grand total[2]	24,684	2,418,296	25,133	2,514,432

[1]Includes most of 778,515 tons of byproduct gypsum in 1985 and most of 652,562 tons in 1986.
[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	1985 Thousand square feet	1985 Thousand short tons[1]	1985 Value (thousands)	1986 Thousand square feet	1986 Thousand short tons[1]	1986 Value (thousands)
Lath:						
3/8 inch	27,800	21	$4,404	23,460	17	$3,980
1/2 inch	1,750	2	237	1,000	1	159
Total[2]	29,550	22	4,641	24,460	18	4,139
Veneer base	428,860	435	58,167	453,770	456	61,793
Sheathing	349,860	328	52,389	337,890	316	54,531
Regular gypsumboard:						
3/8 inch	454,246	340	53,301	433,450	324	51,724
1/2 inch	10,851,776	9,539	1,134,940	11,493,000	10,136	1,188,138
5/8 inch	1,395,919	1,252	173,496	1,578,700	1,442	195,767
1 inch	79,900	142	18,532	84,500	148	20,646
Other[3]	276,220	180	31,898	227,620	143	25,230
Total[2]	13,058,061	11,453	1,412,168	13,817,270	12,193	1,481,506
Type X gypsumboard	4,387,049	5,015	546,862	4,357,990	4,935	563,985
Predecorated wallboard	134,650	129	45,346	132,200	124	42,833
5/16-inch mobile home board	651,549	489	64,567	570,770	433	54,932
Water/moisture-resistant board	477,828	441	80,977	521,980	485	79,485
Other	5,592	7	1,232	84,800	87	19,020
Grand total[2]	19,522,999	18,320	2,266,348	20,301,130	19,048	2,362,225

[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.

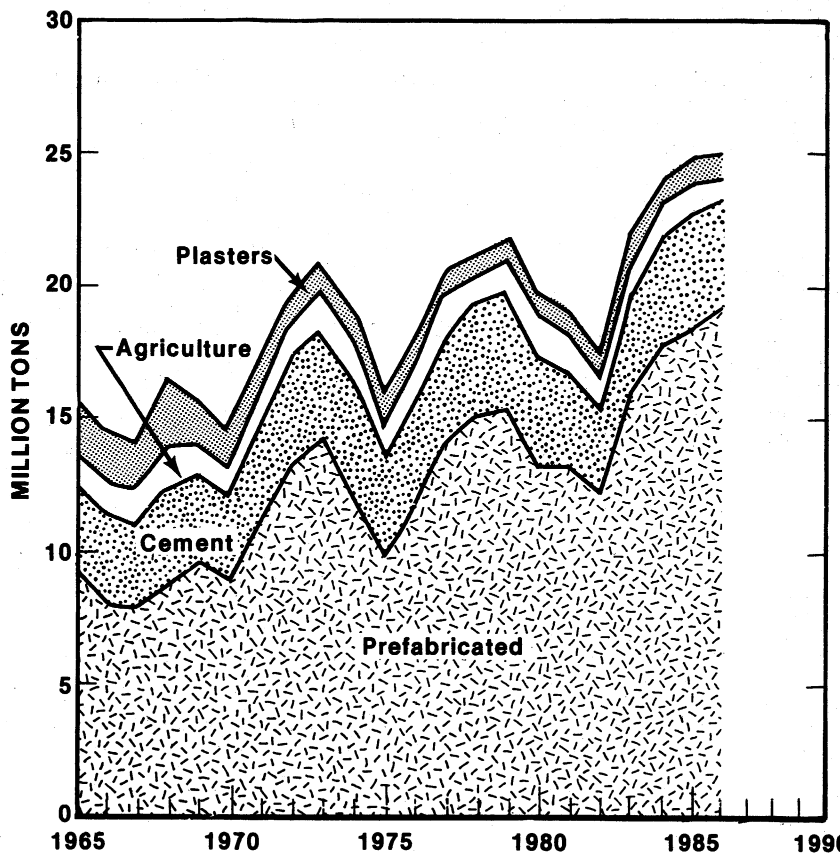

Figure 2.—Sales of gypsum products, by use.

ENERGY

Energy consumption per thousand square feet of gypsum wallboard sales remained about the same at 2.44 million British thermal units. As reported by the Gypsum Association, fuel sources for the gypsum industry were natural gas, 85.2%; electricity, 5.9%; propane, 1.0%; fuel oil, No. 2, 2.8%; fuel oil, Nos. 4 and 6, 2.1%; and coal, 2.9%.

PRICES

On an average-value-per-ton basis, crude gypsum decreased 17% to $6.46, calcined gypsum decreased 23% to $18.19, and byproduct gypsum decreased 8% to $7.12.

The average value of gypsum products sold or used increased slightly to $99.75 per ton. Prefabricated products were valued at $124.01 per ton, industrial plasters at $113.71 per ton, building plaster at $130.82 per ton, and uncalcined products at $11.58 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 $104 per thousand square feet at Denver to $280 at Boston. The average price in December for 20 cities was $177 per thousand square feet, with some minor discounts for prompt payment. This represented a slight increase compared with that of December 1985.

FOREIGN TRADE

The gypsum industry continued to rely on imports of crude gypsum rock for a significant fraction, 38%, of apparent consumption. Imports of crude gypsum, principally from Canada (65%), Mexico (21%), and Spain (13%), decreased 4% to 9.6 million tons. Most of the imported crude gypsum was mined by subsidiaries of U.S. companies in Canada and Mexico.

Total value of gypsum and gypsum products imported was $181 million, an increase of 17%. Gypsum wallboard imports, principally from Canada, 97%, were 834 million square feet, a 6% increase. Total value of gypsum product exports to all countries was $29 million, a 9% increase.

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		
1984	131	12,711	17,141	29,852
1985	83	13,021	13,398	26,419
1986	155	15,481	13,324	28,805

[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				
1984	8,904	73,965	11	392	3,300	86,962	5,048	169,667
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

[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]Comprised of 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	1985		1986	
	Quantity	Value	Quantity	Value
Australia	16	130	--	--
Bahamas	--	--	18	75
Canada[1]	6,516	45,445	6,252	44,511
Hong Kong	--	--	20	129
Jamaica	17	118	23	135
Mexico	2,162	9,896	2,040	9,455
Spain	1,207	8,052	1,200	10,502
Other	4	447	6	189
Total	9,922	[2]64,089	9,559	64,996

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

Source: Bureau of the Census.

WORLD REVIEW

Estimated world production of crude gypsum increased slightly to 97 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.

Canada.—Canada remained the world's second largest producer of crude gypsum, accounting for 10% of the world total. Production increased slightly to 9.4 million tons, 72% of which came from Nova Scotia. Ontario accounted for 15% of total production, and the remaining production came from British Columbia, Manitoba, and Newfoundland.[4]

The Gypsum Association in the United States, of which all Canadian gypsum wallboard manufacturers were members, announced that yearend Canadian wallboard capacity was 3.72 billion square feet, a slight increase from that of 1985.

Egypt.—A gypsum processing plant was under construction in the Sinai Peninsula. It was scheduled to be operational in 1987.[5]

Italy.—Gypsum production was concentrated in the Provinces of Ravenna, Pesaro e Urbino, Bologna, and Reggio Emilia. Most of the production was consumed domestically. Only minor amounts of gypsum were imported or exported.[6]

Morocco.—Gypsum production was centered near the port city of Safi in southern Morocco. Producing companies included Margosypse, Compagnie Marocaine de Production et d'Exploration, Safio Gypse, and Somarex. Gypsum was used domestically and exported, mainly to countries in Europe and Africa.[7]

Thailand.—Gypsum exports in the first 9 months increased 26% and for the year were expected to reach 1.5 million tons. Gypsum provided more export income for Thailand than any other industrial mineral.[8]

United Arab Emirates.—The Ministry of Petroleum and Mineral Resources reported that large quantities of gypsum, up to 95% pure, were found in eastern Abu Dhabi. The gypsum was expected to be used by the cement manufacturing industry, which presently relies heavily on gypsum imports.[9]

Table 9.—Gypsum: World production, by country[1]

(Thousand short tons)

Country	1982	1983	1984	1985[p]	1986[e]
Afghanistan[e]	[2]3	3	3	3	3
Algeria[e]	220	275	275	275	303
Angola[e]	22	22	22	22	22
Argentina	679	637	625	[e]585	610
Australia	2,054	1,664	678	1,695	1,760
Austria[3]	802	828	816	765	770
Bolivia[e]	[2]1	1	1	1	1
Brazil	750	613	544	617	630
Bulgaria	414	425	433	428	430
Burma[4]	29	38	30	43	[2]43

See footnotes at end of table.

Table 9.—Gypsum: World production, by country[1] —Continued

(Thousand short tons)

Country	1982	1983	1984	1985[p]	1986[e]
Canada (shipments)[3]	6,600	8,275	8,550	9,311	9,420
Chile	99	73	185	216	210
China[e]	3,900	4,700	5,300	[r]6,300	7,200
Colombia	309	[r]262	287	276	276
Cuba[e]	140	145	145	145	145
Cyprus	33	35	24	18	[2]33
Czechoslovakia	875	935	928	[e]840	940
Dominican Republic[e]	230	230	230	[2]363	390
Ecuador[e]	2	2	2	2	2
Egypt	1,026	795	[e]800	927	1,000
El Salvador[e]	6	5	5	4	4
Ethiopia[e]	[2]4	5	5	5	5
France[3]	6,657	6,111	5,954	[e]6,000	6,000
German Democratic Republic[e]	397	397	397	397	375
Germany, Federal Republic of (marketable)[3]	1,897	2,739	2,493	2,609	2,090
Greece	756	711	[r e]720	[r e]720	720
Guatemala	31	43	28	19	22
Honduras[e]	22	25	25	25	25
Hungary[e 3]	29	31	33	33	33
India	1,070	1,145	1,519	1,389	1,840
Iran[e]	5,500	6,000	5,500	5,500	5,500
Iraq[e]	190	190	330	330	330
Ireland	409	388	358	335	[2]318
Israel	46	46	51	[r e]50	50
Italy	1,472	1,530	1,393	1,390	1,430
Jamaica	118	119	199	197	198
Japan[5]	7,014	6,443	[e]6,700	[e]6,900	7,000
Jordan	44	45	121	[e]120	120
Kenya[3]	([6])	1	[e]2	[e]2	[2]12
Korea, Republic of[e 5]	800	1,000	[2]558	[2]873	880
Laos[e]	70	80	[2]90	120	140
Lebanon	6	6	[e]6	[e]3	3
Libya[e]	193	198	198	198	198
Luxembourg	([6])	[e]([6])	([6])	[e]([6])	([6])
Mauritania[e]	6	4	1	6	6
Mexico	2,251	3,261	4,696	5,074	4,960
Mongolia[e]	35	35	35	35	35
Morocco[e]	463	485	500	500	500
Nicaragua	22	13	[e]10	9	9
Niger[e]	3	3	3	3	3
Pakistan	365	351	413	451	450
Paraguay	7	4	7	3	3
Peru	[e]400	85	74	32	33
Philippines[5]	121	122	124	[e]124	124
Poland[3]	1,430	1,430	1,430	[r]1,870	1,980
Portugal	262	275	251	[e]275	250
Romania[e]	1,800	1,800	2,000	1,700	1,700
Saudi Arabia	400	[e]550	331	[e]330	300
Sierra Leone	--	4	4	[e]4	4
South Africa, Republic of	590	571	590	505	[2]446
Spain	5,564	6,195	5,914	6,090	6,060
Sudan[e 3]	9	9	[2]9	[2]7	8
Switzerland[e]	[r]100	[r]200	[r]240	[r]240	220
Syria	[e]90	186	220	220	220
Taiwan[5]	2	3	2	2	[2]2
Tanzania[e]	13	13	13	13	13
Thailand	831	838	1,224	1,404	1,540
Tunisia[e]	80	88	95	100	110
Turkey	[e]100	83	64	86	88
U.S.S.R.[e 5]	5,400	5,400	5,400	5,400	5,500
United Kingdom[3]	3,021	3,271	3,459	3,515	3,530
United States[7]	10,538	12,884	14,319	14,726	[2]15,789
Uruguay	135	167	82	[e]110	110
Venezuela	175	226	158	147	275
Vietnam[e]	30	30	30	30	30
Yemen Arab Republic	24	26	27	27	27
Yugoslavia	705	687	[e]720	[e]750	750
Total	[r]79,891	[r]86,515	89,008	93,839	96,556

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through July 7, 1987.
[2]Reported figure.
[3]Includes anhydrite.
[4]Data are for years beginning Apr. 1 of that stated.
[5]Includes byproduct gypsum. (In the case of Japan, byproduct gypsum was virtually all the gypsum consumed during 1982-86.)
[6]Less than 1/2 unit.
[7]Excludes byproduct gypsum.

TECHNOLOGY

Production of gypsum wallboard in the United States using synthetic gypsum as the feed material came closer to fruition during 1986. At yearend, Windsor Gypsum Co.'s Henderson plant was nearly ready to begin production. The new plant, in east Texas, was designed to use synthetic gypsum from Texas Utilities Co. powerplants and was expected to start production in early 1987.

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[1]Physical scientist, Division of Industrial Minerals.
[2]Industrial Minerals (London). No. 230, Nov. 1986, p. 13.
[3]Rock Products. V. 89, No. 9, Sept. 1986, p. 9.
[4]Canadian Mining Journal. V. 108, No. 3, Feb. 1987, pp. 14-15.
[5]Rock Products. V. 89, No. 4, Apr. 1986, p. 20.
[6]Robbins, J. Italy's Industrial Minerals. Ind. Miner. (London), No. 231, Dec. 1986, p. 37.
[7]Power, T. Morocco—Phosphates Footing the Bill. Ind. Miner. (London), No. 225, June 1986, p. 44.
[8]Industrial Minerals (London). No. 233, Feb. 1987, p. 75.
[9]Work cited in footnote 8.

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 1,509 million cubic feet (MMcf) in 1986.[2] Grade-A helium exports by private producers were 432 MMcf, for total sales of 1,941 MMcf of U.S. helium. The Bureau's price, f.o.b. plant, for Grade-A helium was $37.50 per thousand cubic feet (Mcf). The price of Grade-A helium gas sold by private producers was about $36 per Mcf at the end of the year, and the price of liquid helium averaged $55 per Mcf gaseous equivalent with some producers posting surcharges to these prices.

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, 100% responded, and 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. Private helium production in 1986 was not sufficient to provide for the private market because one of its crude helium separation plants was shut down for 9 months. Private crude helium previously stored under contract with the Government was returned to the owners for purification as needed to provide for private industry's demand.

DOMESTIC PRODUCTION

In 1986, 12 privately owned domestic helium plants were operated by 9 companies. Exxon Co. U.S.A., started producing helium from the Riley Ridge area in Wyoming during October 1986 at its Shute Creek plant. Eight privately owned plants and one Bureau of Mines plant extracted helium from natural gas. Both private and Bureau plants used cryogenic extraction processes. Pressure-swing adsorption was used for helium purification at three newer private helium plants and at the Bureau's plant. Cryogenic purification was used by other producers. The Bureau and all seven private plants that produced Grade-A helium also liquefied helium. They were Air Products and Chemicals Inc., Hansford County, TX; Navajo Refined Helium Co., Shiprock, NM; Kansas Refined Helium Co., Otis, KS; Exxon, Shute Creek, WY; and Union Carbide Corp., Linde Div., in Bushton, Elkhart, and Ulysses, KS.

The volume of helium recovered from natural gas decreased slightly in 1986. One of private industry's larger crude helium plants shut down in April 1985 and resumed operation in October 1986. Exxon initiated production from the Riley Ridge Field in October, which maintained recovery volume. All of the natural gas processed for helium extraction came from gasfields in Kansas, New Mexico, Oklahoma, Texas, and Wyoming.

Exxon began processing Riley Ridge gas at its Shute Creek, WY, plant in September 1986. The initial helium production and sales from the plant were made in October 1986. The facility is composed of two parallel plants, each of which has the capacity to process 240 million cubic feet per day (MMcfd) of Riley Ridge gas, purify 1.5 MMcfd of helium, and liquefy 2,400 liters per hour of liquid helium. Essentially all of the plant's helium is liquefied for delivery in semitrailers to other parts of the country, which saves freight and delivery expenses in many cases. This liquid helium may be used as a liquid or regasified at the delivery point, depending on the purpose for which the helium is needed.

Table 1.—Ownership and location of helium extraction plants in the United States in 1986

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]
Cities Service Cryogenics Inc	Scott City, KS	Crude helium.[2]
Cities Service Helex Inc	Ulysses, KS	Crude helium.
Exxon Co. U.S.A	Shute Creek, WY	Grade-A helium.[1 3]
Kansas Refined Helium Co	Otis, KS	Grade-A helium.[1]
Navajo Refined Helium Co	Shiprock, NM	Do.
Northern Helex Co	Bushton, 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]Output is piped to Ulysses, KS, for purification.
[3]Initial production began October 1986.

Table 2.—Helium recovery in the United States[1]

(Thousand cubic feet)

	1982	1983	1984	1985	1986
Crude helium:					
Bureau of Mines:					
Total storage	-350,235	-275,714	-314,969	-411,681	-379,827
Private industry:					
Stored by Bureau of Mines	113,261	282,018	506,092	487,576	431,917
Withdrawn	-724,113	-729,134	-605,935	-956,462	-980,209
Total private industry storage	-610,852	-447,116	-99,843	-468,886	-548,292
Total crude helium	-961,087	-722,830	-414,812	-880,567	-928,119
Stored private crude helium withdrawn from storage and purified by the Bureau of Mines for redelivery to industry	-51,234	-65,015	-49,057	-5,339	-18,658
Grade-A helium:					
Bureau of Mines sold	305,071	241,733	294,460	397,446	333,447
Private industry sold	939,496	1,120,955	1,342,961	1,485,662	1,607,963
Total sold	1,244,567	1,362,688	1,637,421	1,883,108	1,941,410
Total stored	-1,012,321	-787,845	-463,869	-885,906	-946,777
Grand total recovery	232,246	574,843	1,173,552	997,202	994,633

[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)

	1984	1985	1986
Grade-A supply:			
Inventory at beginning of period[1]	22,400	18,163	3,173
Helium recovered: Exell plant[2]	339,280	387,795	366,716
Total	361,680	405,958	369,889
Grade-A disposal:			
Sales	294,460	397,446	333,447
Redelivered to private producers	49,057	5,339	18,658
Inventory at end of period[1]	18,163	3,173	17,784
Total	361,680	405,958	369,889

[1]At Amarillo and Exell helium plants.
[2]Includes 49,057 Mcf purified for private industry in 1984, 5,339 Mcf in 1985, and 18,658 in 1986.

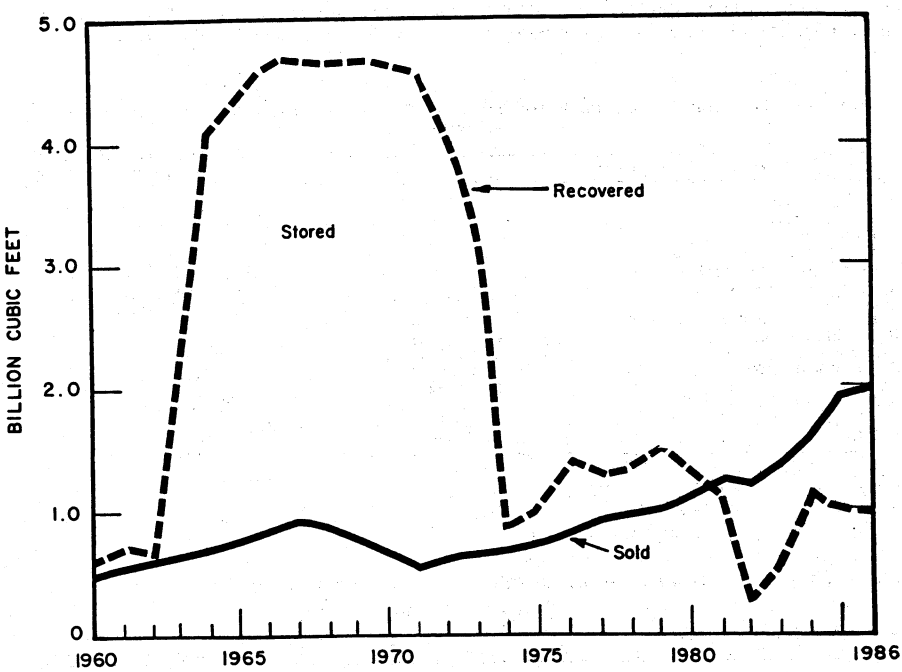

Figure 1.—Helium recovery in the United States, 1960-86.

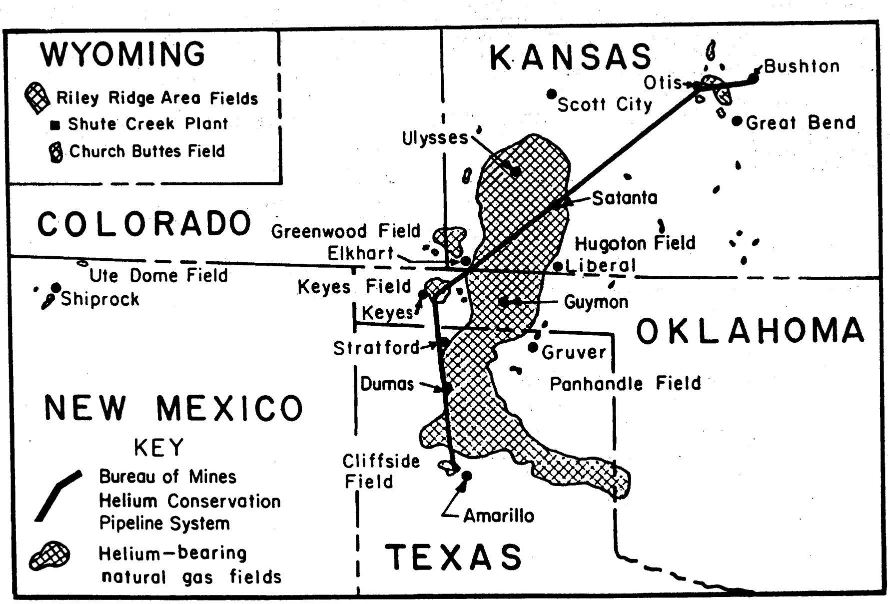

Figure 2.—Major U.S. helium-bearing natural gas fields.

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 sales to Federal agencies and their contractors totaled 333 MMcf in 1986, which is a decrease of about 17% when compared with that of 1985. This decrease was due primarily to slowdowns and to changes being made in the National Aeronautics and Space Administration (NASA) and U.S. Department of Defense (DOD) space programs that require helium.

Federal agencies purchase their major helium requirements from the Bureau of Mines. Direct helium purchases by the U.S. Department of Energy (DOE), DOD, NASA, and the National Weather Service constituted most of the Bureau's Grade-A helium sales. All of the remaining sales to Federal agencies were through private helium distributors, who purchased equivalent volumes of Bureau helium under contracts described in the Code of Federal Regulations (30 CFR 602). These sales increased slightly in 1986, which reduced the impact of decreases in NASA and DOD sales. Some of the private distributors also have General Services Administration helium supply contracts. These contracts make relatively small volumes of helium readily available to Federal installations at reduced freight charges.

Table 4.—Total sales of Grade-A helium in the United States

(Million cubic feet)

Year	Volume
1982	867
1983	995
1984	1,245
1985	1,444
1986	1,509

Table 5.—Bureau of Mines sales of Grade-A helium, by purchaser[1]

(Thousand cubic feet)

	1984	1985	1986
Federal agencies:			
Department of Defense	117,047	120,225	95,444
Department of Energy	34,599	37,731	41,275
National Aeronautics and Space Administration	49,323	103,144	45,684
National Weather Service	752	909	729
Other	4,052	7,604	4,827
Total	205,773	269,613	187,959
Federal agency sales supplied by private contract helium distributors[2]	86,434	124,299	140,071
Commercial sales	2,253	3,534	5,417
Grand total	294,460	397,446	333,447

[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.

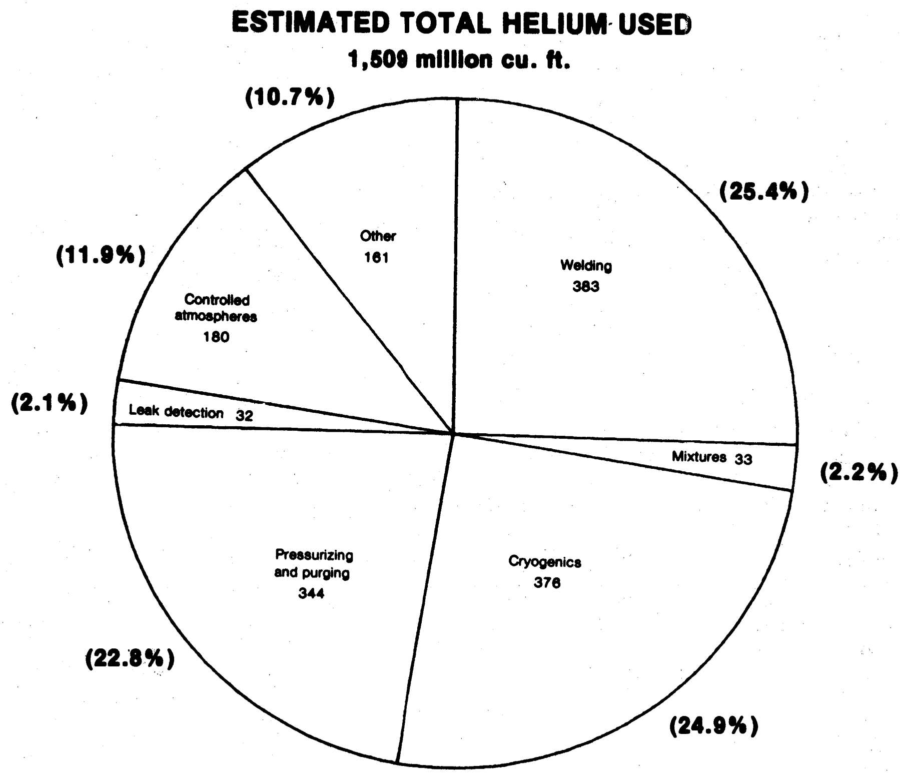

Figure 3.—Estimated helium consumption in the United States in 1986, by end use (million cubic feet).

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 more than 36 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 1986, 432 MMcf of private helium was delivered to the Bureau's helium conservation storage system, and 999 MMcf was withdrawn, for a net decrease of 567 MMcf of private helium in storage.

Table 6.—Summary of Bureau of Mines helium conservation storage system[1] operations

(Thousand cubic feet)

	1984	1985	1986
Helium in conservation storage system at beginning of period:			
Stored under Bureau of Mines conservation program	35,511,661	35,196,692	34,784,996
Stored for private producers under contract	2,963,507	r2,814,605	2,340,395
Total	38,475,168	r38,011,297	37,125,391
Input to system:			
Net deliveries from Bureau of Mines plants[2]	-314,969	-411,681	-379,827
Stored for private producers under contract	506,092	487,576	431,917
Total	191,122	75,895	52,090
Redelivery of helium stored for private producers under contract[2]	-654,992	-961,801	-998,867
Net addition to system[2]	-463,869	-885,906	-946,777
Helium in conservation storage system at end of period:			
Stored under Bureau of Mines conservation program	35,196,692	34,784,996	34,405,169
Stored for private producers under contract	r2,814,605	r2,340,395	1,773,445
Total	r38,011,297	r37,125,391	36,178,614

rRevised.
[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, 1986 (the latest figures available), were estimated to be 539 Bcf. The total identified helium resources were about 35 Bcf more than reported in 1985. The increase is due primarily to an increase in the estimate of probable natural gas resources made by the Potential Gas Committee, which increased the contained helium volumes. The resources included measured reserves and indicated resources estimated at 236 and 29 Bcf, respectively, in natural gas with a minimum helium content of 0.3%. The measured reserves included 37 Bcf stored in the Bureau of Mines helium conservation storage system. Measured helium resources in natural gas with a helium content of less than 0.3% are estimated to be 46 Bcf. Indicated helium resources in natural gas with a helium content of less than 0.3% are estimated to be 228 Bcf. Approximately 88% of the domestic helium resources under Federal ownership are in the Riley Ridge and Church Buttes Field areas 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 95 gasfields in 11 States. About 91% of these reserves is contained in the Hugoton Field in Kansas, Oklahoma, and Texas; the Keyes Field in Oklahoma; the Panhandle and Cliffside Fields in Texas; and the Riley Ridge area in Wyoming. The Bureau of Mines analyzed a total of 349 natural gas samples from 20 States during 1986 in conjunction with a program to survey and identify possible new sources of helium.

TRANSPORTATION

All Grade-A gaseous helium sold by the Bureau 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 a portion 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 private producers' price for Grade-A helium was about $36 per Mcf at yearend. The price of liquid helium averaged $55 per Mcf gaseous equivalent, plus possible surcharges.

FOREIGN TRADE

Exports of Grade-A helium, all by private industry, decreased by 1.5% in 1986 to 432 MMcf (table 7). Over 55% of the exported helium was shipped to Europe. Belgium-Luxembourg, France, and the United Kingdom, collectively, received almost 95% of the European helium imports. About 31% of the U.S. helium exports went to Asia; 4% to South America; 3% to Australia and New Zealand; 2% each to Central America, North America, and the Middle East; and less than 0.5% each to Africa and the Caribbean. The shipments of large volumes of helium to Western Europe were attributed to helium's use in cryogenic research and superconducting equipment. Significant volumes were also being used in breathing mixtures for diving, in welding in the exploration for North Sea oil and gas, and as a lifting gas. Although no helium was imported in 1986, import tariffs on helium decreased 0.1% on January 1, 1986, to 3.9%. One more decrease is currently planned, with the import tariff finally reaching 3.7% on January 1, 1987.

Table 7.—U.S. exports of Grade-A helium

(Million cubic feet)

Year	Volume
1982	378
1983	368
1984	392
1985	439
1986	432

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 and to India, which began producing helium in a small plant this year.

TECHNOLOGY

Until recently, all superconductors required liquid helium to reach superconducting temperatures. Current research on superconductors has resulted in the discovery of superconducting materials that operate above liquid nitrogen temperatures. When and if these materials can be successfully utilized in superconducting equipment, the liquid helium market will be adversely impacted. Most helium suppliers estimate it will be at least 5 years before the new materials affect helium demand.

Meanwhile, technology that utilizes liquid helium to produce superconducting temperatures continues to be developed and operated. Oak Ridge National Laboratory has completed preliminary testing of six 45-ton helium-cooled superconducting electromagnets. These six magnets each incorporate a slightly different design, each of which is being tested to determine the best configuration for the confinement of fusion systems for the production of clean nuclear energy.

Liquid helium continued to be used at Fermi National Accelerator Laboratory for Tevatron/Tevatron 1, 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 presently the highest energy particle accelerator in the world (1.6 trillion electric 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).

Liquid helium's use 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 diagnoses of problems where exploratory surgery has previously been required to determine problems. Another medical application that is being developed uses MRI to determine by blood analysis whether a patient has any form of cancer.

Lifting gas applications are increasing. Various companies in addition to Goodyear, are now using "blimps" for advertising. The Navy and the 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 that 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.

Other technologies that are evolving and that 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, and (5) liquid-helium-cooled microswitches called Josephson junctions, which are much faster than conventional semiconductors and use less power.

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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 A. Lyday[1]

Three producers of crude iodine supplied less than one-half of domestic demand; the remainder was imported. The President was authorized by Public Law 99-661 to dispose of excess quantities of materials that included iodine from the National Defense Stockpile.

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 88% of the total production. Production data are withheld to avoid disclosing company proprietary data.

Legislation and Government Programs.—The U.S. National Defense Stockpile contained 7.2 million pounds of crude iodine valued at $51 million in inventory at yearend. The stockpile goal remained at 5.8 million pounds.

On November 14, 1986, the National Defense Authorization Act of 1987 (Public Law 99-661), authorized disposal of 800,000 pounds of iodine under upgrading contracts with the Office of National Defense Stockpile. The disposal in any 1 month was limited to 200,000 pounds offered in lieu of cash to pay contractors for materials supplied and/or services performed on acquisition or upgrading contracts and was to begin after December 9. In December, 190,120 pounds of stockpile-grade excess iodine was disposed for $1,118,000.

On September 1, the recommended amount of iodine consumed in animal feeds was lowered from 50 to 10 milligrams per head per day, according to a Food and Drug Administration (FDA) Compliance Policy Guideline (7125.18). The decision was based on two National Academy of Sciences-National Research Council studies on the nutrient requirements of beef cattle. The new guideline was expected to reduce consumption of iodine in animal feeds by about 80% the first year. About 25% of reported domestic consumption of iodine was in animal feeds, primarily as the compound ethylenediamine dihydroiodide, or EDDI, but also as potassium iodide, calcium iodate, and calcium periodate. Iodine is 1 of 14 mineral commodities listed by the National Feed Ingredients Association as used for domestic meat production.

The FDA 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 grape-like color used in carbonated soft drinks, powdered drinks, gelatin desserts, icings, and pet foods.

DOMESTIC PRODUCTION

The Dow Chemical Co. discontinued recovery of iodine from mineral-rich brines as a byproduct of bromine and other salts on April 30, 1986. The decision was part of the company's move to consolidate production of brines at other locations and stop all brine recovery at the Midland, MI, plant.

North American Brine Resources operated two miniplants at Dover and Hennessey in Kingfisher County, OK. The plants were situated at oilfield reinjection disposal sites where iodine concentrations ranged up to 1,200 parts per million. Iodine of 98% to 99% 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. (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 brines was from the Morrowan Formation of Pennsylvanian age, where the iodine concentration averaged 300 parts per million. Iodine purity was greater than 99.8%. Plant capacity was reported at 2 million pounds per year.

CONSUMPTION AND USES

Establishing an accurate end-use pattern was inhibited because intermediate iodine compounds were marketed before reaching their ultimate end uses. The downstream uses of iodine were animal feed supplements, catalysts, inks and colorants, pharmaceuticals, photographic equipment, sanitary and industrial disinfectants, stabilizers, and other uses. Other uses included production of motor fuels, smog inhibitors, lubricants, high-purity metals, and iodized salt. Iodine also had application in cloud seeding and radiopaque diagnosis in medicine.

The U.S. International Trade Commission (ITC) publication "Synthetic Organic Chemicals, 1985" reported that Mallinckrodt Inc. and the Sterling Organic Div. of Sterling Drug Inc. were the only domestic producers and/or sellers of roentgenographic contrast media. These media are injected intravenously or intracerebrally into a patient to produce X-ray photographs of the internal structure of the body. Clinical use included cardioangiography, cerebral angiography, various arteriographies, urography, and phlebography. Media listed as being produced were meglumine diatrizoate, sodium diatrizoate, iopanoic acid, meglumine iothalamate, sodium tyropanoate, and another category. These substances contained between 47% and 67% iodine by weight. A nonionic contrast medium containing 46% iodine was licensed by Nyconed S.A., Oslo, Norway, produced by Sterling Drug in Puerto Rico, and marketed in the United States under the trade name Omnipaque Iohexol. The nonionic nature of the medium produced less severe adverse reactions in patients that experienced reactions.

The ITC reported in "Synthetic Organic Chemicals, 1985" that Red No. 3 dye was sold by four companies. The companies reporting production were H. Kohnstamm & Co. Inc., McCormick & Co. Inc., Sterling Drug, and Warner-Jenkinson Co.

Domestic demand for hydriodic acid was estimated to be between 300,000 and 400,000 pounds per year, of which approximately 70% was used in sanitizers and disinfectants. Between 10% and 15% was used in pharmaceuticals.[2]

Several major consumers of iodine were for sale during 1986. Mallinckrodt, a specialized chemicals and medical products company, was the largest domestic consumer of crude iodine and had been acquired by Avon Products Inc. in 1982 for $715 million. During 1986, Mallinckrodt was acquired by International Minerals & Chemical Corp. (IMC), the world's largest private-sector producer of fertilizer materials, for $675 million. At yearend, Mallinckrodt announced a plan to triple, over the next 2 years, its Diagnostic Imaging Services network of domestic nuclear pharmaceuticals used as tracers primarily in university and hospital research.

In addition, Uniroyal Chemical Co., a subsidiary of Uniroyal Inc., was sold to Avery International Corp. for $760 million in cash. The subsidiary manufactured agricultural and industrial chemicals, specialized rubber and plastic products, and other specialty chemicals. Titanium tetraiodide and diethylaluminum iodide were used as a catalyst to produce stereospecific polybutadiene and polyisoprene, major synthetic rubbers.

Shortages of certain iodine chemicals or purchases of specific combinations of chemicals may indicate that illegal drugs are being synthesized. Hydriodic acid and other acids and potassium iodides are used to synthesize amphetamine, methamphetamine, and ethylamphetamine.[3]

The International Trade Administration of the U.S. Department of Commerce published a Market Share Reports Commodity Series on Tall Oil (PB 85-790336). The report showed the dollar values for exports to the world, the United States, and 102 foreign country markets, from 14 principal exporting countries for 1980 to 1983. Iodine is used as a stabilizer in tall oil fractionally distilled from sulfate-process pulping of softwoods. Nonreactive polyamide resins are used in flexographic inks and reactive polyamides have principal applications as epoxy curing agents used in protective coatings and adhesives. Domestic capacity was reported at 840,000 tons per year.[4]

Table 1.—U.S. consumption of crude iodine, by product

Product	1985 Number of plants	1985 Consumption (thousand pounds)	1986 Number of plants	1986 Consumption (thousand pounds)
Reported consumption:				
Resublimed iodine	6	191	6	154
Potassium iodide	8	1,077	7	1,046
Sodium iodide	5	145	7	136
Other inorganic compounds	28	1,248	17	1,245
Ethylenediamine dihydroiodide	5	1,199	4	1,016
Other organic compounds	16	1,312	15	1,538
Total	[1]27	5,172	[1]24	[2]5,136
Apparent consumption	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 $5.68 per pound. Declared c.i.f. values of iodine imported from Japan averaged $5.82 per pound. Declared c.i.f. values for iodine imported from Chile averaged $5.51 per pound. Stockpile-grade excess iodine disposals from the National Defense Stockpile in December were valued at $5.88 per pound. Reported prices for calcium iodide and crude iodine decreased compared with those of 1985.

Table 2.—Yearend 1986 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	$10.72- 11.63
Iodine, crude, drums	6.12- 8.16
Iodoform, N.F., 300-pound drums, f.o.b. works	24.00
Potassium iodide, U.S.P., granular, crystals, drums, 1,000-pound lots, delivered	10.72- 12.39
Resublimed iodine, U.S.P., granular, 100-pound drums, works	14.21- 14.59
Sodium iodide, U.S.P., crystals, 300- to 500-pound lots, drums, freight equalized	14.72

[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. 230, No. 26, Dec. 29, 1986, pp. 25-31.

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 per pound for iodine, and crude iodine categorized as resublimed, was 6 cents. Effective on January 1, 1988, 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	1985		1986	
	Quantity	Value[1]	Quantity	Value[1]
Iodine, crude:				
Belgium	21	174	--	--
Canada	1	3	--	--
Chile	1,651	8,105	1,383	7,622
Japan	3,299	18,479	1,645	9,576
Total[2]	4,971	26,761	3,028	17,199
Iodine, potassium:				
Belgium	3	17	(3)	3
Brazil	--	--	2	10
Canada	1	3	6	37
Germany, Federal Republic of	6	30	(3)	3
India	12	64	50	279
Italy	2	3	4	5
Japan	41	226	17	111
Switzerland	--	--	(3)	1
United Kingdom	2	54	2	42
Total[2]	67	396	82	492
Iodine, resublimed:				
Germany, Federal Republic of	(3)	4	(3)	8
Japan	408	2,158	2,654	15,530
Mexico	1	13	--	--
Sweden	2	17	2	24
Total[2]	410	2,193	2,656	15,562
Grand total	5,448	29,350	5,766	33,253

[1]Declared c.i.f. valuation.
[2]Data may not add to totals shown because of independent rounding.
[3]Less than 1/2 unit.

Source: Bureau of the Census.

WORLD REVIEW

Chile.—María Elena and Pedro de Valdivia were the only surviving nitrate mines of an industry that began producing in Chile between 1810 and 1812. The mines were owned by the Sociedad Química y Minera de Chile. (SOQUIMICH), which was founded in 1968 to mine and market the nitrate reserves. The Government development agency Corporacíon de Fomento de la Producción (CORFO) initially had a 37.5% share, with the remainder owned by Anglo Lautara Nitrate Co. During 1986, CORFO owned 92.8% of the company. Iodine sales accounted for about 25% of total sales of $149 million during 1985. Approximately 70% of sales was derived from exports.[5] Final products included sodium nitrate, potassium nitrate, sodium sulfate, and iodine. Iodine of 99.7% purity was shipped in 50-kilogram cardboard drums with a double polyethylene inner lining.

To produce iodine, sodium iodate was leached from the ore and treated with sodium bisulfite solution to reduce iodate to iodide. Iodine was filtered, washed, and dried, and may be further purified by sublimation. Potential iodine reserves had been estimated at 300 million pounds of economically recoverable iodine in ore surrounding existing mining operations, and another 440 million pounds in overburden and waste dumps close to plants. About 4,400 employees worked for SOQUIMICH in 1985.

China.—The Wengfu Mine produced phosphate with 20% carbonates, 10% silicates, and 0.004% iodine. Because of its high magnesium content, the ore was not suitable for phosphoric acid manufacture. Calcination at 1,050° C yielded an iodine-rich gas for further processing. Iodine was recovered during process design testing.[6]

Japan.—Japan produced wet, propane-butane-rich and dry, methane-rich natural gas, but all of the iodine produced in Japan occurred in the dry type of gasfields. Production was from subterranean brines from various strata buried with natural gas between 1.7 and 24 million years ago. The natural gas reservoirs were found within the sedimentary basin of the marine Kazusa Group of late Pliocene to middle Pleistocene in sediments deposited in water 600 feet or more in depth. The group is distributed over an area of about 12,000 square kilometers.[7]

Japan led the world in production of iodine in 1986. The major iodine-producing area was the southern Kanto Gasfield, which extends over Chiba, Tokyo, and Kanagawa Prefectures. Iodine was produced in the Niigata and Nakajo Gasfields in Niigata Prefecture, on the Sea of Japan side of central Japan, and the Sadowara Gasfield in Miyazaki Prefecture, southern Kyushu. Iodine also is present in gasfields in southern Okinawa, the Oshamanbe, Hokkaido, and the Ishikawa, Honshu. Iodine concentration of 97 parts per million was confirmed in a methane well on Okinawa. Iodine production was from brines that average 60 parts per million of iodine.[8]

U.S.S.R.—A nuclear accident on April 26 at the graphite-moderated Chernobyl powerplant, 60 miles north of Kiev, released radioactive iodine (I^{131}) into the atmosphere. Potassium iodide (KI) ingestion can reduce the radiation dose to specific organs. To block up to 90% of the utilization of radioactive I^{131} by the human thyroid gland, KI in tablet or liquid form can be administered before exposure. KI administered 4 hours after exposure can block 50% of the uptake of I^{131}. A dosage of 130 milligrams of KI before exposure is recommended. Between 1 and 2 million pounds of iodine was shipped to the U.S.S.R. to minimize radiation effects on the exposed population.

Table 4.—Crude iodine: World production, by country[1]

(Thousand pounds)

Country	1982	1983	1984	1985[p]	1986[e]
Chile	5,723	6,158	5,866	[r] [e]6,600	6,600
China[e]	1,000	1,000	1,000	1,000	1,000
Indonesia	64	55	55	29	33
Japan	15,829	16,034	16,098	15,986	16,300
U.S.S.R.[e]	4,400	4,400	4,400	4,400	4,400
United States	W	W	W	W	W
Total[2]	27,016	27,647	27,419	28,015	28,333

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."
[1]Table includes data available through June 16, 1987.
[2]Excludes U.S. production.

TECHNOLOGY

The U.S.S.R. and the United States continued research on the first organic polymers that spontaneously become magnetic at ambient temperatures, a phenomenon known as ferromagnetism. Ferromagnetic behavior was observed in a polymeric material produced by the reaction on 1,3,5-triaminobenzene with iodine. The material remained ferromagnetic until its decomposition at temperatures near 400° C. Organic ferromagnets have potential for replacing metals or metallic compounds in existing applications of their magnetic properties, such as replacing chromium dioxide as a magnetic coating on recording tape. Replacement of chromium dioxide was desirable because the United States has no chrome production and must rely on imports primarily from the Republic of South Africa.[9]

[1]Physical scientist, Division of Industrial Minerals.
[2]Chemical Marketing Reporter. Drugs & Fine Chemicals. V. 229, No. 17, 1986, p. 16.
[3]Chemical & Engineering News. Chemicals Give Clues That Illegal Drugs Are Being Made. V. 64, No. 38, 1986, p. 25.
[4]Mannsville Chemical Products. Chemical Products Synopsis. Tall Oil, May 1985, 2 pp.
[5]Fertilizer International. Corporate. No. 237, 1986, p. 16.
[6]World Mining Equipment. Phosphates: A Review of Processing Techniques. V. 10, No. 4, 1986, pp. 40-44.
[7]Fukuta, O. Japanese Iodine—Geology and Geochemistry. Paper in Salts & Brines '85. Soc. Min. Eng. AIME, 1985, pp. 149-171.
[8]———. Written communication, Aug. 14, 1986; available on request from P. A. Lyday, Washington, DC 20241.
[9]Chemical & Engineering News. First Ferromagnetic Organic Polymers Prepared. V. 65, No. 13, 1987, p. 5.

Iron Ore

By Peter H. Kuck[1]

The iron ore industry of the United States and Canada underwent a major restructuring in 1986 that included the trading and selling of extensive corporate assets. Consumption of ore and agglomerates at U.S. iron and steel plants dropped to 55 million tons[2] and was only slightly higher than that of 1982, making 1986 the second worst year for U.S. ore producers since 1939. The decline in U.S. raw steel production, increased use of scrap instead of ore by the domestic steel industry, a high level of steel imports, weakening prices for domestic pellets, and a worldwide oversupply of ore all contributed to the rapidly deteriorating U.S. situation. Continuing problems in the steel industry finally forced LTV Corp., the parent company of the Nation's second largest steel company, to file for bankruptcy in July. The LTV filing and the company's equity trading just prior to the filing triggered a series of events that will shape both industries for years to come.

The second half of 1986 was marked by the indefinite closure and bankruptcy of the Reserve Mining Co. and the acquisition of Pickands Mather & Co. by its long-time competitor, The Cleveland-Cliffs Iron Co. The future of at least three other mines was uncertain. A work stoppage halted operations at the steel and domestic mining division of USX Corp. on August 1, idling the Minntac Mine, the Saxonburg sinter plant, and all of the company's ironworks and steelworks for the rest of the year. Production of usable ore in 1986 was only about 46% of productive capacity as a result of the USX work stoppage, the closure of Reserve, and the succession of layoffs and temporary shutdowns. Yearend stocks of

Table 1.—Salient iron ore statistics

(Thousand long tons and thousand dollars unless otherwise specified)

	1982	1983	1984	1985	1986
United States:					
Iron ore (usable,[1] less than 5% manganese):					
Production	35,433	37,562	51,269	48,751	38,825
Shipments	35,756	44,596	50,883	49,411	41,327
Value	$1,491,809	$1,944,988	$2,247,686	$2,076,730	$1,472,511
Average value at mines dollars per ton	$41.72	$43.61	$44.17	$42.03	$35.63
Exports	3,178	3,781	4,993	5,033	4,482
Value	$150,522	$182,744	$239,257	$240,557	$204,738
Imports for consumption	14,501	13,246	17,187	15,771	16,743
Value	$470,847	$445,731	$529,065	[r]$452,267	$460,643
Consumption (iron ore and agglomerates)	63,916	70,629	72,514	70,575	61,116
Stocks, Dec. 31:					
At mines[2]	12,129	[3]4,122	[3]5,265	[3]5,951	[3]3,255
At consuming plants	29,923	25,494	24,017	21,290	17,163
At U.S. docks	5,750	3,174	2,942	2,404	1,987
Manganiferous iron ore (5% to 35% manganese): Shipments	28	30	79	18	13
World: Production	[r]768,566	[r]728,510	821,926	[p]839,865	[e]847,775

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Direct-shipping ore, concentrates, agglomerates, and byproduct ore.
[2]Excludes byproduct ore.
[3]These stocks are not comparable to those of previous years owing to the reclassification of some stocks from the usable to the byproduct category.

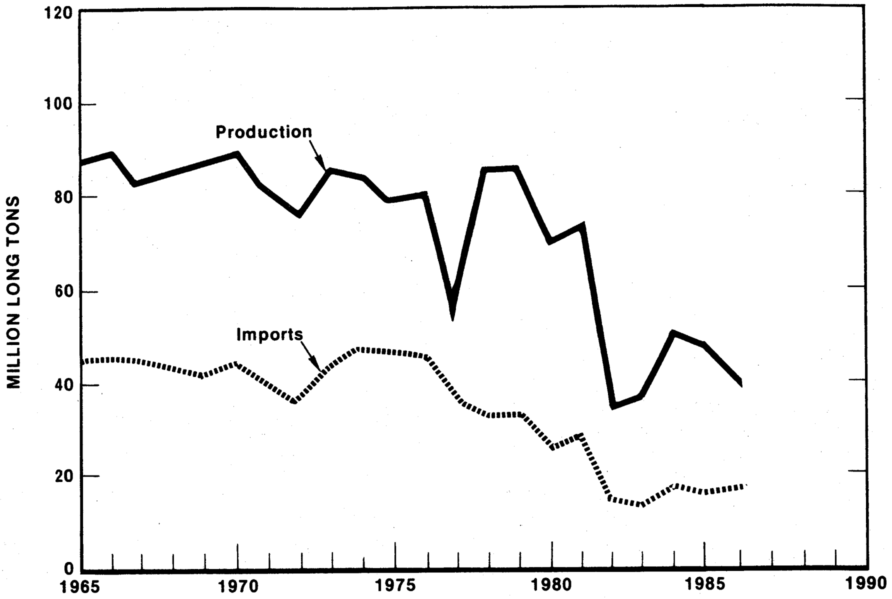

Figure 1.—U.S. iron ore production and imports for consumption.

iron ore at U.S. docks and furnace yards were at their lowest levels in more than 30 years.

In the rest of the world, the oversupply of iron ore and agglomerates worsened in 1986. Increased imports on the part of China, Taiwan, and some other emerging countries failed to offset consumption cutbacks by established integrated steelmakers in Japan, the United States, and Western Europe. The appreciation of the Japanese yen against the U.S. dollar put the Japanese steel industry in a particularly difficult situation. Capacity cutbacks and mine closings in Canada, France, Spain, and Scandinavia were more than offset by the startup or expansion of operations in Brazil, Australia, and India. The new Carajás Mine alone reached a production level of 25 million tons per year, equivalent to 64% of total U.S. production for 1986. The oversupply situation led to the financial restructuring of several major producers including Minerações Brasileiras Reunidas S.A. (MBR), Iron Ore Co. of Canada (IOC), Cleveland Cliffs Inc. (CCI), Robe River Iron Associates (RRIA), and Mount Newman Mining Co. Pty. Ltd. A number of medium-sized operations in Africa and the Americas had serious financial problems. A few, such as the Marampa Iron Ore Co. Ltd. of Sierra Leone and the National Iron Ore Co. Ltd. of Liberia, were even forced to suspend operations and faced bankruptcy. Several established producers in Australia, India, and the U.S.S.R. began encountering declines in ore grade, a situation reminiscent of that experienced by the United States in the Lake Superior region during the 1960's.

On the positive side, the marketing and financial difficulties have forced many producers to upgrade their mine equipment and port facilities, streamline management, and jettison unproductive and obsolete work rules. The construction of new super ore carriers and the adoption of topping practices are expected to keep ocean freight rates at their present low levels for the rest of the decade.

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 43 addressees to whom the 1066-A form was sent, 34 responded, representing 79.9% of total production shown in tables 1 through

4. Production for nonrespondents to the annual survey was estimated from monthly surveys (1066-M), using data from railroad reports and reported production levels in prior years, 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.

Legislation and Government Programs.—On November 17, the President signed the Water Resources Development Act of 1986 (Public Law 99-662). This law establishes a Federal Port Use Tax and requires local port authorities to partially fund future harbor construction projects. In the past, the Federal Government has funded most harbor construction. Effective April 1, 1987, shippers must pay the U.S. Customs Service an ad valorem tax of 0.04% on iron ore and nearly every other commodity moving through coastal and Great Lakes ports. The revenue raised from the Federal tax will be used to pay part of the costs of channel dredging, harbor maintenance, and related operations at deep-draft and general cargo ports. The new law also permits local port authorities to collect harbor dues upon completion of a project to help defray their share of the construction expenses.

In 1986, the U.S. and Canadian Great Lakes fleets loaded a total of 38.05 million tons of iron ore at U.S. ports, a tonnage equivalent to 92% of all shipments from domestic mines. Great Lakes shipping costs and dock handling charges accounted for about 9% to 16% of the total cost of Lake Superior pellets delivered to steelworks in the Chicago, Cleveland, Detroit, and Pittsburgh areas. Any Government action that U.S. steelworks. (See "Transportation.")

EMPLOYMENT

Statistics on employment and productivity in the U.S. iron ore industry in 1986, 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 680 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. 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.

Average quarterly employment was 26% lower than that of 1985, with total hours worked and output of usable ore declining by 18% and 20%, respectively. In the Lake Superior district, which accounts for the bulk of U.S. output, average productivity for usable ore was 4% lower than that of 1985, but 54% higher than that of 1981. The significant gain since 1981 is primarily the result of drastic reductions in employment made by the principal producers in 1982, who were being battered both by plummeting demand for domestic steel and a high level of steel imports. The 1982 contraction process appears to have resumed again in 1986 on a less intense scale, allowing the potential productivity of highly mechanized operations to be increasingly realized. As a result of this process, U.S. production was concentrated in just eight large-scale taconite operations in the Lake Superior district. Several of the eight operations had considerable excess production capacity, suggesting that one or two were still in a precarious situation and could be forced to close if U.S. steel production fails to recover.

The contraction of the iron mining and steel industries has also led to a "graying" of the 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. Although older workers may often be more productive and reliable than younger ones, this shift in age is certain to create problems for iron ore producers by the turn of the century.

DOMESTIC PRODUCTION

The USX work stoppage and a weakening of demand from the iron and steel industry at midyear were largely responsible for the 20% decline in iron ore production from the 1985 level of 48.75 million tons. An 11% decrease in demand from Canada added to producers' problems. Output of usable ore in the first half of the year was 14% lower than that in the comparable period of 1985, shipments were down 7%, and production of pig iron decreased slightly. In July, demand began to drop further and, during the last 5 months of the year, monthly production of pig iron was significantly below 1985 levels. Five of the seven taconite operations in Minnesota were shut down for 6 or more weeks during the second half of the year. One of the five—Reserve—never reopened. The patterns of production, shipments, and plant closings were similar to those experienced in 1984 and 1985 and reflected a continuing weakness in demand for domestic iron and steel. Total output of usable ore was equivalent to about 46% of installed production capacity on January 1.

Iron ore was produced by 18 open pit mines and 1 underground mine. Twelve mines produced ore for the iron and steel industry, but only 2 mines were operated throughout the year. Neither of the two produced at rated capacity. One taconite mine and an associated pelletizing plant were shut down indefinitely in July and another was being liquidated. One large, permanently closed "natural ore" mine made a final shipment of concentrates to cement plants, exhausting its stocks. Installed production capacity for usable ore at yearend was estimated at 85 million tons per year, including 79 million tons of capacity for pellets. Effective production capacity for pellets was at least 14 million tons less than installed capacity.

An average of 3.1 tons of crude ore was mined in 1986 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 99.9% of total crude ore production. U.S. production of pellets totaled 37.20 million tons, 95.8% of usable ore output. Average iron content of usable ore produced was 64.1%, while that of usable ore shipped was 64.0%.

The iron ore industry of the United States and Canada underwent a major restructuring in 1986 aimed at lowering pellet costs and improving the financial health of several companies.

No significant reorganizing occurred until March when Pickands Mather assumed management of Reserve's operations, which included the Peter Mitchell Mine near Babbitt, MN, and the E. W. Davis pelletizing plant at Silver Bay on the north shore of Lake Superior. The Reserve organization lost 105 administrative and clerical positions as a result of the management change.

Then in May, Bethlehem Steel Corp. became the largest shareholder in IOC after exchanging equity interests with LTV Steel Co. Inc. The exchange raised Bethlehem Steel's interest in IOC from 20.26% to 32.84%. M. A. Hanna Co., National Steel Corp., and four other companies retained their previous interests in IOC, but modified their existing pellet contracts by extending terms and amending volume and price provisions. IOC is the largest iron ore producer in Canada and owns mining and pelletizing facilities in Newfoundland and Quebec, a 360-mile railway in the two Provinces, and a shiploading terminal at Sept-Iles, Quebec. A significant portion of IOC's production is consumed by its U.S. steel company partners.

Bethlehem Steel and Stelco Inc. split LTV Steel's 16% interest in the Hibbing Taconite Co. of St. Louis County, MN, raising Bethlehem Steel's share in that company to 70.3%. Stelco's share rose to 14.7%, while Pickands Mather retained its original 15%. At the time of the trade, the Hibbing Taconite operation had an annual capacity of 8.1 million tons of pellets and employed 550 people. In exchange, LTV Steel became full owner of the Erie Mining Co., which has mining and pelletizing operations 40 miles away at Hoyt Lakes. Erie had been a joint venture between Bethlehem Steel, 45%; LTV Steel, 35%; Stelco, 10%; and Interlake Inc., 10%.

On July 17, LTV, the parent company of LTV Steel, filed a set of petitions for reorganization under chapter 11 of the Federal Bankruptcy Code. The bankruptcy filing, which took place in the United States Bankruptcy Court for the Southern District of New York, triggered an avalanche of problems throughout the iron mining and steel industries. LTV Steel is the second largest domestic steel producer, and LTV was the largest industrial corporation ever to file for bankruptcy. Continuing weak demand for steel, especially for oil-country tubular goods, led to increased financial losses and an insufficient cash flow to meet corporate needs. Since the filing, the corporation has tried to reduce costs by gaining additional labor concessions, by eliminating or renegotiating high-cost, long-term supply contracts, and by eliminating certain pension liabilities.

The bankruptcy proceeding forced Reserve, a joint venture between LTV Steel and Armco Inc., to cancel plans to restart its operations after a 5-week vacation-and-maintenance shutdown. Because of the way the Reserve ownership was structured, the company and its employees became creditors of LTV Steel. On July 21, Reserve suspended production at both the Peter Mitchell Mine and the E. W. Davis pelletizing plant. Prior to the maintenance shutdown, Reserve employed 640 hourly workers and 110 salaried workers.

On July 24, LTV Steel announced that it would triple the annual production rate of its now wholly owned Erie operation to 6 million tons in order to compensate for the closure of Reserve. That same day, Pickands Mather, the managing company for both Erie and Reserve, was put up for sale by its parent company, Moore McCormack Resources Inc. of Stamford, CT. At the time, Pickands Mather had equity interests in Hibbing Taconite, 15%; the Savage River Mines of Tasmania, Australia, 36%; and the Wabush Mines of Newfoundland and Quebec, Canada, 5.2%. The Moore McCormack subsidiary was also managing the idle Griffith Mine in Ontario, Canada, as well as five active metallurgical and steam coal mines in Kentucky and West Virginia.

Moore McCormack said that it had decided to divest all of its iron ore, coal, silicon metal, and shipping businesses. However, the firm did retain its operations in cement and concrete products as well as oil and gas. The businesses for sale included Cleveland-based Pickands Mather, Interlake Steamship Co. (a Great Lakes shipping company also based in Cleveland), Moore McCormack Bulk Transport Inc. (an ocean transport firm operating out of Stamford, CT), and Globe Metallurgical Inc. (a producer of silicon metal and ferroalloys headquartered in Beverly, OH). Roughly one-half of Interlake's shipping volume has been iron ore, coal, and limestone destined for LTV Steel's blast furnaces in Indiana, Ohio, and western Pennsylvania. Moore McCormack officials said the shrinking capacity of the steel industry has permanently reduced the profitability of its steel-related assets, and LTV's bankruptcy filing accelerated the firm's decision to sell these assets.

That same week, Armco decided that it could not carry the entire cost of operating Reserve by itself and tried unsuccessfully to attract a new partner. On August 7, First Taconite Co., a wholly owned subsidiary of Armco, filed a petition in the same bankruptcy court to reorganize Reserve under chapter 11.

CCI announced on November 18 that it had agreed in principle to acquire Pickands Mather in exchange for all of CCI's oil and gas reserves, which amounted to 2.0 million equivalent barrels with a market value of $12.4 million. The acquisition was completed on December 30. A new subsidiary, Cliffs Mining Co., was established to manage both Cleveland-Cliffs Iron and Pickands Mather. As a result of the acquisition, 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; Hibbing Taconite (15%); Wabush (5.2%); and Savage River (36%). Pickands Mather also continued to manage Erie for LTV Steel.

At the beginning of 1986, CCI sold its 15.9% equity in RRIA along with other iron ore interests in Western Australia to Peko-Wallsend Ltd. for $54 million. The Robe River transaction produced a $27.8 million increase in equity for CCI shareholders. This consolidation put CCI in control of over 40% of North American production capacity.

In the midst of all of this restructuring, contract negotiations broke down between USX and the United Steelworkers of America (USWA), triggering the first nationwide work stoppage against that company in 27 years. The work stoppage on August 1 affected 22,100 workers at 16 locations in 9 States, including 1,280 at the Minntac taconite operations in Mountain Iron, MN. The new contract would have covered an additional 22,900 workers already on furlough. The labor dispute idled all four of the active iron ore freighters belonging to Duluth-based USS Great Lakes Fleet Inc. A week earlier, USX had begun shutting down furnaces, coke batteries, and other selected production facilities at its steel mills in anticipation of the stoppage.

USX negotiators rejected a union offer to extend the old 40-month contract, which expired on July 31. The Nation's largest steelmaker had been seeking significant wage, benefit, and work rule concessions from the union in order to remain competitive. One industry analyst estimated that USS, the steel division of USX, was losing about $43 million per month because of the stoppage. The deadlock came at a time when the entire steel industry was plagued by excess capacity, competition from imported steel products, and depressed prices.

Contract negotiations were resumed on October 21, but made little headway. USX reportedly had been under pressure from a New York investor to restructure its oil and steel operations. The investor held an 11.4% interest in the company during this period. The work stoppage continued throughout the remainder of the year. However, labor and management were able to resolve several of their differences in the last weeks of December and were close to a settlement.

Minnesota produced 70% of the national output of usable ore in 1986. Production of pellets totaled 36.44 million tons, equivalent to about 61% of installed production capacity of the State's seven taconite plants. The remainder of the output consisted of hematite concentrates produced from natural ores by LTV Steel and Rhude & Fryberger Inc. Pittsburgh Pacific Co. shipped 113,000 tons of concentrates recovered from stockpiled natural ores. All seven taconite plants were operated in 1986, but each was idle for part of the year. An eighth, the Butler Taconite facility near Nashwauk, was being dismantled by Investment Recovery Systems Inc. Hanna, Butler's former operator, shipped 125,000 tons of pellets from the defunct operation's stockpiles at the port of Superior.

National Steel Pellet Co. (NSPC) was operated from January 1 to June 7 and from August 3 to December 6, producing 4.02 million tons of pellets. On November 13, NSPC announced that it may be forced to permanently close its mine and 4.0-million-ton-per-year plant at Keewatin when the company's power contract with Minnesota Power and Development Co. expires in December 1988. The mining company was warned earlier by its parent company, National Steel Corp., that it must cut costs by more than 20% to remain viable. Power reportedly accounts for 27% of NSPC's production costs.

Reserve, a joint venture of Armco and LTV Steel, operated from January 1 until June 21, when it halted production for 5 weeks of vacation and maintenance. During the 171-day period of operation, the joint venture produced 1.56 million tons of pellets with a wet analysis of 63.65% iron (Fe), 0.015% phosphorus (P), and 4.88% silica (SiO_2). The company canceled plans to restart after LTV filed for bankruptcy on July 17. Four days later, Reserve suspended all operations indefinitely.

The LTV filing had the opposite effect on operations of Erie. Erie had already resumed production of pellets at Hoyt Lakes on April 7, recalling the first of 1,100 workers and starting up 16 of its 24 pellet furnaces. The complex, idle since November 30, 1985, was the last of the seven taconite mines to reopen in 1986. Pickands Mather continued to manage Erie after the May 8 trade between Bethlehem Steel and LTV. On May 18, Pickands Mather laid off 95 workers and shut down 4 of the 16 active furnaces. The cutback was followed by a summer shutdown that lasted from June 15 to July 19. The mine's schedule for the second half of 1986 was suddenly revised when LTV filed for bankruptcy. Pickands Mather was instructed to resume operations on July 20 and triple the facility's production rate. By yearend, Erie had produced 4.50 million tons of pellets and shipped 5.46 million tons through the port of Taconite Harbor.

Hibbing Taconite operated from January 12 to November 8 and produced 4.88 million tons of pellets, about 4% less than that of 1985. The company was unaffected by the labor problems elsewhere on the Mesabi Range because it had signed a 3-year contract with the USWA in October 1985 that froze wages and eliminated cost-of-living increases for 2-1/2 years. In exchange for the wage concessions, management agreed not to hire outside workers to do routine maintenance and repair jobs.

The Minntac facility of USX was idle for a total of 178 days, producing only 5.62 million tons of pellets or 30% of installed capacity. Operations were resumed on January 12 after a 41-day winter shutdown. At that time, management set a production goal of 10.9 million tons for 1986. Although the pelletizing plant at Mountain Iron is designed to produce 18.5 million tons per year, its effective capacity is more like 12.5 million tons. The goal was never met because of the work stoppage. Minntac was shut down for an additional 14 days from June 15 to July 13 because of unanticipated production cutbacks at the company's steel mills. Then on August 1, all operations were halted indefinitely when the USS Div.'s nationwide contract with the USWA expired. The two sides were unable to reach an agreement on either wages or the use of nonunion contractors, shutting down the entire division, including Minntac, for the rest of the year. More than 1,300 Minntac employees were among the 22,000 steelworkers idled by the labor dispute.

Eveleth Mines halted operations on November 15 after meeting its production goal of 3.45 million tons of pellets. Eveleth has a design capacity of 6.0 million tons per year; however, the No. 1 grate-kiln system at the Fairlane plant has 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 temporarily in a difficult position by the LTV bankruptcy filing. LTV did not purchase any pellets from Oglebay in 1986 and chose instead to raise the output of its now wholly owned Erie Mine.

Since 1984, Eveleth has been producing trial quantities of pellets using an organic binder called "Peridur" in place of the conventional bentonite. About 40% of the 1986 production used Peridur together with 1% limestone as a binding agent. Blast furnace tests of the improved Peridur-plus-limestone (PL) pellet have been so successful that all of Eveleth's 1987 production was scheduled to be made with the new binding agent. (See "Technology.")

Inland Steel Mining Co. resumed production at its Minorca Mine in March, after a 4-month shutdown. However, only 290 of the 405 workers employed at the time of the shutdown were recalled because of a decision to downsize the operation from 2.6 million tons per year to 2.0 million per year. The mine and plant operated from March 16 to June 28 and from July 13 to December 20, producing 1.85 million tons of pellets. Mining was suspended in November 1985 after Inland Steel's parent company began eliminating unneeded hot metal capacity at its Indiana Harbor Works in East Chicago, IN. Since then, Inland Steel has budgeted $14.5 million to improve the pelletizing facilities at both Minorca and the Empire joint mining venture near Palmer, MI. The improvements will enable Inland Steel to convert its production to fluxed pellets by the fourth quarter of 1987. In the fluxed pellet process, limestone is ground and added to the iron ore concentrate prior to pelletizing rather than at the blast furnace stage. The limestone will come from the quarrying operation of the Inland Lime & Stone Co. in Gulliver, MI. The fluxed pellets will be used in the No. 7 blast furnace at Indiana Harbor and are expected to improve hot metal quality, increase furnace productivity, reduce fuel use, and prolong the life of the furnace lining.

In late summer, workers began dismantling the last ore concentrating plant on the Cuyuna Range. The plant, at the Virginia Mine site near Ironton in Crow Wing County, was owned by Pittsburgh Pacific of Hibbing Taconite. Pittsburgh Pacific bought the plant from Zontelli Bros. Inc. in 1958 and used it to process ores from the nearby Algoma-Zeno Mine up until 1981. Between 1911 and 1984, mines on the Cuyuna Range shipped a total of 106.4 million tons of manganese-bearing iron ore, of which 62.4 million tons was direct-shipping ore and 44.0 million tons was gravity concentrate or sinter. Production of usable ore containing less than 5% manganese totaled 70.3 million tons for the 73-year period.

Michigan produced 27% of the national output of usable ore in 1986. Production consisted entirely of pellets produced from ores mined at the Empire and Tilden Mines in Marquette County. Both mining ventures are managed and partially owned by Cleveland-Cliffs Iron. The company's wholly owned Republic Mine remained idle throughout the year. Production of pellets totaled 10.6 million tons, of which 7.1 million tons was produced at the Empire plant and 3.5 million tons was produced at Tilden. The Empire facility was operated throughout the year and produced at 89% capacity. In contrast, the effective utilization of Tilden for the year was only 44%.

In mid-May, Cleveland-Cliffs Iron was forced to cut back operations at the Tilden Mine and temporarily lay off 145 of the 900 employees. On August 10, the mine and 8.0-million-ton-per-year pelletizing plant were shut down for 15 weeks because of anticipated cutbacks in consumption by some of the steel producing partners. The mining complex is owned jointly by Cleveland-Cliffs Iron, 39% equity; The Algoma Steel Corp. Ltd., 30%; LTV Steel, 12%; Stelco, 10%; Sharon Steel Corp., 5%; and Wheeling-Pittsburgh Steel Corp., 4%. Cleveland-Cliffs Iron has been absorbing the carrying cost of LTV Steel's interest since July when LTV Steel filed for bankruptcy protection. Approximately 700 hourly and salaried workers were recalled when Tilden resumed production on November 23. Only one of the two pelletizing lines was being operated in December.

In Missouri, Pea Ridge Iron Ore Co. produced about 803,000 tons of iron ore products, including 727,000 tons of olivine-enriched pellets, from magnetite ore produced at its underground mine near Sullivan. The mine and plant, wholly owned by St. Joe Minerals Corp., were operated throughout 1986. 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. 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 the year. Lone Star had been a major customer of Pea Ridge together with National Steel. Pea Ridge continued to ship pellets on the Union-Pacific Railroad 100 miles to National Steel's Granite City steelworks, across the Mississippi from St. Louis. Pea Ridge also produces heavy-medium magnetite for coal cleaning, ceramic-grade iron oxide for use in ceramic magnets, and hematite for use in well-drilling fluids.

CONSUMPTION AND USES

Consumption of iron ore was about 13% less than that of 1985, owing to decreased demand from the iron and steel industry. Consumption for ironmaking and steelmaking totaled about 55.5 million tons, including 47.8 million tons in blast furnaces, 7.3 million tons in sintering plants, 0.2 million tons for production of direct-reduced iron (DRI), and 0.1 million tons in steelmaking furnaces. An additional 0.1 million tons was used by the industry for miscellaneous and unspecified purposes. Consumption of iron ore for manufacture of ballast, cement, heavy-medium materials, pigments, and miscellaneous products was approximately 1.1 million tons.

In the iron and steel industry, monthly consumption of ore averaged 4.61 million tons, compared with 5.30 million tons in 1985. The decrease in consumption occurred mainly in the second half of the year. Between January 1 and May 30, pig iron production held steady with the number of operating blast furnaces ranging from 47 to 50. Monthly consumption during the 6 months averaged 5.27 million tons and reached a peak of 5.52 million tons in March. In June, however, demand for ore began to slide.

By September, monthly consumption had fallen to 3.75 million tons and remained low for the rest of the year. Consumption of ore for the second half averaged 3.94 million tons, with only 31 blast furnaces operating at the end of September. The work stoppage at USX was responsible for a large part of the 19% drop between June and September. During the last quarter of 1986, an additional blast furnace was brought on-line by one of USX's competitors, bringing the total at yearend up to 32.

Consumption of iron ore and agglomerates reported by integrated producers of iron and steel totaled 59.79 million tons, including 44.78 million tons of pellets, 14.14 million tons of sinter, and 0.87 million tons of natural coarse ore. Of the primary ore consumed, an estimated 73% was of domestic origin, 15% came from Canada, and 12% came from other countries.

Estimated consumption of other materials in sintering plants included 1.98 million tons of mill scale, 0.60 million tons of flue dust, 3.22 million tons of limestone and dolomite, 1.17 million tons of slag and slag scrap, and 0.67 million tons of coke breeze. Other iron-bearing materials charged directly to blast furnaces included about 49,000 tons of manganiferous iron ore, 1.04 million tons of steel furnace slag, 0.25 million tons of mill scale, and 0.81 million tons of slag scrap.

In November, Koch Carbon Inc. agreed to acquire the C. Reiss Coal Co. of Sheboygan, WI. Reiss Coal is the parent company of Reiss Viking Corp., a producer of both heavy-medium magnetite for coal cleaning and black oxide for the foundry industry. Reiss Viking operated magnetite grinding plants at Tazewell, VA, and Fairmont, WV. Koch Carbon is headquartered in Wichita, KS, and markets a variety of coal and other carbon products.

STOCKS

Stocks of iron ore and agglomerates reported at U.S. mines, docks, and consuming plants at yearend continued to decline in 1986 and were at their lowest level in more than 30 years. The decline of 24% in total stocks from that of 1985 was due primarily to a reduction of stocks of domestic ore at U.S. docks and furnace yards. Stocks reported at these facilities at yearend included 14.17 million tons of domestic ores, 2.75 million tons of Canadian ores, and 2.23 million tons of other foreign ores. Mine stocks at yearend were 45% less than those of 1985, as the quantity of ore shipped from most Minnesota mines was greater than production.

End-of-month stocks reported at mines peaked at 13.04 million tons in April and declined to 3.26 million tons at yearend, while stocks of ore reported at consuming plants ranged from a low of 10.31 million tons in April to a high of 17.16 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 828,000 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 38.05 million tons, about 14% less than those of 1985. 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 3.63 million tons and accounted for about 22% of U.S. imports. The balance of imports, 13.07 million tons, was shipped primarily through ports on the east and gulf coasts.

Ore shipments from four of the seven U.S. ports on the upper Great Lakes declined from the levels of 1985, with the largest decrease at Two Harbors, MN. Shipments from Taconite Harbor and Superior increased slightly. Tonnage shipped from each port in 1986 was as follows:

Port	Date of first shipment	Date of last shipment	Total tonnage (thousand long tons)
Duluth, MN	Apr. 5	Dec. 24	5,035
Two Harbors, MN	Apr. 1	Dec. 14	6,156
Silver Bay, MN	Apr. 12	July 15[1]	1,450
Taconite Harbor, MN.	Apr. 11	Dec. 28	5,457
Superior, WI	Apr. 8	Dec. 24	8,998
Marquette, MI	Apr.18	Jan. 2	3,574
Escanaba, MI	Mar. 24	Dec. 24	7,378
Total[2]			38,047

[1]Operations ceased after LTV Steel Co., the co-owner of Reserve Mining Co., filed for bankruptcy on July 17.
[2]Data do not add to total shown because of independent rounding. Includes 22,761 tons shipped in Jan. 1987.

Source: Lake Carriers' Association, 1986 Annual Report.

The number of vessel shipments from all seven ports totaled 1,009, indicating an average cargo of 37,745 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 26,471 tons at Marquette to 55,757 tons at Silver Bay. Continuing high water levels in Lake Michigan permitted a record-high loading of iron ore at Escanaba for the second year in a row, when 72,351 tons of pellets was loaded on Bethlehem Steel's 1,000-foot carrier *Lewis Wilson Foy* for delivery to Indiana Harbor, IN. This cargo was the largest ever hauled in a Great Lakes vessel and surpassed the previous record high set in 1985 by 2,650 tons. A record-breaking 64,390 tons of ore also was hauled through the Soo Locks, by the *Indiana Harbor*, a 1,000-foot self-unloader owned by the American Steamship Co.

On July 15, Reserve was forced to suspend loading operations indefinitely at Silver Bay as a result of LTV's bankruptcy filing. Only 1.45 million tons was shipped through the port during its 94 days of operation, compared with 3.43 million tons for all of 1985. The port's best year was 1978, when 9.61 million tons was loaded.

Lake freight rates for iron ore, in effect since April 1984, were as follows, per ton: from Head of the Lakes to lower lake ports, $7.41; from Marquette to lower lake ports, $6.11; from Escanaba to Lake Erie ports, $5.64; and from Escanaba to lower Lake Michigan ports, $4.45.

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 principal issues concerning U.S. lake shipping in 1986 were proposed construction of a second Poe-class lock at Sault Ste. Marie, additional Coast Guard user charges proposed by the Federal Governments of the United States and Canada, and the inclusion of cabotage laws (Merchant Marine Act of 1920, also known as the Jones Act) in the ongoing U.S.-Canadian free trade negotiations.

When the Poe Lock was opened in 1969, companies hauling bulk cargo on the Great Lakes began upgrading their fleets to take advantage of the economy of size permitted by the new lock. Between 1972 and 1981, 13 self-unloaders with a length of at least 1,000 feet were added to the U.S. Great Lakes fleet. In addition, 16 existing vessels were lengthened and/or converted to self-unloaders. The 1982-83 recession and the accompanying decline in shipments forced owners to retire many of their older, smaller, and less efficient vessels. Since 1981, 30 vessels in the U.S. Great Lakes fleet have been scrapped. As a result of this upgrading, 29 of the remaining 70 vessels in the fleet must use the Poe Lock to transit the St. Mary's Falls Canal. These 29 vessels account for 65.6% of the fleet's total hauling capacity.[4]

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. The cost of converting the aging and narrow Sabin and Davis Locks into a new Poe-sized lock was estimated to be $227 million. The U.S. Army Corps of Engineers, which has studied the problem for many years, released a final feasibility study in March 1985 recommending construction of a second lock that could accommodate all vessel sizes in the fleet. Construction of the new lock was authorized by Congress in section 1149 of the Water Resources Development Act of 1986 (Public Law 99-662), but funding remains a problem. To date, the States bordering the Great Lakes have been unable to put together a regional authority capable of raising the $57 million required under Public Law 99-662. At the same time, Congress has been unwilling to make an exception and fund 100% of the construction from general revenues because of budgetary constraints.

The Office of Management and Budget had proposed that Congress levy user charges for U.S. Coast Guard services that are currently funded from general revenues. These user charges would help pay for navigation aids, vessel inspections, ice breaking, and search and rescue missions. The Lake Carriers' Association (LCA) and other segments of the maritime industry have been adamantly opposed to the proposed charges. According to LCA, most Coast Guard functions are multipurpose and should continue to be funded from general revenues. LCA argues that assistance to commercial shipping is just one of many Coast Guard responsibilities that include national defense, enforcement of fisheries treaties, drug interdiction, and environmental protection.

The cabotage issue is a complex one with serious long-term implications for the U.S. Great Lakes fleet. U.S. cabotage laws have two key features. First, domestic commerce is reserved to U.S.-flag vessels and second, only U.S.-built ships may engage in coastal trade. The Government of Canada wants the present cabotage restrictions waived for Canadian vessels as part of the free trade agreement. The hard-pressed members of LCA oppose the Canadian proposal and are concerned that differences in shipbuilding costs and government policies will enable the Canadian Great Lakes fleet to capture most of the cargo moving between U.S. lake ports. The Canadian fleet already hauls more than 95% of the lakes' bulk trade between the two countries.

On June 25, the Wisconsin Supreme Court ruled that a Wisconsin tax of 5 cents per ton on out-of-State pellets shipped through Lake Superior docks was unconstitutional. The court agreed with the Burlington Northern Dock Corp. that the tax, in effect since 1977, violated the commerce clause of the U.S. Constitution by discriminating against ore mined outside Wisconsin. Burlington Northern had brought suit against the City of Superior, the recipient of 70% of the taxes collected on pellets railed during the last 9 years from the western half of the Mesabi Range to the company's Allouez terminal.

The court decision could mean that the City of Superior and the State will have to refund the $2.4 million paid under protest by Burlington Northern between 1977 and 1980, plus interest. A separate suit covering $2 million in taxes paid between 1981 and 1984 was still pending. The effect on future tax collections remained unclear since the

Wisconsin Legislature eliminated the exemption for instate ore in 1985 and there has been no iron ore production in Wisconsin since 1982. At yearend 1986, the Wisconsin Attorney General was seeking to have the ruling overturned by the U.S. Supreme Court.

Published railway freight rates for pellets from mines to upper lake shipping ports increased in Minnesota in 1986 but were essentially unchanged in Michigan, compared with rates in late 1985. On April 3, the rate for pellets from the western Mesabi Range to the Allouez docks at Superior, WI, was raised from $4.99 to $5.01 per ton. For pellets from the Marquette Range of Michigan, the rates to Presque Isle and Escanaba were $2.40 and $2.68 per ton, respectively. Dock handling charges at Duluth, Superior, and Escanaba ranged from 64 to 94 cents per ton.

Rail rates from lower lake ports to a number of consuming points were raised at the beginning of 1986 together with ore transfer charges. On November 17, some of these rates and charges were rolled back to 1985 levels. At Lake Erie ports, ore transfer charges from rail-of-vessel or dock-receiving areas direct into railway cars ranged from $0.97 to $1.16 per ton, up 1 cent from those of 1985. This 1-cent increase was rescinded in the November rollback. Key rail rates for mid-1984 through 1986 are compared in the following:

From	To	Type of rate	Dollars per long ton		
			July 1, 1984	Jan. 1, 1986	Nov. 17, 1986
Lake Erie Ports	Pittsburgh and Wheeling districts.	Multiple car	10.62	10.74	10.62
Baltimore, MD	Pittsburgh district	do	11.55	11.68	11.49
Do	do	Single car	14.93	15.77	NA
Philadelphia, PA	do	do	14.93	16.48	NA
Mesabi Range	Granite City, IL	Multiple car	18.90	19.07	23.35
Pea Ridge, MO	do	do	6.41	6.41	NA
Mesabi Range	Geneva, UT	do	41.03	43.35	NA

NA Not available.

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 645,000 tons, down from 1.5 million in 1985 because of the USX labor dispute; the greater part of this tonnage was shipped to Geneva, UT, from the Minntac plant. An additional 15,000 tons of miscellaneous ore products was hauled all-rail, for a total ore movement on the railway in 1986 of 12.14 million tons.

Published nominal ocean freight rates for iron ore from eastern Canada to U.S. east coast ports were $3.50 to $3.75 per ton, but spot rates quoted for cargoes of 50,000 to 60,000 tons ranged from $1.70 to $2.25 per ton. A few shipments reported from Brazil to east coast ports indicated freight rates of $3.00 to $5.25 per ton.

PRICES

In the second half of 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 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 have 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. These prices were maintained throughout 1986.

Other published prices for Lake Superior pellets ranged from 58.0 cents to 86.9 cents per ltu of iron, natural, delivered rail-of-vessel at lower lake ports. The lower price was quoted by Mineral Services Inc. and reflects an 8.0-cent reduction made in August 1985 after Pickands Mather switched price bases; the upper one, quoted by CCI, Hanna, and Oglebay Norton, has been in effect since 1982.

The range of all of the above prices was approximately equivalent to $37.12 to $55.62 per long ton of pellets containing 64% iron, delivered rail-of-vessel at lower lake ports.

Published prices for other 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. CCI stopped quoting a price for Old Range non-Bessemer ore. The Old Range non-Bessemer price had been an industry indicator since 1855, when the American Iron Association, a forerunner of the present American Iron and Steel Institute, was organized. These prices were not very significant in 1986, because most Mesabi non-Bessemer ore was produced and consumed by LTV Steel, and little or none of the other grades of ore was produced. Pellets made up more than 98% 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 the Census, was $36.04 per long ton. Data from this source indicated average f.o.b. values of $14.70 per ton for Liberian ores and $19.23 per ton for Brazilian ores. Other sources indicated 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 1985, 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 ranged from about $79 to $110 per long ton.

FOREIGN TRADE

U.S. exports of iron ore were 11% lower than those of 1985 because of decreased 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 12.42 million tons, about 7% less than that of 1985.

U.S. imports for consumption of iron ore increased 6% to 16.74 million tons. Tonnage was 10% greater than the mean of the previous 4 years, 15.18 million tons. Sharp rises of ore imports into the Baltimore and New Orleans customs districts more than offset a 41% decline from 1985 levels in the Chicago district. Slightly more than one-half of U.S. imports came from Canada. In the last few years, Canada has had to struggle to maintain its traditional 13% to 23% share of the increasingly competitive U.S. market, which has shrunk by 52% since 1979. Brazil, the next largest supplier after Canada, has been somewhat more successful, gradually increasing its share from a 10-year low of 1.8% in 1982 to 6.7% in 1986 at the expense of Venezuela. In July, Mauritanian ore entered the United States for the first time ever as part of a barter transaction for railway locomotives built by General Motors Corp.

On July 18, the U.S. International Trade Commission (ITC) unanimously determined that subsidized imports of Brazilian pellets had not materially injured the U.S. iron ore industry.[5] The Commissioners, rejecting a petition from three domestic producers who wanted a countervailing duty levied on the subsidized pellets, said that the volume of Brazilian imports was low relative to apparent consumption. The Commissioners also pointed out that the bulk of the pellets were either sold under long-term contracts negotiated in the 1970's, or shipped into Atlantic and Gulf of Mexico coastal areas where domestic producers cannot compete because of high inland transportation costs. The ITC determination ended a countervailing investigation begun on March 22, 1985, after the U.S. Department of Commerce found that benefits given Cia. Vale do Rio Doce (CVRD) by the Government of Brazil were equivalent to a pellet export subsidy of 2.09% ad valorem.

The original petition for countervailing duties was filed in December 1984 by CCI, Pickands Mather, Oglebay Norton, and

USWA. The petitioners stated that subsidies being granted by the Government of Brazil allowed CVRD pellets to be delivered to U.S. consumers for at least 30% less than pellets produced in the United States, especially injuring U.S. merchant producers. The petitioners argued that the estimated 1.8 million tons of Brazilian pellets imported in 1984 was equivalent to about 30% of the amount available for sale by the merchant producers even though the imported tonnage was less than 4% of U.S. consumption. Rio Doce America Inc., the U.S. subsidiary of CVRD, countered for Brazil, claiming that CVRD did not need subsidies to compete in the U.S. market because the high grade of its ore allowed pellets to be made in Brazil for about $20 per ton less than what it cost U.S. producers. CVRD also argued that 75% of its 1984 pellet sales in the United States were under long-term contracts to Armco and the former United States Steel Corp. (now USX), and that about one-half of the remainder was sold in areas of the United States where domestic pellets could not compete because of high transportation costs.

WORLD REVIEW

Compared with the 1985 level, world production in 1986 increased slightly. However, there was a significant shift in sources of production, with decreases in North America and Western Europe being balanced by increases in Asia and Latin America. World production of pig iron, which directly reflects ore consumption, declined slightly to 481 million long tons.

The world ore trade was estimated at 360 million tons, of which about 84% was oceanborne. Brazil was the leading exporter, followed by Australia. Brazil shipped 91 million tons to world markets in 1986, an amount identical to that of 1985. Australian shipments, though, dropped from 87 to 81 million tons because of reduced imports by Japanese steelmakers who cut back pig iron production by 7%. The newly expanded European Communities (EC) received 119 million tons of ore and agglomerates, replacing Japan as the world's principal importer. Japanese imports decreased 8% from 123 million tons to 113 million tons. Part of the reranking resulted from a statistical deviation generated by the inclusion of Spanish and Portuguese import data with those of the 10 standing members of the EC. Spain has been importing 4.1 to 5.1 million tons annually for more than a decade.

World production of pellets was estimated at 193 million tons, about 79% of installed capacity. Most pelletizing plants in Canada, South America, and the U.S.S.R. operated close to rated capacity, contrasting sharply with the situation in the United States. The recently completed merchant plant in Bahrain had difficulty operating in the midst of the Iran-Iraq war. New plants were completed in India and Turkey.

World output of DRI was estimated by Midrex Corp. at 12.5 million tons, about 54% of installed capacity, as low prices for ferrous scrap continued to limit production. New modules or, in a few instances, entirely new plants were brought on-line in Egypt, India, New Zealand, and the U.S.S.R., raising global capacity from 21.3 million tons to 23.2 million tons. The startup of this additional capacity, together with improved utilization of existing facilities in Indonesia, Saudi Arabia, the Republic of South Africa, Trinidad and Tobago, and Venezuela, was responsible for the 15% increase in world DRI production between 1985 and 1986. About 47% of the total output for 1986 was produced in Mexico, Venezuela, and other countries in Latin America.

Almost all of the 1986 price negotiations in Japan and Western Europe were completed by mid-July. Most prices declined. In December 1985, Canadian producers supplying the West German market agreed to cut their concentrate prices slightly. Société Nationale Industrielle et Minière then quickly agreed to a similar price cut for its three types of Mauritanian fines. CVRD, the largest shipper to the European continent, had hoped for a price hike, but was now in a difficult position and reluctantly accepted a slight cut for both its fines and pellets. The majority of the remaining suppliers followed CVRD's lead.

The price reductions in Western Europe toughened the resolve of the Japanese steelmakers, who were in the midst of scaling back pig iron production and were determined to hold costs down. The Japanese were able to win price cuts of 4.0% to 5.4% for most types of Australian, Brazilian, and Indian ores. Peruvian and South African suppliers were forced to accept even larger cuts of 6.5% to 9.5% because their ores have a higher alkali content than most. The Japanese success at the negotiating table upset a price balance between the Western European and Japanese markets that had existed since 1982.

On an f.o.b. (shipping port) basis, most 1986 prices apparently ranged from about $13.00 to $16.50 per long dry ton (ldt) for fines, $15.50 to $20.00 per ldt for lump, and $23.00 to $24.00 per ldt for pellets. Delivered prices (at receiving port) were about $2 to $9 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 indicated:

Country and producer	Ore type	Prices	
		FY 1985	FY 1986
Australia:			
Hamersley Iron Pty. Ltd. and Mount Newman Mining Co. Pty. Ltd.	Lump ore	31.55	30.29
Do	Fines	27.05	25.97
Robe River Iron Associates	do	24.05	22.97
Savage River Mines Ltd.	Pellets	37.10	36.02
Brazil:			
Cia. Nipo-Brasileira de Pelotização (Nibrasco).	do	36.25	35.29
Cia. Vale do Rio Doce (Carajás)	Fines	--	23.66
Cia. Vale do Rio Doce and Minerações Brasileiras Reunidas S.A.	Lump ore	24.65	23.66
Minerações Brasileiras Reunidas S.A	Fines	25.33	24.21
Samarco Mineração S.A	Pellet fines	20.46	19.46
Canada: Iron Ore Co. of Canada (Carol Lake).	Concentrates	23.37	22.44
Chile: Cía. Minera del Pacífico S.A. (El Algarrobo).	Pellets	37.60	36.10
India:			
Minerals and Metals Trading Corp. (Bailadila).	Lump ore	30.73	29.21
Do	Fines	26.23	24.95
Liberia: LAMCO Joint Venture Operating Co	do	23.30	22.40
Peru: Empresa Minera del Hierro del Perú S.A.	Pellets	29.50	27.59
South Africa, Republic of:			
South African Iron and Steel Industrial Corp. Ltd.	Lump ore	[1]25.86	[1]23.91
Do	Fines	[1]22.26	[1]20.55

[1]Price per dry metric ton unit.

Source: TEX Report (Tokyo), v. 18, Nos. 4261 and 4262, Aug. 15 and 19, 1986.

Two super carriers, each with a capacity exceeding 300,000 deadweight tons (dwt), were commissioned in 1986 to haul Carajás iron ore from the new Brazilian Port of Ponta da Madeira to Japan and Western Europe. Three other carriers belonging to the same class were under construction and scheduled to be delivered in 1987. These five new vessels, while more efficient, will worsen the existing oversupply of bulk carriers and force shippers to keep their freight rates at current depressed levels.

The first of the new vessels was the *Docefjord*, a 305,000-dwt ore-oil carrier built in Brazil for the Wilsea Shipping Corp. Wilsea is a Liberian corporation owned equally by Wilh. Wilhelmsen of Norway and Vale do Rio Doce Navegacao S.A. (DOCENAVE). DOCENAVE is the wholly owned shipping subsidiary of CVRD. The 332-meter-long *Docefjord* has begun hauling ore from CVRD's terminal at Ponta da Madeira to Yawata and other Japanese ports. The second of the vessels was the 343-meter-long *Berge Stahl*, a 365,000-dwt carrier owned by Sig Bergesen D&Y A/S of Norway and built at the Ulsan shipyards of Hyundai Heavy Industries Co. Ltd. in the Republic of Korea. The *Berge Stahl* was placed under a long-term contract to Rohstoffhandel GmbH and has begun shuttling on a monthly basis between Ponta de Madeira and the Ertsoverslagbedrijf Europoort transshipment terminal in Rotterdam. The *Berge Stahl* will also be available for loadings at Tubarão, CVRD's port in the State of Espirito Santo.

Ocean freight rates for iron ore continued to decline. Published rates for spot charterings to the EC from Western Australia ranged from $5.30 to $7.30 per dwt for cargoes of 120,000 to 140,000 dwt, compared with $6.00 to $9.00 in 1985. The 1986 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	2.70-5.20
Do	do	220-250	2.80-3.25
Canada	Sept-Iles or Port Cartier.	100-140	2.10-4.10
Liberia	Buchanan or Monrovia.	60- 80	2.75-4.50
Mauritania	Nouadhibou.	80-100	2.00-2.90
Sweden	Narvik (Norway).	80-100	1.70-2.55
Venezuela	Puerto Ordáz.	40- 60	4.25-8.25

Source: Drewry Shipping Consultants Ltd. (London) and The Tex Report (Tokyo).

Rates for cargoes of 60,000 to 100,000 dwt to Japan from Australia ranged from $3.20 to $4.20, with the highest rate applying to Port Latta in Tasmania. Rates to Japan from the Brazilian Port of Tubarão for somewhat larger cargoes were $4.35 to $7.20.

Australia.—Production of iron ore for ironmaking and steelmaking totaled 88.6 million tons, down 5% from the record-high 92.9 million tons (revised) in 1984. Ore and pellet shipments totaled about 87.6 million tons, including 9.2 million tons for domestic consumption. Actual exports were 78.4 million tons, of which 81% was destined for Japan and other Asian countries, and 19% was destined for Western Europe. Exports consisted of about 57% sinter fines, 41% lump ore, and 2% pellets. The 8% decrease in exports was tied to steel production cutbacks in both Japan and Western Europe and would have been worse if China and Taiwan had not increased their ore purchases. Shipments by individual producers follow, in million tons: Hamersley Iron Pty. Ltd., 34.5; Mount Newman Mining, 27.9; RRIA, 11.0; The Broken Hill Pty. Co. Ltd. (BHP), 5.8; Goldsworthy Mining Ltd. (GML), 5.5; and Savage River Mines Ltd., 2.0.

On January 3, BHP Minerals Ltd., a wholly owned subsidiary of BHP, completed its purchase of the 25% share held by AMAX Inc. in the Mount Newman Joint Venture. BHP now has an 85% share in the Western Australian project. Mount Newman was in the midst of installing a 22-million-ton-per-year in-pit crusher and waste conveyor system at its Mount Whaleback Mine. Mount Newman also has made a number of modifications to its Port Hedland facilities so that they can now receive vessels up to 270,000 dwt. In October, the Port Hedland Port Authorities completed its channel-dredging project at Nelson Point, deepening the channel from 11.8 meters to 14.3 meters. Mount Newman's two berth pockets at Nelson Point were deepened to 19.0 meters from 17.3 meters and 16.1 meters, respectively. Approximately $60 million has been spent since September 1984 on port expansion work and the purchase of new tugboats at Port Hedland.

In late 1986, BHP Minerals started development of its Yandicoogina pisolitic limonite deposit, about 100 kilometers northwest of the mining town of Newman. Leighton Contractors was given a contract to mine, crush, and truck a 200,000-ton sample to the Mount Newman Mining Railroad siding at Weeli. From there, the sample was to be railed to Port Hedland and later shipped to BHP's Port Kembla steelworks on the coast of New South Wales for sintering and blast furnace trials. Bulk sampling was scheduled to begin in February 1987 in conjunction with upgrading of the railroad access road and the building of a construction camp for 100 workers. BHP's Yandicoogina leases contain an estimated 1,800 million tons of limonite, averaging 58.5% Fe.

In a related action, CRA Ltd. acquired a 50% interest in the Yandicoogina deposit held by CSR Ltd. CSR's lease is adjacent to BHP's holdings and contains demonstrated resources of pisolitic limonite that exceed 1,200 million tons. A feasibility study of this second deposit was in progress at yearend.

In 1985, BHP Minerals shipped a total of 3.48 million tons of ore from its two island mining operations in Yampi Sound. About 2.40 million tons was run-of-mine hematite ore, averaging 66.5% Fe and 3.0% SiO_2, from the open pit operation on Koolan Island. The rest came from a 1-million-ton stockpile of high-grade hematite ore on Cockatoo Island. BHP closed the Cockatoo Island Mine in November 1984 after depleting reserves, but continued to meet contracts throughout 1985 from the stockpile. When the Cockatoo stockpile was exhausted in March 1986, BHP increased the production rate on Koolan to 3.0 million tons per year. Koolan's reserves at midyear totaled

22.12 million tons, of which 16.55 million was in the Main ore body and an additional 5.57 million in four minor ore bodies (Eastern, Acacia, Mullet, and Barramundi). If Nippon Steel Corp., Kobe Steel Ltd., and other Japanese consumers allow BHP to raise the SiO_2 content of its Koolan ore blend from 3% to 4%, BHP should be able to increase the island's reserves to 34 million tons and extend the life of the mine to 1998.

GML began drawing up long-range plans to beneficiate 100 million tons of marginal ores stockpiled or in situ near its Shay Gap and Sunrise Hill Mines in the eastern Pilbara. GML's contracts with Nippon Steel, Nippon Kokan K.K., and other Japanese steelmakers were due to expire in June 1987, at the same time that existing high-grade reserves near exhaustion. GML is owned by Consolidated Gold Fields Ltd., 58.33%, and BHP's Utah Development Co. Ltd. subsidiary, 41.67%. Approval of the project by both partners would enable the joint venture to continue shipping ore at a rate of 4.5 million tons per year for the next 15 to 20 years. The Finucane Island loading facilities at Port Hedland would be expanded to accommodate 170,000-dwt vessels, and a second berth would be added. The proposed beneficiation plant also would be at Port Hedland, where low-grade ore averaging 58.0% Fe would be upgraded to 63.6% Fe lump and 62.8% Fe fines. Starting in January 1989, new reserves would be developed and mined in the Shay Gap, Sunrise Hill, and Nimingara mining areas. The Kennedy Gap and Yarrie areas would not be developed until 2009. Representatives from both GML and Consolidated Gold Fields have already asked their Japanese customers for cooperation during the critical bridging period between July 1987 and December 1988. At yearend 1986, BHP's role in the extension project was still unclear.

On February 27, CCI sold its holdings in Cliffs Robe River Iron Associates and other iron ore interests in Western Australia to Peko-Wallsend. The sale, which was retroactive to January 1, generated a $27.8 million increase in equity for Cliff's shareholders and raised Peko-Wallsend's share in the joint venture from 35% to 50.9%. The other partners were Mitsui Iron Ore Development Pty. Ltd., 31.5%; Nippon Steel Australia, 8.0%; Sumitomo Metal Australia, 6.0%; and Westralian Iron Associates Ltd., 3.6%. The restructured partnership was renamed Robe River Iron Associates.

In a related action, BHP sold its 50% interest in the Robe River rail and port facilities to the joint venture in order to concentrate on its iron activities in the Mount Newman area of the eastern Pilbara. In 1985, BHP shelved its own plans for the Robe River district and agreed to sublease its J and K areas of the Deepdale iron ore deposits to the Robe River venture. The J and K areas, which have more than 400 million tons of ore reserves, are adjacent to the L, M, and N areas of RRIA's Pannawonica Mine at East Deepdale. The additional reserves will extend the life of the Robe River project to at least 2015. In 1986, the Robe River project had an annual production capacity of 20 million tons of goethite fines, averaging 56.5% Fe.

In July, the new management, guided by Peko-Wallsend, introduced a series of work-rule changes in an attempt to increase productivity and make the joint venture more competitive. When the unionized work force of 1,560 resisted these changes, management declared a lockout on August 11, canceled the existing labor contract, and shut down Pannawonica. The Industrial Relations Commission (IRC) of Western Australia intervened, but failed to produce an acceptable mediation plan and was forced to order reinstatement of the suspended work force. RRIA resisted the IRC's order and appealed to the Industrial Appeals Court of Western Australia. On September 3, the Appeals Court ruled in favor of the IRC, allowing the mine to be reopened that same day, but ordered new labor-management talks. The 3-week lockout cost Nippon Steel, the largest Japanese consumer of Robe River ore and a partner in RRIA, more than $1 million in demurrage charges. Two of Nippon Steel's ore carriers, the *Kaien Maru* and the *Otaka Maru*, were unfortunate to have berthed August 10 at Port Walcott, RRIA's loading port on Cape Lambert.

From September to mid-December, ore production was at its normal level of 40,000 to 55,000 tons per day. However, on December 16, heavy equipment operators at Pannawonica struck over RRIA's reduction of personnel levels and the use of nonunion labor, and remained off the job for the remainder of 1986. The heavy equipment operators were joined by the dock workers at Port Walcott, who staged a sympathy strike and refused to load vessels, halting all shipments of ore.

Because of the two labor-management

disputes, Robe River exports for the calendar year totaled only 11.0 million wet tons, down 26% from the 14.9 million tons of 1985. The two disputes generated considerable misgivings among integrated steelmakers in Japan, who were facing recessionary pressures and preparing to close down a number of blast furnaces. The unfortunate events at Robe River cost the joint venture about $14 million, placing it and other Australian producers at a serious disadvantage in their 1987 price negotiations, and has encouraged the Japanese to strengthen their relationships with Canadian, Indian, Swedish, and Venezuelan ore producers.

Bahrain.—Arab Iron and Steel Co. (AISCO) was forced to suspend operations at its 4.0-million-ton-per-year pelletizing plant early in the year, after producing only 1 million tons of pellets. The project, which includes a desalination plant, a hydrated lime facility, and a powerplant, cost $310 million. The company has had a difficult time since the plant's startup in November 1984 because of weak demand for pellets worldwide and extraordinary marketing obstacles created in the Persian Gulf region by the Iran-Iraq war. Most of AISCO's sales to date have been to Turkish, West German, Austrian, and Portuguese steelmakers. Kawasaki Steel Corp. bought 80,000 tons of nonstandard pellet feed that was unsuited for AISCO's process and was left in the yard. The material apparently can be used as sinter feed.

Brazil.—Shipments of iron ore for export and domestic consumption rose to record-high levels for the third consecutive year. Exports totaled 92.0 million tons, only slightly higher than those of 1985, while net shipments for domestic consumption increased 21% to 43.5 million tons. Exports included about 46.1 million tons to Europe and 26.3 million tons to Japan. Total shipments of pellets were estimated to be 23.6 million tons, compared with 21.5 million tons in 1985. Exports from CVRD's new Carajás Mine through Ponta da Madeira were offset by a 17% decrease in exports through Tubarão, the largest of Brazil's five loading ports. CVRD has gradually begun shipping a greater percentage of the production of its Itabira mines to domestic customers.

CVRD produced 79.4 million tons of iron ore products and exported 50.87 million tons. CVRD also exported 18.23 million tons for other companies, including about 8.29 million tons of pellets for its joint ventures at Tubarão with Italian, Japanese, and Spanish companies, 7.33 million tons of ore products for Ferteco Mineração S.A., and 2.62 million tons for S.A. Mineração da Trindade (SAMITRI). Most of CVRD's production in the Minas Gerais Iron Ore Quadrangle came from the Cauê and Conceição Mines near Itabira. Minas da Serra Geral S.A., owned 51% by CVRD, sold 8.5 million tons of ore from the Capanema Mine for beneficiation at the Timbopeba plant and shipment to the Tubarão steelworks.

CVRD continued to develop and expand operations at its Greater Carajás Mining Project in the State of Pará.[6] The Serra dos Carajás iron deposits, discovered in 1967 by a Brazilian exploration subsidiary of United States Steel Corp. (now USX), form bald, flat mountain tops, covered by a limonitic crust, in the midst of the tropical rain forest. The high-grade ores occur in the supergene enrichment zones of the Carajás Formation, a Precambrian banded iron formation with hematite and silica beds that is highly weathered in outcrop. The five main ore bodies, four in the Northern Range and an enormous one in the Southern Range, are composed of soft hematite with minor amounts of clays, magnetite, and goethite. The immediate mining district has 18 billion tons of ore reserves, averaging 66% Fe. The Carajás reserve data are summarized in the following tabulation:

Carajás	Reserves (million long tons)	Iron content (percent)
N1	841	66.4
N4W	1,697	65.3
N4E	1,432	66.3
N5	1,554	66.2
S11	10,171	66.3
Other	1,908	65.2
Total or average	17,603	66.1

Almost all of the mining to date has been in the N4E ore body, where the ore averages 66.3% Fe, 0.48% manganese (Mn), 0.03% P, 0.01% sulfur (S), and 0.05% alkalis (Na_2O+K_2O).

CVRD's new marine terminal at Ponta da Madeira was inaugurated on January 1, 1986. The *Docepolo*, which entered the port on December 24, departed on January 7 with a 124,879-ton trial shipment of Carajás ore for Nippon Steel and Kawasaki Steel. Nine additional trial shipments, totaling 662,255 tons, were made during the first quarter to European, U.S., and other Brazilian ports. Regular shipments began in April, exceeded 1 million tons in May, and remained above that level for the rest of 1986. Carajás shipments for the first year totaled 11.40 million tons, of which 11.28 million tons was exported. By mid-December, Carajás was producing at a rate of 2.0 million tons per month, close to the planned level of 25 million tons per year. Because of the global oversupply situation, CVRD decided not to raise the Carajás production rate to 35 million tons per year in July 1987 as previously scheduled. However, the company will continue to install the equipment needed to bring the mine's annual capacity up to the 35-million-ton level.

MBR, Brazil's second largest producer, shipped 15.94 million tons of ore in 1986, including 13.79 million tons for export. Most of the ore was produced at the Aguas Claras Mine, southeast of Belo Horizonte in the Iron Ore Quadrangle, and shipped through the Port of Sepetiba. The company began installing a new 6.4-million-ton-per-year beneficiation plant at its Mutuca Mine and was trying to raise $120 million to finance the shortening of the railway route between Sepetiba and its Minas Gerais Mines.

Prior to November 30, MBR was controlled by Empreendimentos Brasileiros de Mineração S.A. (EBM), 51.00%; St. John d'el Rey Mining Co. PLC, 34.27%; and Cia. Auxiliar de Empresas de Mineração (CAEMI), 14.73%. On that day, Hanna sold its 96.37% interest in St. John, a British corporation, to CAEMI for $72 million, triggering a capital restructuring of MBR. EBM, a joint venture of CAEMI; BELEM, a wholly owned Brazilian subsidiary of Bethlehem Steel; and a group of Japanese companies retained its 51.00% share. St. John also retained its 34.27% share but became a wholly owned subsidiary of CAEMI. Mitsui & Co. Ltd. acquired the remaining 14.73% share from CAEMI for $32 million. In the end, CAEMI directly or indirectly controlled 70.02% of the shares in MBR.

Ore shipments by other producers, in million tons, follow: Ferteco, 9.91 (including 2.28 in local sales); SAMITRI, 8.66; Samarco Mineração S.A., 7.22; Cia. Siderúrgica Nacional, 4.9 (estimated); and Empresa de Mineração Esperanca S.A., 0.24.

Canada.—Shipments of iron ore products totaled 36.7 million wet tons, compared with 39.8 million wet tons (revised) in 1985. Exports totaled 30.5 million wet tons, of which 59% was destined for EC countries and 31% was destined for the United States. Canadian iron and steel plants consumed 14.0 million tons of ore and agglomerates.

Shipments by individual producers, in million tons, follow: IOC, 14.7 including 9.4 of pellets, 4.7 of concentrates, and 0.6 of direct-shipping ore; Quebec Cartier Mining Co. (QCM), 13.9, including 6.7 of concentrates and 7.2 of pellets; Pickands Mather, 4.8 of pellets including 4.7 from Wabush Mines; Cliffs of Canada Ltd. (for Dofasco Inc.), 2.0 of pellets from the Adams and Sherman Mines; and British Columbia producers, 0.06 of pellet feed obtained from stockpiled ore. In addition, Algoma shipped 8.9 million tons of superfluxed sinter from Wawa, Ontario, to its steelworks at Sault Ste. Marie. Feed to the plant included 1.3 million tons of siderite ore produced at the MacLeod underground mine. Algoma has been blending the Wawa sinter with acid pellets from the Empire Mine in Michigan to obtain a suitable feed for its four blast furnaces at Sault Ste. Marie.

Consumption cutbacks in the United States and Canada during 1986 put pressure on producers in Quebec and Labrador to sell a larger share of their production outside North America. This sales problem came at a time when steel production was being reduced in both Western Europe (Canada's major market) and Japan. As a result, Canadians had to accept lower prices for their products, causing the average revenue per ton to drop to $35.32 from $37.60 in 1985. At the same time, intensified marketing efforts led to new contracts with steelworks in the Republic of Korea and Japan. Pohang Iron and Steel Co. Ltd. signed a contract with IOC for 1.48 million tons of concentrate to be delivered over the next 5 years, while Nippon Steel and Nisshin Steel Co. Ltd. agreed to take a 167,000-ton trial shipment of concentrate from QCM at 20.93 cents per dry long ton unit, f.o.b. Port Cartier.

Two producers in Ontario adopted a different strategy and responded to the U.S. and Canadian consumption cutbacks by reducing capacity. In March, Stelco Inc. permanently closed its Griffith Mine northwest of Ear Falls and increased shipments from its Wabush Mines joint venture to compensate for the closure. Algoma dropped the annual production rate at its MacLeod Mine from 3 to 1.4 million tons of ore, cutting back sinter shipments from Wawa to the 900,000-ton-per-year level. A total of 138 hourly workers and 30 staff were laid off at the mine and sinter plant as a result of the cutback.

The long-term shift from production of concentrates and direct-shipping ores to pellets continued. IOC made a record-high

1.2 million tons of fluxed pellets in 1986 at its Carol Lake complex, using local dolomite and imported limestone. Two new wet-grinding units were added to the Carol Lake concentrator to improve efficiency in the fall and winter months. QCM operated its Port Cartier pelletizing plant at near capacity throughout the year. Wabush Mines was investigating ways to lower the 2% manganese content of its pellets so that they would be more marketable. Wabush may be able to blend its concentrate with low manganese material from QCM. Wabush could also extract the manganese from the concentrate utilizing a leach, crystallization, and roast process and then sell it as a byproduct. Dofasco invested $1.1 million in its Adams and Sherman Mines so that they could produce fluxed pellets instead of acid pellets. The two mines, situated on the Ontario side of the Lake Timiskaming Rift Valley, will use dolomite and limestone from quarries elsewhere in the Province. Both are managed by CCI, which has a 10% equity in the Sherman.

On July 3, cumulative shipments of ore through IOC's Sept-Iles terminal on the Gulf of St. Lawrence passed the 500-million-ton mark. By then, the terminal had handled 16,798 cargoes since the first loading on July 31, 1954.

Chile.—Shipments by Cía. Minera del Pacífico S.A. (CMP) totaled 5.72 million tons, consisting of 3.37 million tons of El Agarrobo pellets, 1.75 million tons of El Romeral fines, and 0.56 million tons of El Romeral lump ore. Only 4.57 million tons of material was exported to Japan, Chile's major customer for more than 20 years, compared with 6.96 million in 1980. The United States and Mexico received 0.15 million and 0.05 million tons, respectively. The remaining 0.94 million tons went primarily to the Huachipato blast furnaces operated by CMP's parent company, Cía. de Aceros del Pacífico S.A. de Inversiones.[7]

The marked decline in exports over the past 6 years reflects the increasing competitiveness between suppliers worldwide and the deteriorating situation facing Japanese pig iron producers since 1984. To remain competitive, CMP has been working to improve the quality of its iron ore products and upgrade its loading facilities. The company has been trying to lower the phosphorus and sulfur contents of its Romeral ores by selective mining so that they are more in line with levels in Australian and Brazilian ores. In Japanese fiscal year 1985, ending March 1986, Romeral fines averaged about 0.097% P compared with 0.037% for Robe River fines and 0.030% for MBR fines. The slaked lime additive used in the El Algarrobo pellets has been replaced by a combination of limestone and slaked lime. The Port of Guayacán was dredged in 1982 so that it can now accommodate 200,000-dwt vessels, and new ship loading and mooring equipment were acquired. The Chilean actions were at least partly successful because the Japanese have agreed to a new 3-year contract that runs until March 1989.

China.—The No. 1 blast furnace at the new Baoshan steelworks near Shanghai was commissioned on September 15, 1985. In the first 12 months of operation, the 4,063-cubic-meter furnace produced 2.30 million tons of pig iron. The integrated steelworks will require 3.5 million tons of ore and agglomerates per year as well as significant amounts of imported ferrous scrap. The initial ore supplies are coming from Australia, Brazil, India, and the Shilu Mine on Hainan Island. China imported 13.5 million tons of iron ore in 1986, up 37% from 9.8 million tons in 1985. Australia provided about 8.4 million tons; Brazil, 3.1 million; and India, 0.4 million. At the end of December, the central Government abolished the ad valorem export duty of 20% on pig iron. The duty, in effect since June 1981, reportedly was abolished to shore up the nation's diminished foreign exchange reserves. Obsolete ironmaking facilities were being modernized or dismantled at several locations elsewhere in China. The management of the Anshan Iron and Steel Complex in Liaoning Province agreed to buy portions of two idle pelletizing plants in Western Australia from RRIA for about $2.0 million. The two plants, which have a combined production capacity of 4.2 million tons per year, have not been operated since May 1, 1980, because of the increase in fuel oil prices.

Egypt.—Alexandria National Iron and Steel Co. S.A.E. (ANSDK) commissioned its El Dikheila steelworks in December. The complex, on the shore of the Mediterranean 10 kilometers southwest of Alexandria, is a joint venture of 11 Egyptian companies, 87% equity; a Japanese consortium, 10%; and the International Finance Corp., 3%. The melting part of the $800 million steelworks is equipped with a 705,000-ton-per-year DRI plant, four 70-metric-ton electric furnaces, and three 4-strand continuous casters. The single series 600 Midrex direct-reduction (DR) unit utilizes natural gas from the nearby Abu Qir Bay Field. AISCO was to have provided the El Dikhelia unit with pellets from its Bahraini operation. However, in July, Samarco was awarded a contract to supply ANSDK with 500,000 tons of Brazilian pellets at 43.91 cents per Fe unit per dry metric ton (dmt), cargo and freight (C-F). The DRI will be melted with scrap iron in a ratio of 3 to 1.

India.—Production, exports, and consumption of iron ore increased in 1986, compared with 1985 levels. Exports totaled 31.7 million tons, and domestic consumption was estimated at 13.6 million tons. Exports included 20.6 million tons to Japan, 4.4 million tons to Romania, and 2.8 million tons to the Republic of Korea. Goan exports through the Port of Mormugao totaled 14.1 million tons and were the largest in more than a decade. Exports from Mormugao for 1980-86 are shown in the following tabulation:

Year	Gross weight (thousand wet tons)[1]
1980	13,963
1981	11,208
1982	12,934
1983	10,805
1984	11,626
1985	13,657
1986	14,121

[1]Includes some non-Goan ore exported through Mormugao by Minerals and Metals Trading Corp.

Source: Chowgule & Co. Pvt. Ltd.

In July, the Nehru Bridge over the Mandovi River partially collapsed, hampering the passage of barges transporting Goan ore to Mormugao for several months. Shipments from Vishakhapatnam, Madras, and other east coast ports by the National Mineral Developments Corp. Ltd. (NMDC) totaled 7.52 million tons.

NMDC continued to expand its Bailadila mining complex in the State of Madhya Pradesh. Development work at the Bailadila No. 11C deposit was well under way, and full-scale production was scheduled to begin in January 1989. The work included stripping, road construction, and the installation of a primary crusher and conveyor system. The crude ore from the No. 11C pit would be hauled on the conveyor to the existing concentrator at the No. 14 Mine for further processing. Japanese buyers were studying NMDC's proposal to blend the conventional fines from the No. 14 Mine with fines made from "blue dust," beginning in 1990. The blue dust is a more friable, poorer quality ore, with a higher alumina content, that has been left behind in the upper benches. The depth of the No. 14 Mine would be increased by 72 meters, increasing its recoverable reserves from 9 to 31 million tons. The deepening would extend the life of the No. 14 Mine to at least March 1992.

Upgrading of the loading facilities at the Bailadila No. 5 Mine (93 million tons of reserves) was expected to be completed by February 1987. Under the new plan, the Bailadila complex would produce a total of 5.6 million tons of lump ore and 5.2 million tons of fines on an annual basis.[8] Part of the increased production would go to two blast furnaces being built at the Vishakhapatnam Steelworks. The No. 4, No. 10, and No. 13 deposits would continue to be held in reserve. In 1985, Bailadila produced 4.61 million wet tons of lump ore and 0.66 million wet tons of fines. Most of this production was railed to Vishakhapatnam Harbor for export. An additional 1.24 million wet tons of lump ore and 1.01 million wet tons of fines were produced at NMDC's Donimalai Mine in Karnataka and exported through Madras.[9]

Minerals and Metals Trading Corp. (MMTC) of India, shipping agent for the Bailadila, Donimalai, and Kudremukh Mines, announced plans to raise its exports from 16 to 19 million tons in 1987. Japanese and South Korean buyers have been pressing MMTC to expand the port facilities at both Vishakhapatnam and Paradip. MMTC submitted a proposal to the Government of India to deepen the channel at Paradip at a cost of $90 million so that the port can accommodate vessels up to 170,000 dwt, compared with the present 60,000 dwt. Port expansion and upgrading work at Vishakhapatnam would cost at least an additional $40 million. Dredging work at Madras was completed in April, making it possible for 130,000-dwt vessels to enter that harbor's berths.

The Kudremukh Iron Ore Co. Ltd. (KIOCL) produced 3.32 million tons of concentrate in 1986 at its mine, northeast of Mangalore in the Western Ghats of Karnataka. The concentrate was slurried and pumped 67 kilometers to the Port of Mangalore on the Arabian Sea for export to six Japanese steelmakers, Eastern Europe, and BHP's operations in Australia. KIOCL exported a record-high 3.12 million tons, a 91% increase over the previous year's 1.63 million tons. Weak sales have kept the concentrator from operating at its full capacity of 7.4 million tons per year. The

Government of Iran's decision not to purchase Kudremukh concentrate in the near future has placed the company in a difficult marketing position. Under an agreement signed in November 1975, KIOCL was set up to ship Iran 150 million tons of concentrate over a 21-year period, beginning in September 1980. The suspension of operations at the AISCO pelletizing plant in Bahrain, a major KIOCL customer, has complicated the situation even further.

KIOCL's new 3.0-million-ton-per-year pelletizing plant at Mangalore became fully operational in midyear and shipped trial quantities of pellets to China, Hungary, and Poland. In addition, BHP has given MMTC, the sales agent for KIOCL, a letter of intent to purchase 83,000 tons of Kudremukh pellets on a trial basis. The plant, built by Romania using Lurgi technology, was designed to produce high-quality pellets for DRI plants. Limited amounts of Kudremukh pellets have been tested successfully at a variety of plants employing the HYL (Hylsa SA), Midrex, or Nippon Steel (Trengganu) processes.

Liberia.—Production of iron ore products totaled 15.05 million tons and was essentially identical to that of 1985. However, the 1986 total represented the output from only two of Liberia's three mining companies. Bong Mining Co. produced 4.11 million tons of concentrate for use as sinter feed and 2.91 million tons of pellets. The output of the LAMCO Joint Venture, in contrast, included 6.72 million tons of washed fines, 767,000 tons of washed lump ore, only 540,000 tons of concentrate, and no pellets. The third company, National Iron Ore Co. Ltd. (NIOC), suspended operations on April 9, 1985, because of financial difficulties. Creditors prevented NIOC from shipping the 150,000 tons of fines and lump ore that the company had stockpiled at the Freeport of Monrovia. Liberian exports totaled 14.26 million tons, of which 84% was destined for the EC and 12% was destined for the United States.

In February, the Governments of Liberia and Guinea agreed to work together to develop the Pierre Richaud deposit in the Nimba Mountains of Guinea. Three months later, Gränges International Mining AB, the sales agent for LAMCO, formally asked Japanese steelmakers if they would be willing to import 1 million tons per year of sinter feed prepared from a blend of Pierre Richaud and Tokadeh ores, beginning in 1990. If the Japanese accept the Gränges sales offer, LAMCO will form a joint development company with the Guinean developer Société des Mines de Fer de Guinée pour l'Exploitation des Monts Nimba (MIFERGUI-NIMBA).

The joint development company would have to build a 27-kilometer-long railroad loop that would connect the Pierre Richaud minesite in Guinea with the existing terminus of the LAMCO Railway at Yekepa. The Guinean deposit has proven reserves of 350 million tons and would produce 10 million tons per year of concentrate averaging 68.1% Fe, 0.024% P, and 0.88% SiO_2. Ores from the two mines would be hauled over the existing 265-kilometer-long LAMCO line to Buchanan, where they would be blended together and washed. LAMCO's berth and loading facilities at Buchanan would be upgraded to accept 120,000-dwt vessels.

Recently, LAMCO began shifting production from its nearly depleted Nimba Mine to Tokadeh. The main ore body at Nimba could be exhausted as early as 1989. Tokadeh has 222 million tons of proven reserves, averaging 47.9% Fe, 0.076% P, and 27.4% SiO_2. A 9.5-kilometer railway loop would be built from Yekepa to Gangra to facilitate the shipment of Tokadeh ore. The blending of the Tokadeh ore with the higher grade Pierre Richaud material would improve the marketability of the Liberian ore and enable LAMCO to remain competitive beyond 2010. At the same time, MIFERGUI-NIMBA would avoid having to construct redundant and prohibitively expensive infrastructure and port facilities. As it stands, the joint Guinean-Liberian project is expected to cost more than $900 million.

Libya.—The DR plant at the new Misurata Iron and Steelworks was nearly completed.[10] The plant consists of two Midrex Series 600 modules that will use Libyan natural gas to reduce imported pellets. Each of the modules is capable of producing 540,000 tons of DRI per year. The steelworks, situated on the Gulf of Sidra, 210 kilometers east of Tripoli, has its own port, two melt shops with three 90-ton electric arc furnaces each, five continuous casters, a combined power and desalination plant, and a variety of mills and finishing facilities. Limestone and dolomite will come from the Sedala quarries, 100 kilometers west of Misurata.

South Africa, Republic of.—Production of iron ore was essentially unchanged from 1985 levels, even though exports dropped 13% largely because of economic sanctions by some traditional trading partners. Production totaled 24.09 million tons, compared with 24.03 million tons in 1985. Exports declined to 8.76 million tons, with 5.42 million tons going to Japan and more than 2 million tons to the EC. Domestic sales exceeded the 12-million-ton level for the first time ever, with pig iron production increasing 15% and the output of DRI almost doubling to 780,000 tons. The four new Lurgi DR rotary kilns at the Vanderbijlpark steelworks of South African Iron and Steel Industrial Corp. Ltd. (Iscor) produced 503,000 tons of DRI during the fiscal year ending June 30, 1986. By May, the plant was operating at 92% of its design capacity of 709,000 tons of DRI. The DR plant at the Dunswart steelworks produced an additional 75,000 tons during the 1985-86 fiscal year.

Iscor was supplied with about 9.5 million tons of iron ore products from the Sishen Mine and 2.33 million tons from the Thabazimbi Mine. The parastatal industrial group has four blast furnaces at Vanderbijlpark and one at Newcastle. An additional 8.07 million tons was exported from the Sishen Mine through Saldanha Bay. At Thabazimbi, exploration drilling continued on top of and around the newly discovered ore body west of the Donkerpoort open pit. Construction of a 300,000-ton-per-year ironmaking plant was also well under way at Iscor's Pretoria steelworks. The plant will utilize the KR (Kohle Reduktion) (coal reduction) process developed by Korf Engineering GmbH.

During the first half of 1986, Iscor also extracted ore from the Bruce Mine for its owner, Associated Manganese Mines of South Africa Ltd. (AMMOSAL). Since May 1980, much of the Bruce ore has gone to AMMOSAL's customers in Japan. The Bruce open pit mine is adjacent to Sishen and was being worked as part of the Sishen South operation. However, AMMOSAL did not renew its Bruce agreement with Iscor when it expired in June 1986.

AMMOSAL will replace the Bruce production with production from the company's other iron mine at Beeshoek, which is operated without Iscor's assistance. The production rate at Beeshoek already has been increased to 1.8 million tons per year, with the surplus being railed 930 kilometers to Saldanha Bay for loading on carriers bound for the EC or Japan. Beeshoek, like Bruce and Sishen, is situated in the Postmasburg area of Cape Province and has proven reserves of 60 million tons. The Beeshoek lump ore being exported averages 66.41% Fe, 2.70% SiO_2, 0.050% P, and a troublesome 0.18% (Na_2O+K_2O).

A variety of economic sanctions were imposed at yearend 1986 on trade to and from the Republic of South Africa by the Governments of the EC, Japan, and the United States. The sanctions affecting imports of South African ferrous metal products by these Governments included an EC ban on steel products (effective September 16), a Japanese ban on steel products and pig iron (September 19), and a U.S. ban on iron and steel products, pig iron, and iron ore (October 27).

Sweden.—Production of iron ore products totaled 20.2 million tons, a level almost identical to that of 1985. Exports, however, decreased 6% to 16.9 million tons as a result of declining sales of both fines and lump ore to continental Europe. Part of this decline was offset by the increasing acceptance and use of Swedish olivine pellets by several steelmakers in the EC. About 3.4 million tons of iron ore products was consumed in Sweden during 1986. Producers' stocks have fallen every year since 1982 as part of a plan to restore profitability and were only 2.62 million tons on December 31, 1986. Four years earlier, yearend stocks stood at 10.91 million tons.

Luossavaara-Kiirunavaara AB (LKAB) produced 17.6 million tons of finished products, including a record-high 8.7 million tons of pellets.[11] About 67% of the total tonnage was prepared from crude ore mined at Kiruna, with the rest coming from Malmberget. The plants at Malmberget, Kiruna, and Svappavaara produced 3.1 million tons, 3.0 million tons, and 2.6 million tons of pellets, respectively. LKAB shipped 18.3 million tons of ore products, mostly for export. Since 1968, sales of high-phosphorus Kiruna ore have declined from 69% of total sales to only 15%. At the same time, pellet sales have climbed from 12% to 56%. This change in product mix reflects the marketing success that LKAB has had with its olivine pellets over the last 3 years as well as the company's efforts to lower the relatively high phosphorus and alkali contents of its sinter fines.

The LKAB olivine pellet, introduced in 1981, has a higher melting temperature and better reducibility than the traditional acid pellet, which uses quartzite as a pellet strengthener. In an acid pellet undergoing reduction, the silica is free to react with unreduced iron oxide and form a liquid slag phase that plugs the pellet pores and prevents the reducing gas from readily reaching the core of the pellet. The magnesium oxide in the olivine, on the other hand, prevents the formation of any liquid phase before the iron melts, keeping the pellet porous throughout the entire reduction process. This improved reducibility makes the pellet behave more like sinter, lowering fuel consumption in the blast furnace. In 1986, the 6.7 million tons of olivine pellets produced by LKAB accounted for 36% of the company's total shipments of finished products.

Svensk Stål AB produced 1.91 million tons of concentrates, including 1.11 million tons of granulated sinter feed, at its Grängesberg Mine in central Sweden. An additional 586,000 tons of ore products was produced at the company's smaller Dannemora Mine north of Uppsala. These production levels were about 20% lower than those of 1985. Combined shipments totaled 2.49 million tons including 1.27 million tons for export.

Turkey.—On April 23, Turkiye Demir ve Celik Isletmeleri (TDCI/Turkish Iron and Steel Works) started up its new 1.3-million-ton-per-year pelletizing plant at Divrigi in Sivas Province.[12] The pelletizing plant is part of a $300 million project begun in 1975 to expand the capabilities of several mines in the district and was expected to be fully operational by 1988. A new beneficiating plant was completed in September 1985, giving the complex the capability of also producing 1.9 million tons of concentrate for use as sinter feed. Shipments in 1986 from Divrigi included 500,000 tons of pellets averaging 67.3% Fe and 1.36% SiO_2, 450,000 tons of concentrate, and 300,000 tons of lump ore. Most of the material was railed either to TDCI's steelworks on the Gulf of Iskenderun or to its Karabuk steelworks in the Black Sea Province of Zonguldak. Iskenderun, the largest integrated steelworks in Turkey, was planning to expand its annual capacity to produce pig iron from 2.2. million tons to 4.0 million tons. Some Divrigi pellets also were railed to the Black Sea Port of Samsun for transhipment by vessel to the Eregli steelworks on the coast of Zonguldak.

Iron ore was mined at Divrigi as early as the 15th century. However, significant production did not begin until 1938 when the A and B ore bodies were developed as near-surface underground mines to provide sinter feed for the then newly built steel complex at Karabuk. In 1982, TDCI began converting the mine workings into two open pits. The A ore body is a pyrometasomatic deposit of magnetite formed by the intrusion of syenite into limestone. The deposit has 40 million tons of reserves, averaging 54.5% Fe, but the ore contains 2.0% to 2.5% sulfur. The B ore body, on the other hand, is a hydrothermal deposit of hematite with only 14 million tons of reserves, averaging 55% Fe. The sulfur content of the B ore is much lower than that of the A ore, ranging from 0.2% to 0.3% sulfur. Because of the wide variations in the hematite-magnetite ratio and sulfur content, the two ores must be blended to provide the pellet plant with a uniform feed.

There were two other mines operating in the Divrigi area: the nearly exhausted Akdag hematite mine, which produced about 100,000 tons of lump ore and sinter feed and the new Dumluca Mine. The Dumluca open pit operation, 10 kilometers southwest of Divrigi, produced a total of 400,000 tons of direct-shipping ore and sinter fines during the year. This fourth mine, which opened in 1985, has reserves of 7 million tons of mainly hematite ore, averaging 56.5% Fe.

U.S.S.R.—Soviet exports were estimated at 46.2 million tons. According to the Association of Iron Ore Exporting Countries, exports in 1985 totaled 43.2 million tons, of which 9.8 million tons was pellets and 33.4 million tons was lump ore and other products. The material in the latter category included 10.8 million tons shipped to Poland, 9.5 million tons shipped to Czechoslovakia, 4.3 million tons shipped to Romania, and 2.8 million tons shipped to the German Democratic Republic. Shipments to Hungary dropped from 3.9 million tons in 1984 to 1.9 million in 1985 apparently as a result of that country's anticipated purchase agreements with India and other market economy countries.

Production of pellets in the U.S.S.R. in 1984, the most recent year reported by the United Nations, was 62.1 million tons. The largest mining enterprises were the Severnyy mining and beneficiation complex in the Krivoy Rog Basin producing 43.1 million tons of ore in 1986 and the Kachkanarskiy mining and beneficiation complex in Kazakhstan producing slightly less than 43 million tons. The Krivoy Rog Basin in the Ukraine accounted for over 40% of the country's iron ore production.

In recent years, the quality of ore has been deteriorating at several established mines in the Ukraine. Some ores were running only about 42% Fe, compared with a national average of 54.6%. Mining in both the Krivoy Rog Basin and the neighboring

Kursk Magnetic Anomaly of Central Russia was becoming increasingly expensive because of pit deepening. One-third of Soviet iron ore was being extracted from open pits at least 250 meters deep. Some open pits, such as the Sarbayskiy and Sokolovskiy of north-central Kazakhstan, reach 320 meters. To counter these problems, Soviet planners were (1) rapidly expanding new mines in Central Asia and Karelia, (2) upgrading beneficiation facilities and haulage equipment in the Krivoy Rog Basin, and (3) considering blending lower grade domestic ores with 63% to 67% material imported from Brazil and India. A new beneficiation plant at Krivoy Rog was to be added as part of a Council for Mutual Economic Assistance project during the 12th 5-year plan (1986-90). The new plant is supposed to convert annually 30 million tons of oxidized, ferruginous quartzite ores into 12.6 million tons of self-fluxing pellets. A significant fraction of the pellet production was to go to the Eastern European partners.

In Kazakhstan, the annual production capacity of the new Kachar mining and beneficiation complex already has been increased from 3 to 5 million tons, and was scheduled to be raised to 7 million by 1990. Although the Kachar complex had been under development for 10 years, it did not begin operating until 1985.

The No. 5 blast furnace at the Cherepovets Iron and Steel Works was commissioned in April 1986. The steelworks is on the north shore of the Rybinsk Reservoir west of Vologda and produces a variety of steels for the machinery industries of Leningrad. The 5,580-cubic-meter furnace had an annual capacity of 3.4 million tons of pig iron; however, construction work was still continuing. When fully operational, the blast furnace will have an annual capacity of 4.4 million tons and be the largest in the world. Nonfluxed pellets for the charge are being supplied by the new Kostamush Mine in Karelia. In the past, ore for the steelworks came largely from mines on the Kola Peninsula.

The third of four Midrex DR modules was almost ready for commissioning at the Stary Oskol Iron and Steel Works 125 kilometers southeast of Kursk. Each of the three gas-based, Series 400 units has a production capacity of 410,000 tons per year, raising the total annual capacity of the DR operation to 1,230,000 tons. The first module was brought on-line in late 1983, with the fourth one scheduled to be completed in late 1987. The management of the complex, Oskolskiy Electro-Metallurgicheskiy Kombinat (OEMK), was evaluating a proposal to construct an additional eight modules, beginning in 1995. The completion of all 12 modules would make OEMK the largest DRI producer in the world.

Venezuela.—Shipments of iron ore products by the state-owned C.V.G. Ferrominera del Orinoco C.A. (FERROMINERA) increased from 13.58 million tons (revised) in 1985 to 15.27 million tons. Exports through the Orinoco River Ports of Puerto Ordáz and Palua totaled 9.87 million tons, including 6.29 million for the EC and 1.97 million for the United States. The remaining 5.40 million tons was consumed domestically, primarily by the Matanzas steelmaking complex of C.V.G. Siderúrgica del Orinoco C.A. (SIDOR), another subsidiary of Corporación Venezolana de Guayana (CVG).

Trial shipments of hematite and martite ore from FERROMINERA's new Cerro San Isidro Mine near Cerro Bolivar reached Japan in November. Kawasaki Steel and Kobe Steel received 65,000 and 56,000 tons, respectively, of fines for sintering tests. To date, the relatively high-phosphorus content (0.055% to 0.062% P), friability, and dustiness of the San Isidro ore have bothered Japanese steelmakers and impeded the signing of a long-term contract with CVG.[13] A significant amount of San Isidro lump ore already has been exported to Belgium. Leaner ore from the Cerro Bolivar Mine that has even higher phosphorus (0.11% P) was being blended with San Isidro ore at the Puerto Ordáz loading yards. The blend is less dusty, but still marketable in terms of the iron and phosphorus content. FERROMINERA was expected to raise the annual capacity of San Isidro from 5 to 8 million tons by 1990. The mine has reserves of 400 million tons and would have a life of at least 50 years even at the increased rate of production. FERROMINERA was selecting bids from contractors for the construction of a 40,000- to 60,000-dwt transfer vessel. The transfer vessel would operate between Puerto Ordáz and the mouth of the Orinoco, topping off ore carriers as large as 160,000 dwt.

Venezuela was the largest producer of DRI in the world with 19% of world capacity. Production of DRI in 1986 was 2.87 million tons, of which about 52% was made by the Midrex process, 38% by the HYL process, and the rest was produced by Fior de Venezuela S.A.

In October, CVG and Kobe Steel, the parent company of Midrex, agreed to renovate the idle DR plant of Minerales Ordáz C.A. (MINORCA) at Puerto Ordáz and convert the operation to the Midrex process.[14] The renovated plant would have a capacity of 820,000 tons per year of hot briquetted iron and would be operated by a Venezuelan subsidiary of Kobe Steel under an 11-year lease from CVG. MINORCA is a wholly owned subsidiary of FERROMINERA and initially will use lump ore from San Isidro. The original plant, commissioned in 1973, never produced more than 200,000 tons per year. The facility was modified by MINORCA in 1977, but continued to have problems with its fluidized bed reactors and was closed finally in 1982. Midrex will replace the reactors with a single shaft furnace of its own design that has proven successful at the Labuan Island plant of Sabah Gas Industries Malaysia Sdn. Bhd. in eastern Malaysia.

There were two other DR producers in the Matanzas area. SIDOR is the larger of the two and has four Midrex modules and four HYL modules, with a total annual capacity of 4.04 million tons of DRI. Fior operates a single module that utilizes a process of its own design and has a capacity of 400,000 tons.

TECHNOLOGY

Intense competition in iron ore and steel markets and the need to reduce costs continued to stimulate technological improvements in iron ore production and use.

One of the more promising advances is a cold-bond agglomeration process that has been under development at Michigan Technological University (MTU) since the 1960's.[15] In July 1986, MTU and Pellet Technology Corp. (PTC) began constructing a demonstration plant near Negaunee, MI, to test a novel ironmaking technology that integrates the cold-bond agglomeration process with several other patented processes. The $15 million plant was being built around the Eagle Mills research center donated to MTU by Cleveland-Cliffs Iron. A grant from the State of Michigan provided $5.75 million of the plant's cost. The remaining $10 million was being borne by PTC, a partnership between MTU and a Pennsylvania entrepreneur.

The cold-bonded pellets are made by mixing iron oxide fines, carbon fines, burnt lime, and silica with a small amount of water and running the wet mixture through a pelletizer. The green pellets are then dried and fed to an autoclave where the materials bond with one another under hydrothermal conditions.

Laboratory studies have shown that these cold-bonded pellets are far superior to the acid pellets presently being used in blast furnaces. The kinetics of the iron reduction reaction are accelerated when cold-bonded pellets are substituted, drastically reducing melt time and fuel consumption. In conventional blast furnace operation, the surface of the acid pellet is in contact with relatively large particles of coke, about 3/8 inch in diameter. Under these conditions, a large fraction of the coke reacts with the furnace gases to form unusable carbon dioxide instead of oxidizable carbon monoxide. The cold-bonded pellet, in contrast, already contains micrometer-size carbon particles. Because these carbon particles are largely shielded in the interior of the pellet from diatomic oxygen in the furnace atmosphere, they react to form carbon monoxide instead of carbon dioxide. As a result, the cold-bonded pellet can be fully metallized in 5 to 10 minutes in a blast furnace as opposed to the traditional 12 hours required for an acid pellet. In addition, the faster reduction rate allows the cold-bonded pellet to be reduced in a hot-blast cupola, where the metal-to-slag ratio is much greater than that in a blast furnace. The addition of burnt lime and silica, which also undergoes hydrothermal alteration, makes the pellet self-fluxing as well as self-reducing.

The pelletizing section of the Eagle Mills plant uses dry steam to preheat the autoclave air so that hydrothermal conditions are attained. The 10-ton-per-hour pelletizing unit, which was scheduled for completion in June 1987, will employ four 40-foot-long autoclaves, each capable of holding 12 tons of pellets. The four autoclaves will operate in tandem, with one filling, one emptying, one operating, and one drying so that finished pellets will be produced continuously. Each stage will last 20 minutes so that the entire autoclaving cycle will take 80 minutes. Another key piece of equipment is a 10-ton-per-hour hot-blast cupola also scheduled for completion in June 1987. The hot-blast cupola is designed to convert scrap to hot metal at a rate of 10 tons per hour or pellets to hot metal at a rate of 5 tons of iron per hour. The metal is poured into a continuous pigging machine to produce 15-pound pigs of iron.

MTU was also studying the possibility of making ferrochromium from cold-bonded pellets of chromite ore. Other products under evaluation include stainless pig iron for argon-oxygen-decarburization (AOD) furnaces, ferromanganese, high-purity silicon carbide, high-purity silicon nitride, and Silacarb, an inexpensive substitute for silicon carbide and ferrosilicon. It may be feasible to produce a substitute for foundry coke by cold bonding discarded anthracite coal fines. MTU has proposed building a $10 million Silacarb pellet plant at Hubbel, MI. The Hubbel plant would have a capacity of 200,000 tons per year of Silacarb. The research group has also drawn up preliminary designs for a $55 million stainless steel plant producing 200,000 tons per year of stainless slab. Such a plant would be able to meet the needs of 20% of the present U.S. market for stainless steel.

On July 25, the U.S. Department of Energy (DOE) tentatively agreed to fund $65 million of the $163 million needed to construct the first commercial-scale KR plant in North America. The plant would be built at Weirton Steel Corp.'s facilities in Weirton, WV, and produce 330,000 short tons of iron per year. The project, which still needs Congressional approval, was one of 51 proposals submitted to DOE in April to demonstrate emerging clean coal technologies. The $65 million would come from the Clean Coal Technology Reserve established in 1984 by Public Law 98-473, an omnibus act. Additional funds would be provided by the State of West Virginia and West Virginia coal producers.

The KR process is a novel DR technology that can utilize a wide range of raw coals in place of more expensive coke to make iron.[16] Lump ore, sinter, or pellets can be used to provide the iron units. The direct charging of raw coal lowers hot metal costs and bypasses the environmental pollution problems associated with coke ovens. The KR process also produces a byproduct gas that can be used for heating, to produce oxygen, or to generate electrical energy. The technology has the potential of making the conventional coke-based blast furnace obsolete.

The reactions in the process are similar to those in the conventional blast furnace, but they take place in two separate chambers. One contains a fluidized bed where coal is gasified and prereduced iron is melted. The second chamber is a vertical shaft furnace where ore is reduced by gas from the fluidized bed. The process was developed jointly by Korf Engineering and Voest-Alpine AG. In recent tests at their 60,000-ton-per-year demonstration plant in Kehl, Federal Republic of Germany, hot metal was produced from a charge of Minntac pellets and West Virginia coal at a rate of 6 metric tons per hour. Contract negotiations between Korf Engineering, Weirton, and DOE were progressing slowly because of the financial, legal, and technical complexities of the project. A similar commercial-size plant is already under construction at the Iscor Pretoria Steelworks in the Republic of South Africa.

The North American steel industry has been searching for ways to improve blast furnace productivity and lower coke consumption as part of its struggle to reduce overall production costs and survive in an increasingly competitive marketplace. The substitution of organic binders for bentonite in the conventional pelletmaking process offers one method of improving the reducibility of the furnace burden and cutting coke usage by as much as 16 kilograms per metric ton of iron.[17] Extensive testing has shown recently that organic binders can satisfactorily replace bentonite in both acid and fluxed pellets.

Organic binders do not change the chemical composition of the fired pellet, unlike bentonite. The organic binder is burned off during induration, leaving a pellet with lower silica, alumina, and alkali contents than when bentonite is used. One organic binder, Peridur, has been extensively tested by Eveleth, Inland Steel, CVRD, LKAB, the Studiengellschaft für Eisenerzaufbereitung (Federal Republic of Germany), and others. Peridur is a cellulose-based material produced by Akzo Zout Chemie Nederland and marketed in the United States by Dreeland Colloids Inc. Louisiana Chemical Polymers Inc. also began marketing a competitive product called Tacbind. Tacbind is a custom blend of sodium carboxymethyl cellulose and soda ash (Na_2CO_3) that is manufactured at the company's plant in Baton Rouge.

In July 1984, Eveleth's Fairlane plant produced 51,500 tons of Peridur pellets during a 4-day period for testing by the Rouge Steel Co., one of the mine's owners.[18] Each ton of pellets was made using 1.54 pounds of Peridur and 2.70 pounds of bentonite. Rouge charged these pellets into its C blast furnace at Detroit during a 10-day test and found that they performed satisfactorily. The pellets in this test constituted 85% of the furnace burden. In the spring of 1985, Eveleth produced an additional 193,000 tons of Peridur pellets for Rouge and 181,000 tons for Armco, another Eveleth owner. This larger run of pellets, which contained only 0.20 pound of bentonite per ton, performed better, but created excessively high offgas dust loading levels. Subsequent studies showed that the dusting problem could be solved with a 1.0% limestone addition. Between May 5 and July 16, 1986, Eveleth produced 546,000 tons of PL pellets for Rouge and 254,000 tons for Armco. This third run utilized 1.8 pounds of Peridur and 22 pounds of limestone per ton of pellets. The third set of tests was so successful that Eveleth began permanent production of PL pellets for Armco on September 20. Rouge also has committed its entire share of Eveleth's 1987 output to PL pellet production. The use of Peridur has enabled Eveleth to lower the silica content of its pellets from 5.31% to 4.88% in terms of dry weight.

During the same 3-year period, Inland Steel also has been producing 100,000-ton batches of Peridur pellets at its Minorca Mine and testing them in the company's blast furnaces at East Chicago, IN.[19] The Indiana test results were similar to those found at Armco and Rouge. Acid pellets produced at Minorca using 1.71 pounds of Peridur per ton of fired pellets had a reducibility of 1.24% per minute compared with 1.05% per minute for bentonite. This significant increase in reducibility equates to a coke savings of 13.2 kilograms per metric ton of hot metal.

In a related project, Eveleth and the Bureau of Mines are working together to determine if an inexpensive binder can be made from natural cellulosic materials such as waste paper sludge. Initial research suggests that polymers with a linear-chain molecular structure may be more cost effective than polymers with ring-groups. The Bureau has tested over 180 different binders to date. Many suitable binders are unable to soak up the excess water trapped in the moist filter cake of concentrate. Superabsorbent polymers and starches may be able to be mixed with the binder to correct the absorption problem.

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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 1986, 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	1,716	3,371	33,819	10,558	6,802	64.4	10.03	3.13	2.02
Minnesota	4,100	7,674	84,923	27,005	17,304	64.1	11.07	3.52	2.25
Total[1] or average	5,816	11,046	118,742	37,564	24,105	64.2	10.75	3.40	2.18
Other States[2]	232	431	1,220	1,262	770	61.0	2.83	2.93	1.79
Grand total[1] or average	6,048	11,477	119,962	38,825	24,875	64.1	10.45	3.38	2.17

[1]Data may not add to totals shown because of independent rounding.
[2]Includes California, Missouri, Nevada, New Mexico, and Texas.

Table 3.—Crude iron ore[1] mined in the United States in 1986, 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
Lake Superior:				
Michigan	2	33,819	--	33,819
Minnesota	9	84,923	--	84,923
Total	11	118,742	--	118,742
Other States:				
Missouri	1	--	1,111	1,111
Other[2]	7	109	--	109
Total	8	109	1,111	1,220
Grand total	19	118,851	1,111	119,962

[1]Excludes byproduct ore.
[2]Includes California, Nevada, New Mexico, and Texas.

Table 4.—Usable iron ore produced in the United States in 1986, 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[1]
Lake Superior:				
Michigan	--	--	10,558	10,558
Minnesota	--	1,124	25,882	27,005
Total[1]	--	1,124	36,440	37,564
Other States:				
Missouri	--	47	758	805
Other[2]	72	385	--	457
Total[1]	72	432	758	1,262
Grand total[1]	72	1,556	37,198	38,825

[1]Data may not add to totals shown because of independent rounding.
[2]Includes California, Nevada, New Mexico, Texas, and Utah.

Table 5.—Shipments of usable iron ore[1] from mines in the United States in 1986

(Exclusive of ore containing 5% or more manganese)

District and State	Gross weight of ore shipped (thousand long tons)				Average iron content (natural) percent	Total value (thousand dollars)
	Direct-shipping ore	Concen-trates	Agglom-erates	Total quantity[2]		
Lake Superior:						
Michigan	--	--	10,957	10,957	64.4	W
Minnesota	--	1,345	27,435	28,779	64.0	1,017,261
Total reportable[2] or average	--	1,345	38,392	39,737	64.2	1,017,261
Other States:						
Missouri	--	48	754	803	65.2	W
Other[3]	149	640	--	789	56.0	15,740
Total reportable[2] or average	149	688	754	1,591	60.7	15,740
Total withheld	--	--	--	--	--	439,510
Grand total[2] or average	149	2,033	39,146	41,327	64.0	1,472,511

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, Nevada, New Mexico, New York, Texas, and Utah.

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	Marquette	Menominee	Gogebic	Vermilion	Mesabi	Cuyuna	Spring Valley	Black River Falls	Total[1]
1854-1979	493,158	327,299	320,334	103,528	3,241,832	70,336	8,149	7,919	4,572,552
1980	14,450	1,970	--	--	45,162	--	--	699	62,282
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	--	--	--	27,005	--	--	--	37,564
Total	575,348	329,344	320,334	103,528	3,486,784	70,336	8,149	9,713	4,903,534

[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
1981	64,925	63.13	0.020	5.70	0.17	0.30	2.59
1982	32,173	63.50	.018	5.40	.13	.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

[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.

Table 8.—U.S. consumption of iron ore and agglomerates in 1986, by State

(Thousand long tons and exclusive of ore containing 5% or more manganese)

State	Iron ore and concentrates[1]		Agglomerates[2]		Miscellaneous[3]	Total reportable[4]
	Blast furnaces	Steel furnaces	Blast furnaces	Steel furnaces		
Alabama, Kentucky, Texas, Utah	W	W	5,327	W	W	5,327
Illinois, Indiana, Michigan	W	W	28,356	W	W	28,356
Maryland and Pennsylvania	609	W	9,543	W	W	10,152
Ohio and West Virginia	42	W	15,620	W	W	15,662
Undistributed	139	77	--	321	1,082	1,619
Total[4]	789	77	58,845	[5]321	1,082	61,116

W Withheld to avoid disclosing company proprietary data; included with "Undistributed."
[1]Excludes pellets or other agglomerated products.
[2]Includes approximately 36,407 units of pellets produced at U.S. mines and 8,371 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]Data may not add to totals shown because of independent rounding.
[5]Includes an estimated 240 units of ore and agglomerates used for production of direct-reduced iron for steelmaking.

Table 9.—Iron ore consumed in production of sinter at iron and steel plants in the United States in 1986, by State

(Thousand long tons)

State	Iron ore consumed[1]	Sinter produced
Indiana, Kentucky, Michigan, Utah	3,087	6,854
Maryland and Pennsylvania	3,792	4,937
Ohio and West Virginia	1,373	2,261
Total	[2]8,251	14,052

[1]Includes domestic and foreign ores.
[2]Data do not add to total shown because of independent rounding.

Table 10.—U.S. production of iron ore agglomerates,[1] by type

(Thousand long tons)

Type	1985	1986
Sinter	[2]16,557	[3]14,052
Pellets	46,970	37,198
Total	63,527	51,250

[1]Production at mines and consuming plants.
[2]Includes 7,256 units of self-fluxing sinter.
[3]Includes 5,056 units of self-fluxing sinter.

Table 11.—U.S. exports of iron ore, by country

(Thousand long tons and thousand dollars)

Country	1984		1985		1986	
	Quantity	Value	Quantity	Value	Quantity	Value
Canada	4,988	238,856	5,033	240,435	4,479	204,600
India	(1)	2	--	--	(1)	17
Mexico	(1)	24	(1)	10	1	45
Netherlands	3	262	--	--	(1)	17
United Kingdom	(1)	32	--	--	--	--
Venezuela	(1)	15	(1)	22	(1)	39
Other	1	66	(1)	87	(1)	20
Total[2]	4,993	239,257	5,033	240,557	4,482	204,738

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

Table 12.—U.S. imports for consumption of iron ore, by country

(Thousand long tons and thousand dollars)

Country	1984		1985		1986	
	Quantity	Value	Quantity	Value	Quantity	Value
Brazil	2,533	55,132	2,540	49,322	3,693	71,045
Canada	11,190	413,473	8,557	325,248	8,696	311,757
Chile	--	--	164	2,320	93	2,126
Liberia	1,745	25,270	2,206	r31,014	1,487	21,855
Mauritania	--	--	--	--	65	1,158
Peru	7	76	121	2,722	91	2,429
Spain	34	877	--	--	--	--
Sweden	84	1,659	65	1,503	104	2,473
Venezuela	[1]1,524	[1]31,377	[2]2,068	[2]39,369	[3]2,309	[3]42,126
Other	70	1,201	50	769	204	5,674
Total	17,187	529,065	15,771	r452,267	[4]16,743	460,643

rRevised.
[1]Excludes approximately 64,000 long tons of sponge iron valued at $5,016,000, originally reported as iron ore.
[2]Excludes approximately 214,000 long tons of sponge iron valued at $15,635,828, originally reported as iron ore.
[3]Excludes approximately 83,000 long tons of sponge iron valued at $8,340,609, originally reported as iron ore.
[4]Data do not add to total shown because of independent rounding.

Table 13.—U.S. imports for consumption of iron ore, by customs district

(Thousand long tons and thousand dollars)

Customs district	1984		1985		1986	
	Quantity	Value	Quantity	Value	Quantity	Value
Baltimore	4,668	133,448	3,673	r71,363	5,567	144,725
Buffalo	(1)	(1)	(1)	5	(1)	25
Chicago	2,574	59,705	2,594	58,712	1,537	37,958
Cleveland	3,859	136,654	1,646	59,853	1,707	67,123
Detroit	393	12,927	542	19,107	382	17,798
Houston	133	2,758	165	2,541	42	745
Mobile	1,548	68,283	2,600	111,772	2,434	64,317
New Orleans	643	12,315	878	16,266	1,569	31,052
Philadelphia	3,250	98,777	3,408	107,029	3,237	90,592
Other	119	4,198	266	5,620	268	6,308
Total[2]	17,187	529,065	15,771	r452,267	16,743	460,643

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

Table 14.—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]				
	1982	1983	1984	1985[p]	1986[e]	1982	1983	1984	1985[p]	1986[e]
Albania[e 5]	690	840	[6]1,063	1,100	1,100	230	280	350	370	370
Algeria	3,831	3,626	3,606	3,716	[6]3,307	1,915	1,813	1,839	1,678	1,650
Argentina	[r]1,140	[r]1,144	1,043	1,180	1,180	[r]445	[r]332	312	354	354
Australia	86,309	69,916	92,900	91,400	88,600	54,688	[r]44,583	57,400	[r e]57,600	55,800
Austria	3,277	3,484	3,543	3,218	[6]3,071	1,028	1,090	1,120	1,003	[6]961
Bolivia	8	11	--	--	--	5	7	--	--	--
Brazil	91,687	87,315	110,287	121,057	[6]129,915	60,070	57,064	71,650	[r e]82,300	88,300
Bulgaria	1,527	1,775	2,030	1,954	1,970	467	545	612	597	597
Canada[7]	35,030	32,966	40,416	38,878	35,500	22,279	20,964	25,664	24,730	22,000
Chile	6,368	5,880	7,004	6,407	[6]6,898	[r]3,324	[r]3,023	3,322	3,500	[6]4,243
China[e]	68,000	70,000	74,000	79,000	88,600	34,000	35,000	37,000	39,000	44,300
Colombia	463	449	434	440	443	209	202	195	199	200
Czechoslovakia	1,832	1,873	1,839	[e]1,870	1,870	475	482	473	[e]480	490
Denmark[e]	8	--	--	--	--	3	--	--	--	--
Egypt	2,106	2,188	1,871	1,919	[6]2,101	1,053	1,094	935	960	1,048
Finland[8]	1,218	1,257	1,212	[e]1,180	590	774	809	776	[e]740	380
France	19,085	15,678	14,605	14,219	[6]12,240	6,088	4,981	4,606	4,464	[6]3,800
German Democratic Republic[9]	39	39	39	[e]39	39	20	20	20	[e]20	20
Germany, Federal Republic of	[r]1,291	961	962	1,018	[6]706	380	275	288	304	[6]209
Greece[5]	508	1,322	1,899	2,210	2,170	218	563	797	928	925
Hungary	460	434	377	[e]310	--	110	104	91	[e]74	--
India	40,256	[e]38,187	40,378	43,842	[6]47,045	25,201	23,905	25,276	26,212	[6]29,450
Indonesia	142	131	82	129	145	82	76	47	75	84
Iran[e 10]	740	840	840	840	840	390	440	440	440	440
Italy[11]	3	--	--	--	--	1	--	--	--	--
Japan	356	293	319	333	[6]287	221	182	199	209	[6]179
Kenya[12]	4	--	--	--	--	[e]2	--	--	--	--
Korea, North[e]	7,900	7,900	7,900	7,900	7,900	3,200	3,200	3,200	3,200	3,200
Korea, Republic of	610	645	615	657	[6]573	342	[r]342	344	368	320
Liberia	17,878	14,701	14,862	15,076	[6]15,053	11,082	9,114	[e]9,212	9,271	[6]9,330
Malaysia	336	112	191	179	[6]205	205	69	117	109	[6]125
Mauritania[13]	8,125	7,268	9,377	9,186	8,760	4,675	[e]4,183	5,663	[r e]4,600	4,400
Mexico[14]	8,026	7,913	8,186	7,698	[6]7,183	5,297	5,222	5,402	5,080	[6]4,741
Morocco	220	170	160	[e]188	[6]193	137	104	99	[e]116	[6]121
New Zealand[15]	2,747	2,168	2,376	[e]2,400	2,400	1,566	1,236	1,354	[e]1,402	1,400
Norway	3,489	3,489	3,776	3,413	[6]3,601	[r]2,246	[r]2,271	2,462	2,218	[6]2,340
Peru	5,683	4,289	4,012	5,023	4,900	3,751	2,824	2,676	3,350	[6]3,290
Philippines	6	3	--	--	--	3	2	--	--	--

See footnotes at end of table.

Table 14.—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]				
	1982	1983	1984	1985[p]	1986[e]	1982	1983	1984	1985[p]	1986[e]
Poland	48	10	11	11	11	14	3	3	3	3
Portugal[16]	27	35	35	72	[6]50	9	12	12	11	[6]19
Romania	2,112	1,956	1,886	2,251	2,260	551	607	512	531	530
Sierra Leone	65	[r]413	[e]349	[r e]69	--	40	260	219	39	--
South Africa, Republic of[17]	24,166	16,343	24,258	24,028	24,096	15,467	10,459	15,500	14,838	15,180
Spain[18]	8,238	7,331	7,146	6,361	[6]5,993	4,065	3,457	3,502	3,139	[6]2,734
Sweden	15,888	[r]14,040	17,837	20,131	[6]20,165	10,324	[r]9,124	11,003	13,287	13,306
Thailand	27	39	60	93	[6]36	15	22	32	51	[6]21
Tunisia	271	311	303	304	295	146	166	163	163	159
Turkey	3,007	[r]4,085	3,973	3,371	3,900	1,628	[r]2,213	2,157	1,826	2,132
U.S.S.R	240,551	241,328	243,201	243,728	246,000	129,969	131,454	132,680	[r e]133,900	135,000
United Kingdom	463	378	397	270	[6]284	101	80	84	59	63
United States[18]	35,433	37,562	51,269	48,751	[6]38,825	22,642	24,167	33,110	31,296	24,875
Venezuela	11,023	9,562	12,848	15,972	18,800	6,834	5,924	7,965	9,902	11,650
Yugoslavia	5,025	4,939	5,237	5,391	[6]6,575	1,653	1,505	[e]1,673	1,770	1,970
Zimbabwe	824	911	912	1,083	1,100	492	586	625	650	650
Total	[r]768,566	[r]728,510	821,926	839,865	847,775	[r]440,132	[r]416,440	473,181	487,416	493,359

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through July 14, 1987.
[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, Denmark, 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, except for 1982.
[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]Year beginning Mar. 21 of that stated.
[11]Excludes iron oxide pellets produced from roasted pyrite.
[12]For cement manufacture.
[13]Gross weight is exported iron ore (Mauritania exports all of its iron ore).
[14]Gross weight calculated from reported iron content based on grade of 66% Fe.
[15]Concentrates from titaniferous magnetite beach sands.
[16]Includes manganiferous iron ore.
[17]Includes magnetite ore as follows, in thousand long tons: 1982—4,253; 1983—3,414; 1984—3,780; 1985—3,550; and 1986—Not available.
[18]Includes byproduct ore.

Iron Oxide Pigments

By Donald P. Mickelsen[1]

U.S. mine production and value of shipments of crude iron oxide pigments increased in 1986 while shipments declined. Total domestic shipments of both natural and synthetic finished iron oxides and their unit values increased slightly over those of 1985. Synthetic iron oxide comprised 64% of all shipments. Columbian Chemicals Co., a leading synthetic iron oxide pigment producer, was purchased in December by Phelps Dodge Corp., the largest domestic copper producer.

Coatings was the largest end use for iron oxide pigments, followed, in order of ranking, by construction materials; colorants for ceramics, glass, paper, plastics, rubber, and textiles; foundry sands; industrial chemicals; and other uses.

List prices for iron oxide pigments remained virtually unchanged from those in 1985. The weakening of the U.S. dollar gave domestic iron oxide pigment producers a competitive advantage over lower priced imports and strengthened the domestic market.

The United States imported 28% more iron oxide pigments than it exported in 1986. A decline in imported pigment-grade iron oxides from 1985 levels was attributed to a weakened U.S. dollar compared with foreign currencies. Synthetic iron oxide imports showed a moderate decrease while imports of natural iron oxides exhibited a strong increase. World mine production of natural iron oxide pigments for reporting countries increased slightly compared with that of 1985.

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 four of five companies representing 100% of all iron oxide pigments mined and essentially 100% of all shipments of crude iron oxides in the United States. Of the 16 companies canvassed for finished iron oxide pigments sales data in 1986, 100% responded, representing 100% of the total production shown in table 2. Of the five companies canvassed for sales data for iron oxide recovered from steel plant wastes, including steel plant dust and regenerator oxide, 100% responded, representing 34% 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

	1982	1983	1984	1985	1986
Mine production ____ short tons	28,082	26,499	29,307	32,234	33,889
Crude pigments sold or used ____ do	46,548	41,875	53,017	46,585	40,987
Value ____ thousands	$2,059	$2,427	$2,819	$2,826	$2,908
Finished pigments sold ____ short tons	104,951	122,861	129,492	126,822	131,357
Value ____ thousands	$84,736	$110,662	$122,620	$122,716	$126,788
Exports ____ short tons	9,065	12,661	32,428	29,720	28,841
Value ____ thousands	$17,795	$20,692	$31,832	$27,574	$30,830
Imports for consumption ____ short tons	25,855	30,747	38,239	39,799	36,773
Value ____ thousands	$13,330	$16,684	$21,523	$22,565	$21,517

DOMESTIC PRODUCTION

Mine production of crude iron oxide pigments increased 5% over 1985 levels while shipments decreased 12% in quantity and increased slightly in total value. Four companies mined and shipped various grades of iron oxide pigments. One company in Georgia mined and shipped ocher and umber; 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, increased slightly in quantity and value compared with those of 1985. Synthetic iron oxides, which constituted 64% of all shipments, increased 12% in quantity and 6% in value, while natural iron oxide pigments decreased overall 9% in quantity and 16% in value compared with 1985 levels. Shipments of natural iron oxides decreased in all categories except for magnetite, with a noticeable decrease of 12% in red iron oxide. Red iron oxides, by far the largest category, accounted for 48% of the natural oxides shipped in 1986. Unit values for natural finished iron oxides in general increased, except for red iron oxide, which experienced a sharp drop from that of 1985. Of the 13 natural iron oxide producers canvassed, 6 reported increases in domestic shipments while the remaining producers reported decreases. Synthetic iron oxide shipments in all categories except for the category "Other" increased significantly, although the unit value for each category declined moderately. Five of the seven synthetic oxide producers canvassed reported increases in shipments.

Iron oxide for use in magnetic applications, not shown in table 2, was produced by two domestic companies. Production and shipment data are unavailable because of their proprietary nature.

An estimated 39,000 short tons[2] of steel plant byproduct iron oxides, in the form of regenerator oxide and steel plant dust, was shipped in 1986. Of the five plants canvassed, representing 34% of estimated shipments with a value of $1.1 million, two showed increases in shipments, and three showed decreases. Although data on the remaining steel plant wastes are unavailable, officials in the industry projected their use to be in the manufacture of ferrites.

In December, Columbian Chemicals was purchased by Phelps Dodge, the largest domestic copper producer. Columbian Chemicals, a leading producer of synthetic iron oxide pigments, will continue to operate as an independent business under the present management.[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. To avoid disclosing company proprietary data, several additional iron oxide pigment categories have been withheld for 1986.

Table 2.—Finished iron oxide pigments sold by processors in the United States, by kind

Kind	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)
Natural:				
Black: Magnetite	5,440	$908	6,401	$1,095
Brown:				
Iron oxide[1]	W	W	W	W
Umbers:				
Burnt	3,135	2,778	[2]3,311	[2]2,989
Raw	1,863	1,340	([3])	([3])
Red:				
Iron oxide[4]	25,913	4,321	22,878	3,294
Sienna, burnt	554	502	[5]334	[5]311
Yellow:				
Ocher[6]	14,613	4,494	14,335	4,525
Sienna, raw	233	228	([7])	([7])
Total	51,751	14,571	47,259	[8]12,213

See footnotes at end of table.

Table 2.—Finished iron oxide pigments sold by processors in the United States, by kind —Continued

Kind	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)
Synthetic:				
Brown: Iron oxide[9]	18,484	$25,566	23,213	$28,502
Red: Iron oxide	33,729	47,045	36,182	49,780
Yellow: Iron oxide	18,112	24,225	([10])	([10])
Other: Specialty oxides[11]	4,746	11,309	24,703	36,293
Total	75,071	108,145	84,098	114,575
Mixtures of natural and synthetic iron oxides	W	W	W	W
Grand total	126,822	122,716	131,357	126,788

W Withheld to avoid disclosing company proprietary data.
[1]These data are included with yellow ocher to avoid disclosing company proprietary data.
[2]Includes raw umber.
[3]Included with burnt umber to avoid disclosing company proprietary data.
[4]Includes pyrite cinder.
[5]Includes raw sienna.
[6]Includes yellow and brown iron oxides.
[7]Included with burnt sienna to avoid disclosing company proprietary data.
[8]Data do not add to total shown because of independent rounding.
[9]Includes synthetic black iron oxide.
[10]Included with "Other: Specialty oxides" to avoid disclosing company proprietary data.
[11]Includes mixtures of natural and synthetic iron oxides in 1985 and yellow iron oxide and mixtures of natural and synthetic iron oxides in 1986.

Table 3.—Producers of iron oxide pigments in the United States in 1986

Producer	Mailing address	Plant location
Finished pigments:		
American Minerals Inc	Foot of Jefferson St. Camden, NJ 08101	Camden, NJ.
BASF Corp., Chemicals Div., Dyestuffs & Pigments Group.	491 Columbia Ave. Holland, MI 49423	Wyandotte, MI.
Blue Ridge Talc Co. Inc	Box 39 Henry, VA 24102	Henry, VA.
Chemalloy Co. Inc	Box 350 Bryn Mawr, PA 19010	Bryn Mawr, PA.
Chesapeake Specialty Products, a division of Bethlehem Steel Corp.	5055 North Point Blvd. Baltimore, MD 21219	Baltimore, MD.
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.
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.
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.
St. Joe Lead Co., Pea Ridge Iron Ore Co	7733 Forsyth Blvd. Clayton, MO 63105	Sullivan, MO.
Solomon Grind-Chem Services Inc	Box 1766 Springfield, IL 62705	Springfield, IL.
Sterling Drug Inc., Hilton-Davis Chemicals Div.	2235 Langdon Farm Rd. Cincinnati, OH 45237	Cincinnati, OH.
Crude pigments:		
Cleveland-Cliffs Iron Co., Mather Mine and Pioneer Plant (closed July 31, 1979; shipping from stockpile).	1460 Union Commerce Bldg. Cleveland, OH 44115	Negaunee, MI.
Hoover Color Corp	Box 218 Hiwassee, VA 24347	Hiwassee, VA.
New Riverside Ochre Co	Box 387 Cartersville, GA 30120	Cartersville, GA.
St. Joe Lead Co., Pea Ridge Iron Ore Co	7733 Forsyth Blvd. Clayton, MO 63105	Sullivan, MO.
Virginia Earth Pigments Co	Box 1403 Pulaski, VA 24301	Hillsville, VA.

CONSUMPTION AND USES

Iron oxide pigments were consumed mainly as an ingredient in coatings; in construction materials; 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.

Coatings continued to be the largest end use for iron oxide pigments, comprising 32% of all shipments and totaling 41,900 tons in 1986. This was slightly less than that consumed in 1985. Preliminary data developed by the U.S. Department of Commerce[4] indicate 968 million gallons of coatings valued at $9.7 billion was shipped, up 3% in volume over that of 1985. Architectural coatings comprised 50% of all shipments and totaled 481 million gallons; product coatings-original equipment manufacture was 339 million gallons, or 35% of shipments; and 15%, or 148 million gallons, was special-purpose coatings.

Usage of iron oxide pigments in construction materials increased slightly in quantity and percentage of total shipments over that of 1985. Consumption increased 4% over 1985 levels, to 37,697 tons, and comprised 29% of all iron oxide pigments consumed.

Of all iron oxides, 12%, or 15,637 tons, was consumed as colorants for ceramics, glass, paper, plastics, rubber, and textiles, representing a small increase in consumption over that of 1985. Iron oxides, which are the second largest inorganic pigments consumed, are popular because of their low cost, coloring effectiveness in thermoplastics and thermosets, and because of Food and Drug Administration acceptance for food contact and medical applications.

The remaining 27% of reported iron oxide pigment consumption, in order of ranking, was in the manufacture of foundry sands, industrial chemicals, 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 39,000 tons was shipped for consumption in 1986. 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	
	1985	1986	1985	1986	1985	1986
Coatings (industrial finishes, trade sales: lacquers, paints, varnishes	33	32	22	19	41	39
Construction materials (cement, mortar, preformed concrete, roofing granules)	28	29	30	30	28	28
Colorants for ceramics, glass, paper, plastics, rubber, textiles	12	12	12	12	12	11
Foundry sands	6	7	14	14	--	W
Industrial chemicals (such as catalysts)	5	6	1	W	7	W
Animal feed and fertilizers	6	4	13	11	1	W
Other (including cosmetics and ferrites)	10	10	8	[2]14	11	[3]22
Total	100	100	100	100	100	100

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Data do not include magnetic iron oxide usage.
[2]Includes industrial chemicals iron oxide usage.
[3]Includes industrial chemicals, animal feed and fertilizer, and foundry sands iron oxide usage.

PRICES

List prices for natural and synthetic grades of iron oxide pigments sold in 1986 by major producers remained practically unchanged from those of 1985. The steady decline in the value of the U.S. dollar, however, led to a strengthened domestic iron oxide pigment market in which domestic producers, particularly synthetic producers, could viably compete with lower valued imports. Correspondingly, price discounting for larger accounts in 1985, which in effect nullified attempted price increases, declined in 1986, resulting in an upward turn in prices. The fourth quarter of 1986 indicated a continuation of this trend, with domestic producers maintaining a strong market share and allowing them to begin recouping from the higher production costs of recent years.

Table 5.—Prices quoted on finished iron oxide pigments, per pound, bulk shipments,[1] December 31, 1986

Pigment	Low	High
Black:		
Natural	--	$0.2700
Synthetic	$0.6900	.7150
Micaceous	--	.6875
Brown:		
Ground iron ore	.1300	.1450
Metallic	.1650	.2950
Pure, synthetic	--	.7050
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	--	.6600
Spanish	--	.2950
Yellow:		
Synthetic	--	.6800
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 28% more iron oxide pigments than it exported in 1986. This trade imbalance represented a 6% decrease from that of 1985 and was the result of the weakening of the U.S. dollar compared with foreign currencies. Total value of U.S. exports of iron oxide pigments was $30.8 million, or $9.3 million greater than that of U.S. imports, resulting in a trade surplus.

U.S. imports of iron oxide pigments for consumption decreased 8% in quantity and 5% in value compared with those of 1985 and were received from 24 countries. Imports of synthetic iron oxides decreased 13% in quantity and 8% in value and comprised 78% of all imports received, 5% less than that of 1985. Synthetic black and red grades of iron oxides increased in quantity 42% and 22%, respectively, while synthetic yellow and other synthetic grades decreased 13% and 35%, respectively. The unit value for synthetic black increased 3 cents to 29 cents per pound, synthetic red decreased 4 cents to 21 cents per pound, synthetic yellow iron oxides increased 2 cents to 21 cents per pound, and other grades of synthetic iron oxides increased 17 cents to 68 cents per pound. Synthetic iron oxides were received chiefly from the Federal Republic of Germany, Canada, Mexico, Japan, and the United Kingdom, comprising 49%, 24%, 9%, 8%, and 7% of total imports, respectively.

U.S. imports of natural iron oxides increased 21% in quantity and 36% in value compared with 1985 levels. The most sizable increases, which were responsible for overall increases in natural imports, occurred in crude and finished umbers and in Vandyke brown, which rose 12%, 106%, and 42%, respectively, over 1985 levels. Unit values for all grades of natural crude iron oxides, except crude ocher, and all grades of finished iron oxide pigments, except finished umber, increased. Cyprus, Spain, France, the Federal Republic of Germany, and the United Kingdom, in order of ranking, supplied 97% of all imports of natural iron oxides. Finished umber was primarily received from Cyprus and the United Kingdom; sienna, from 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

1986, iron oxides, including regenerator oxides, were received from Canada and several Western European countries.

U.S. exports of pigment-grade iron oxides and hydroxides decreased slightly in quantity but increased 12% in value compared with those of 1985. These exports were received by 49 countries, principally in Europe, Asia, and other North American countries. Chief destinations for pigment-grade iron oxide pigments, by order of ranking, were the Federal Republic of Germany, Canada, Japan, and the United Kingdom. Exports to the Federal Republic of Germany increased slightly over those of 1985 and had an average value of 27 cents per pound, practically the same as that of 1985. Exports of other grades of iron oxides and hydroxides increased 31% in quantity and 86% in value compared with those of 1985. Main destinations were the Republic of Korea, Mexico, Japan, and Belgium-Luxembourg, in order of ranking.

Table 6.—U.S. exports of iron oxides and hydroxides, by country

Country	1985				1986			
	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
Argentina	2	$9	--	--	2	$31	10	34
Australia	45	89	186	$532	168	250	263	630
Belgium-Luxembourg	2,126	1,099	319	465	35	71	630	945
Brazil	91	259	158	542	83	178	188	736
Bulgaria	44	98	--	--	14	43	6	19
Canada	2,171	2,983	274	441	2,868	3,748	322	817
China	(1)	3	1	5	39	75	52	230
Colombia	59	48	11	17	59	51	20	24
Denmark	3	11	3	12	38	153	--	--
Dominican Republic	1	6	23	6	32	43	3	6
Ecuador	15	31	1	9	23	58	5	9
Egypt	--	--	20	26	--	--	53	35
El Salvador	30	72	4	9	3	4	(1)	1
Finland	24	35	10	14	--	--	20	43
France	666	1,078	118	230	415	1,447	161	289
Germany, Federal Republic of	19,587	10,389	76	176	19,875	10,799	180	353
Hong Kong	358	352	82	304	767	2,151	463	2,023
India	1	2	2	9	2	9	10	29
Indonesia	--	--	616	269	31	95	223	79
Ireland	67	216	--	--	40	87	3	4
Israel	--	--	--	--	3	8	3	31
Italy	268	1,499	7	11	355	1,749	12	19
Jamaica	2	4	--	--	7	9	--	--
Japan	2,186	2,307	1,752	4,708	1,795	2,565	756	1,883
Korea, Republic of	155	154	117	328	74	107	2,584	9,318
Libya	--	--	24	56	--	--	--	--
Malaysia	--	--	--	--	23	23	--	--
Mexico	293	437	390	1,027	376	426	1,073	1,811
Morocco	--	--	33	50	--	--	--	--
Netherlands	115	180	62	159	46	172	88	211
New Zealand	16	38	19	46	7	16	21	47
Oman	--	--	653	301	--	--	--	--
Panama	6	6	--	--	(1)	1	2	4
Peru	1	2	--	--	8	123	--	--
Philippines	15	11	2	3	117	139	3	10
Singapore	22	62	430	409	61	86	181	625
South Africa, Republic of	7	15	--	--	5	11	6	13
Spain	11	42	--	--	5	22	19	12
Sweden	1	2	10	23	--	--	11	16
Switzerland	20	48	--	--	22	66	(1)	1
Taiwan	65	177	94	214	286	625	95	224
Thailand	19	15	4	4	52	48	--	--
Turkey	--	--	--	--	5	34	--	--
United Arab Emirates	--	--	38	63	(1)	1	--	--
United Kingdom	1,073	5,424	274	543	1,049	5,188	237	532
Uruguay	5	6	--	--	5	8	--	--
Venezuela	133	292	42	144	38	87	45	39
Yemen, Aden	--	--	55	104	--	--	--	--
Yemen, Sanaa	--	--	20	43	--	--	--	--
Other	r17	r73	r20	r62	8	23	1	2
Total	29,720	27,574	[2]5,953	11,364	28,841	30,830	7,807	21,154

rRevised.
[1]Less than 1/2 unit.
[2]Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

Table 7.—U.S. imports for consumption of selected iron oxide pigments, by type

Pigment	1985		1986		Major sources, 1986[1] (short tons)
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	
Natural:					
Crude:					
Ocher	1	$6	603	$72	France 603; West Germany 1.
Sienna	225	30	46	13	Japan 44; Italy 2.
Umber	4,564	674	5,119	838	Cyprus 4,783; Spain 293; France 31; West Germany 12.
Other	150	248	207	377	Cyprus 82; Japan 54; Belgium 20; Spain 20; Venezuela 17; West Germany 7; Canada 3; France 3; United Kingdom 1.
Total[1]	4,940	957	5,974	1,301	
Finished:					
Ocher	25	16	1	6	Canada 1.
Sienna	45	19	98	60	Italy 84; Canada 14.
Umber	357	121	736	233	Cyprus 515; United Kingdom 160; West Germany 60; Canada 2.
Vandyke brown	404	140	572	293	West Germany 528; United Kingdom 23; Netherlands 21.
Other	876	313	638	242	Spain 613; Japan 12; West Germany 7; Canada 3; France 2; Switzerland 1.
Total[1]	1,707	608	2,045	834	
Synthetic:					
Black	733	386	1,041	605	United Kingdom 570; West Germany 366; Netherlands 60; Ireland 22; Belgium 20; China 2; Canada 1.
Red	5,724	2,835	6,987	2,960	Canada 2,469; West Germany 2,063; Mexico 897; United Kingdom 594; Brazil 334; Japan 289; Spain 213; Belgium 55; Austria 40; Netherlands 20; China 6; Nauru 4; France 2.
Yellow	15,011	5,773	13,102	5,524	West Germany 10,085; Mexico 1,694; United Kingdom 658; Canada 375; Brazil 210; Japan 38; Peru 20; Nauru 15; China 6.
Other[2]	11,684	12,005	7,624	10,293	Canada 3,962; Japan 1,848; West Germany 1,503; United Kingdom 100; Belgium 70; Netherlands 67; Austria 40; France 15; Mexico 13; Sweden 7.
Total[1]	33,151	20,999	28,754	19,382	
Grand total[1]	39,799	22,565	36,773	21,517	

[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			
	1985		1986		1985		1986	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Australia	20	$10	--	--	--	--	(1)	$3
Austria	20	9	--	--	--	--	79	54
Belgium-Luxembourg	21	7	20	$6	303	$102	145	142
Brazil	--	--	--	--	432	235	545	363
Canada	62	28	22	31	8,292	2,230	6,807	1,612
Cyprus	4,796	742	5,379	947	--	--	--	--
Denmark	--	--	--	--	11	10	1	4
Dominican Republic	--	--	--	--	60	16	--	--
France	41	60	639	104	3	16	18	52
Germany, Federal Republic of	422	177	613	340	15,864	7,997	14,017	7,806
Ireland	--	--	--	--	21	14	22	14
Italy	245	37	86	48	--	--	--	--
Japan	28	157	110	320	3,963	7,826	2,175	6,229
Mexico	--	--	--	--	2,527	1,350	2,604	1,613
Nauru	--	--	--	--	--	--	19	11
Netherlands	96	79	21	10	489	226	146	79
Peru	--	--	--	--	--	--	20	6
Spain	756	159	926	225	143	45	213	40
Sweden	6	10	--	--	17	349	7	165
Switzerland	--	--	1	9	15	11	(1)	2
United Arab Emirates	--	--	--	--	20	10	--	--
United Kingdom	111	47	184	83	958	545	1,922	1,126
Other	25	43	18	12	33	17	15	60
Total[2]	6,647	1,566	8,019	2,135	33,151	20,999	28,754	19,382

[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 only slightly compared with that of 1985. In addition to these countries, other countries, including the centrally planned economy countries, undoubtedly produce natural iron oxide pigments. Natural red iron oxide was produced primarily by India and Spain; yellow ocher was produced principally by France, the Republic of South Africa, Spain, and the United States; and sienna was produced mainly by Cyprus and Italy. Cyprus was the major umber producer, Austria was the principal micaceous iron oxide producer, and the Federal Republic of Germany was the main Vandyke brown producer.

Synthetic iron oxides comprise the largest percentage of colored inorganic pigment production in the world. Their popularity is attributed to 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 also made continuous gains in total market share over natural iron oxides because of product consistency, higher tinting strengths, and more saturated color shades compared with 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.

For 1986, sales of iron oxides in Japan were expected to increase to 160,700 tons, 6% over those of 1985. This follows a 12% drop in sales from 1984 to 1985. Magnetic material end uses were expected to continue to dominate iron oxide sales, comprising 75% of the total or 120,800 tons. The largest consumer of magnetic materials was the electronics industry for use in the manufacturing of office automation and audio and visual equipment. Demand for hard and soft ferrites for use as magnetic materials was forecast to increase 8% in 1986. Other major areas for domestically produced iron oxide and their projected end-use sales were, in order of ranking, paints, roads, printing inks, construction materials, synthetic resin, ceramics, paper, and other uses.[5]

[1]Mineral industry specialist, Division of Ferrous Metals.
[2]Unless otherwise specified, the unit of weight in this chapter is the short ton.
[3]Chemical Week. A Copper Company Diversifies Into Carbon Black. V. 129, No. 21, Nov. 19, 1986, p. 5.
[4]Bureau of the Census (Dep. Commerce). Paint, Varnish, and Lacquer. Rep. M28F (monthly), 1986.
[5]Roskill Information Services Ltd. (London). Roskill's Letter From Japan. Ferric Oxide: 6% Increase in Demand From Ferrite and Magnetic Tape Sectors. RLJ No. 128, Dec. 1986, p. 15.

Table 9.—Natural iron oxide pigments: World mine production, by country[1]

(Short tons)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Argentina	1,027	940	882	[e]880	880
Austria	10,549	12,935	[e]12,700	[e]11,000	12,000
Brazil	5,811	4,211	4,689	[e]5,000	5,200
Canada[e]	3,100	3,100	3,100	2,200	2,200
Chile	2,695	7,442	17,762	[e]16,500	16,500
Cyprus	22,046	17,637	14,440	13,448	13,200
Egypt	[e]160	--	--	--	--
France[e]	17,600	17,600	16,500	[r]16,000	16,500
Germany, Federal Republic of[3]	20,491	21,921	17,833	17,377	17,600
India	93,464	97,701	118,886	119,655	119,000
Iran[e 4]	550	660	660	660	660
Italy[e]	900	1,000	900	[r]950	960
Pakistan	453	[r]911	1,237	516	990
Paraguay[e]	130	200	275	220	220
South Africa, Republic of	2,355	1,861	1,092	829	1,500
Spain:					
Ocher	12,907	10,890	11,371	11,346	11,600
Red iron oxide[e]	25,000	22,000	22,000	[r]23,000	22,000
United States	28,082	26,499	29,307	32,234	[5]33,889
Zimbabwe[e]	1,100	1,100	1,100	1,100	880

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through Apr. 14, 1987.
[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 declined because of weak demand and the effects of a strike at the largest steel producer. The industry again operated at less than two-thirds of its capability, despite continuing reductions in capacity.

Most major integrated steel companies negotiated new, lower cost contracts with their unionized workers. The second largest domestic steelmaker entered bankruptcy, and others changed their corporate structures. Despite reductions in capacity, the industry added new equipment such as continuous casting machines and electrolytic galvanizing lines in order to improve their efficiency or the quality of their products.

Imports again declined because of a program of export restraint agreements that were negotiated with exporting countries. The lower value of the U.S. dollar also tended to reduce imports and to favor exports.

Table 1.—Salient iron and steel statistics

(Thousand short tons unless otherwise specified)

	1982	1983	1984	1985	1986
United States:					
Pig iron:					
Production	43,342	48,770	51,961	49,963	44,287
Shipments	43,449	49,081	52,164	50,010	44,372
Annual average composite price, per ton[1]	$213.00	$213.00	$213.00	$213.00	$213.00
Exports[2]	54	6	57	32	47
Imports for consumption[2]	322	242	702	338	295
Steel:[3]					
Production of raw steel:					
Carbon	64,143	73,783	79,918	76,699	71,413
Stainless	1,235	1,750	1,772	1,683	1,689
All other alloy	9,198	9,082	10,838	9,877	8,505
Total[4]	74,577	84,615	92,528	88,259	81,606
Capability utilization[5] percent	48.4	56.2	68.4	66.1	63.8
Net shipments of steel mill products	61,567	67,584	73,740	73,043	70,263
Finished steel annual average composite price cents per pound[1]	25.271	26.190	27.313	27.582	24,792
Exports of major iron and steel products[2]	2,367	1,589	1,413	1,266	1,197
Imports for consumption of major iron and steel products[2]	17,385	17,964	27,488	25,707	21,884
World: Production:					
Pig iron	[r]504,228	[r]510,241	546,751	[p]555,416	[e]546,833
Raw steel (ingots and castings)	[r]709,860	[r]730,593	782,910	[p]790,036	[e]780,966

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Iron Age.
[2]Bureau of the Census.
[3]American Iron and Steel Institute (AISI).
[4]Data may not add to totals shown because of independent rounding.
[5]Raw steel production capability is defined by AISI as the tonnage capability to produce raw steel for a sustained full order book.

Total world production of iron and steel was little changed, and the world continued to have excess capacity. Changes in the value of currencies in international exchange markets made steel from Japan less competitive. The trend toward reduction of capacity in the traditional industrialized countries and the construction of new capacity in newly industrialized countries continued.

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 30 iron and steel operations to which a survey request was sent, 70% responded, representing 78% 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.

Legislation and Government Programs.—The Tax Reform Act of 1986 (Public Law 99-514) included special provisions for companies in the iron and steel industries to carryback unused tax credits for 15 years. Because many steel companies were unprofitable in recent years, they were unable to use the credits. The new law allowed such companies to claim refunds, of up to 50% of the credits, on taxes paid in the last 15 years. The refunds are to be used for modernization or research and development expenses.

Research was begun at U.S. Department of Energy national laboratories in a joint Government-industry program to develop radically new technology to improve the long-term competitiveness of the domestic iron and steel industry. Two areas for early emphasis in the work were to be the casting of liquid steel to near final shape and new processes for producing liquid steel from ore or scrap.

DOMESTIC PRODUCTION

Production of raw steel and shipments of finished steel products declined significantly in 1986. Raw steel production was at the lowest level since 1982, and the second lowest since 1949. As in other years since 1982, production peaked in the first half of the year and then declined in the second half. Production in the second half of 1986 was depressed by labor strikes as well as seasonal factors. Capability utilization peaked at 75% in March but fell to 50% in early August at the beginning of a major strike. The American Iron and Steel Institute (AISI) estimated that the raw steel production capability of the industry declined to 127.9 million short tons in 1986, down from 133.6 million tons in 1985 and 160.0 million in 1977.

The fraction of domestic steel produced in electric furnaces again increased while that produced in open-hearth furnaces continued to decline. Basic oxygen furnaces (BOF), electric furnaces, and open-hearth furnaces produced 58.7%, 37.2%, and 4.1%, respectively, of raw steel. For the first time, over one-half of domestic raw steel production was continuously cast. The portion of steel continuously cast was 55.2% in 1986 compared with only 10.6% in 1976. The rapid increase resulted from both the installation of continuous casting equipment and shutdown of older plants without continuous casters.

Total shipments and shipments to most consuming industries were down moderately. Shipments of structural shapes, plates, and bars were all lower because of weaker demand by the construction and machinery industries. Overall shipments of sheet were lower, primarily because of 10% lower shipments to the automotive industry. However, demand by the appliance industry, another major consumer of sheet, was higher. Shipments of both hot- and cold-rolled uncoated sheet were lower, but shipments of hot-dipped and electrolytically galvanized sheet increased, because of demand by the automotive industry for more corrosion-resistant material. Shipments of steel to the oil and gas industry fell by 50% because lower oil prices resulted in less activity in that industry. Shipments of rail and shipments of steel for shipbuilding decreased by about one-third. Although shipments of tinplate continued their long-term decline, shipments of black plate and tin-free steel increased. Total shipments of steel to the can and container industry were virtually unchanged, after years of decline.

Employment in the steel industry continued to decline. As reported by AISI, total average annual employment declined from 208,000 workers, in 1985 to 175,000 workers in 1986. The industry employed 128,000 workers on wages and 46,000 on salaries. Total employment declined to 154,000 in

December.

Labor contracts with most of the integrated steel producers were scheduled to expire at the end of July. For the first time in almost 30 years, each of the major steel companies conducted separate negotiations with its workers' union. Prior to 1986, a committee representing most of the major steelmakers had negotiated a contract with the United Steelworkers of America (USWA). Contracts at most other companies not represented on the committee were patterned after that contract. As the financial condition of the integrated steel companies deteriorated, such uniformity in contracts became less workable.

In 1986, most of the integrated steel producers reached new labor agreements without major strikes. The contracts generally resulted in lower overall labor costs. Many contracts reduced benefits such as paid time off, but added profit sharing provisions.

USX Corp., formerly United States Steel Corp., did not reach an agreement with the USWA. Steel production at USX was shut down from August 1 through yearend. Because of generally weak demand and available capacity at other companies, the strike at USX had minimal effect on the national economy.

AISI reported that average employment costs for hourly employees in the iron and steel industry increased from $22.812 per hour in 1985 to $23.242 in 1986. However, because of concessionary contracts that came into effect during 1986, costs decreased during the year. The average cost in December was $22.854 per hour compared with $23.025 in December 1985.

The combined effects of aggressive cost reduction and restraints on imported steel make the current operations of many steel companies at least profitable. However, because of costs for restructuring and losses at USX because of the strike, the companies reporting financial data to AISI reported a total net loss of $4.2 billion in their steel segments.

LTV Corp. and its subsidiary LTV Steel Co., the second largest domestic steel producer, filed for Chapter 11 bankruptcy. LTV was the largest U.S. industrial bankruptcy in history. By filing for bankruptcy, LTV was able to gain protection from creditors and to withdraw from high-priced, long-term raw materials contracts. The bankruptcy of LTV forced its 50%-owned iron ore mining subsidiary, Reserve Mining Co., to also file for bankruptcy. LTV also reopened contract negotiations with the USWA although a new lower cost contract had been signed only months before. The Government's Pension Benefit Guaranty Corp. took over some pension plans and was moving toward taking over others, which would relieve LTV of over $2 billion in pension liabilities.

Other integrated steel companies reorganized. USS became USX Corp. with the steel operations as one of four divisions. USS had completed a merger with Texas Oil & Gas Corp. earlier in the year making USS primarily an energy company. Inland Steel Co. became Inland Steel Industries Inc. with Inland Steel as one of two subsidiaries. Interlake Inc. became The Interlake Corp. and then spun off its steel operations as Acme Steel Co. Lone Star Steel Co. became Lone Star Technologies Inc. with Lone Star Steel as a subsidiary. In each case, the company deemphasized steel and sought to move the company toward more profitable businesses.

Early in the year before LTV filed for bankruptcy, LTV completed the sale of its integrated steel mill in Gadsden, AL, to an investment group, which operated it as Gulf States Steel Inc. LTV also sold its specialty division in a leveraged buyout to a group that organized it as J & L Specialty Products Co.

Birmingham Steel Corp., which owned three minimills at the beginning of 1986, bought three additional mills. Intercoastal Steel Corp., Norfolk, VA, was purchased and renamed Norfolk Steel Corp. The Northwest Steel Rolling Mills Inc. plant in Seattle, WA, was purchased and operated as Salmon Bay Steel Co. Birmingham also bought and reopened the Judson Steel Corp. plant, Emeryville, CA, which had been closed earlier in the year.

In other industry reorganizations, Kentucky Electric Steel Co. was purchased by and reopened as a subsidiary of Newport Steel Corp. Copperweld Corp. spun off its Copperweld Steel Co. as an independent company. British Steel Corp. sold its majority interest in Slater Steel Corp., which operated steel plants in Canada and a stainless steel plant in Indiana. Eastmet Corp. and its subsidiary, Eastern Stainless Steel Corp., filed for Chapter 11 bankruptcy. Continental Steel Corp., which filed for Chapter 11 bankruptcy in 1982 and again in 1985, was forced into liquidation.

Materials Used in Ironmaking.—Domestic pellets charged to blast furnaces in 1986 totaled 40.76 million tons, and sinter charged amounted to 15.77 million tons. Pellets and other agglomerates from foreign sources amounted to 9.37 million tons. A total of 9.26 million tons of iron ore was consumed by agglomerating plants at or near blast furnaces, producing 15.74 million tons of agglomerates. Other materials consumed by agglomerating plants were 2.22 million tons of mill scale, 0.68 million tons of flue dust, 0.75 million tons of coke breeze, and 3.62 million tons of fluxes.

According to AISI, blast furnaces consumed 22.1 billion cubic feet of oxygen. AISI also reported that blast furnaces consumed, in addition to coke, 25.6 billion cubic feet of natural gas; 18.7 billion cubic feet of coke oven gas; 99.7 million gallons of oil; and 8.0 million gallons of tar and pitch.

Materials Used in Steelmaking.—According to AISI, steelmaking furnaces consumed 3.92 million tons of lime, 0.81 million tons of limestone, 0.15 million tons of fluorspar, 0.84 million tons of other fluxes, and 116.0 billion cubic feet of oxygen. Metalliferous materials consumed in domestic steel furnaces, per ton of raw steel produced, averaged 1,076 pounds of pig iron, 1,164 pounds of scrap, 24 pounds of ferroalloys, and 5 pounds of ore and agglomerates. The comparable figures for 1985 were 1,127 pounds of pig iron, 1,113 pounds of scrap, 25 pounds of ferroalloys, and 6 pounds of ore and agglomerates.

PRICES

The annual average composite price for finished steel in 1986, as reported by Iron Age, was 24.792 cents per pound. This was lower than the price reported for 1985 because many companies adjusted their list prices to be more in line with transaction prices. The composite price for pig iron remained unchanged since 1982 at $213 per ton.

Transaction prices for integrated mill products tended higher during the year. Both quantitative limits on imports through negotiated restraint agreements with exporting countries and the decline of the dollar in international markets helped firm prices. However, continuing competition between domestic producers prevented major increases. The labor strike against USX in the second half of the year allowed other producers to raise prices.

Prices in certain product areas and certain geographic areas continued to be weak. Because of the decline in oil prices early in the year, prices for oil country goods fell sharply as suppliers tried to dispose of what they feared were excessive inventories. The west coast was more strongly affected by imports, and domestic producers selling there announced additional discounts.

Early in the year, stainless steel producers effectively increased prices for most consumers by about 4% when they reduced their discounts to service centers.

FOREIGN TRADE

Exports of major iron and steel products were little changed from those of 1985, after declining significantly in each of the prior 5 years. Exports in 1986 were only 25% of those of 1980. Although exports to Canada and Mexico declined, those countries continued to be the largest importers of U.S. iron and steel exports. Other major importing countries included Egypt, Hong Kong, Italy, Japan, and Taiwan. For each of these countries except Japan, a major part of their imports was tinplate. Total exports of tinplate and terneplate increased 51%. Although the lower value of the dollar made U.S. steel more competitive in world markets, exports continued to include a high fraction of higher priced specialized products. The average value of exports of steel mill products was $927 per ton compared with $389 for imports.

Imports for consumption of iron and steel products declined because of the lower value of the dollar and because of restraint agreements with exporting countries. Japan continued to be the largest single source country for steel mill products, supplying 4.4 million tons. Imports from Japan were down by almost one-third from their peak of 6.6 million tons in 1984. Canada continued to be the second largest supplier with 3.2 million tons. The European Economic Community (EEC), including Spain and Portugal in 1986, supplied 6.6 million tons. Among the EEC countries, the major suppliers were the Federal Republic of Germany, 2.0 million tons; France, 1.2 million tons; Belgium-Luxembourg, 1.0 million tons; the United Kingdom, 0.7 million tons; Spain, 0.6 million tons; the Netherlands, 0.5 million tons; and Italy, 0.5 million tons. Imports from the leading steel producers of the newly industrialized countries were lower. Imports from the Republic of Korea were 1.5 million tons, down from 1.9 million tons in 1985 and 2.2 million tons in 1984. Imports from Brazil were 1.1 million tons. Imports from Taiwan, which did not have a restraint agreement with the United States, doubled to 0.5 million tons. Other major exporters to the United States were Sweden and the Republic of South Africa, each with about 0.5 million tons.

The program of export restraint agreements with steel exporting countries, which was begun in 1984, was strengthened. An agreement was negotiated with Yugoslavia. Consultations were held with Canada, Sweden, and Taiwan, the three remaining major steel supplier countries without formal agreements. Imports from Sweden declined compared with those in 1985. Taiwan began a unilateral program to control exports although no formal agreement was reached. A threat to existing agreements was avoided when the U.S. Department of Commerce overruled objections by certain west coast plate producers and ended antidumping duties on certain plate imported from Japan and the Republic of Korea. The steel restraint agreements were negotiated with the understanding that existing unfair-trade duties on products covered by the agreements would be withdrawn.

In July, the United States reached an agreement with the EEC on a quota for exports of semifinished steel. The two sides had reached an agreement on finished steel in late 1985. When an earlier agreement on semifinished steel expired at the end of 1985, the United States unilaterally imposed a quota. The EEC responded by imposing quotas on certain nonsteel U.S. products. The new agreement allowed for imports of 800,000 tons of semifinished products in 1986, with small increases in later years through 1989. British Steel was given a special 200,000-ton share of the quota to supply slab to its affiliate Tuscaloosa Steel Corp.

Unfair trade practice complaints were filed or continued against countries and products not covered by restraint agreements. There was concern in the domestic industry that new or minor suppliers would greatly increase shipments to the United States or that countries with agreements would perform some finishing operations in nonagreement countries in order to avoid the quotas.

WORLD REVIEW

Australia.—The Broken Hill Pty. Co. Ltd. (BHP) was planning to build a 280,000-ton-per-year bar and rod mill at Sydney. The mill was planned to roll billets from BHP's Newcastle integrated works, but the plant would be planned to allow the later addition of a meltshop. A similar mill was under construction at Brisbane and was expected to begin operation in 1987.

Belgium.—Cockerill-Sambre SA planned to improve the productivity of its cold-rolling mill at Liège and make up for the capacity lost when it closes the mill at Jemeppe. The company planned to reduce employment from about 15,000 to 13,000 by mid-1987.

Brazil.—The Brazilian steel industry operated at near capacity because of production problems and because a price freeze on many goods resulted in stronger demand for steel-intensive goods such as appliances and automobiles. However, the price freeze resulted in additional losses at many Brazilian steel companies. Various measures were proposed for the problems of the state-owned steel companies including assumption of steel company debts by the Government and privatization of the companies. Government officials announced plans to proceed with installation of rolling mills at the Aco Minas Gerais S.A. (ACOMINAS) plant. The new plant's blast furnaces and BOF's began production in 1986, but completion of the plant was being delayed by lack of funds.

Expansion of the Brazilian pig iron industry continued despite increasing prices for charcoal used by most merchant pig iron producers. Cia. Vale do Rio Doce (CVRD) signed an agreement with the U.S.S.R. to build a 1.7-million-ton-per-year pig iron plant near the new CVRD Carajás iron mine.

Cia. Siderúrgica Pains (CSP) planned to install a second Korf Energy Optimizing Furnace (EOF) at its Divinopolis plant to replace three open-hearth furnaces. EOF furnaces use coal injection into an oxygen-furnace vessel to provide additional heat for melting scrap, pig iron, or direct-reduced iron (DRI). The EOF can melt a 100% cold charge and is intended to be a lower cost alternative to electric furnaces. CSP continued to operate the first commercial EOF.

Canada.—The Algoma Steel Corp. Ltd. began a restructuring program that will reduce capacity from 3.5 million tons per year to 2.5 million tons per year and eliminate 1,500 jobs. Investment of about $40 million was to include modification of a continuous caster and ladle and vacuum refining equipment. The company planned to eliminate all ingot casting.

QIT-Fer et Titane Inc. began production of steel at a new BOF steel shop at its Sorel, Quebec, ilmenite smelter. The BOF refines pig iron produced as a byproduct of QIT's titanium slag production. The plant will produce up to 225,000 tons per year of billet.

Modernization of the Sydney Steel Corp., Sydney, Nova Scotia, was delayed pending completion of a market study for the plant. The company's primary product in recent years was rail. A weak market and the loss of sales to companies with better quality resulted in the company operating at low capacity utilization and suffering heavy losses.

Chile.—The Government of Chile privatized the state-owned steel company, Cía. de Acero del Pacífico S.A. de Inversiones (CAP). The Government reduced its share of CAP's capital to 51% and later announced plans to reduce it to 20%.

China.—A new 3-million-ton-per-year integrated steel mill was proposed for Ningbo in Zhejiang Province and a British-West German engineering consortium was hired to do a feasibility study. In a departure from past practice, China was seeking foreign investment in the project. Earlier steel projects had been delayed by lack of capital for imported equipment.

In order to minimize the need for foreign currency, China purchased used equipment. A rod mill from LTV's Aliquippa, PA, plant was rebuilt and installed in Shanghai and a stainless pipe mill was purchased in the Federal Republic of Germany.

Construction continued on the second phase of the new integrated plant at Baoshan. There China planned to construct most of the equipment domestically, using experience gained during the construction on the first stage by foreign contractors.

European Economic Community.—The EEC moved to slightly reduce the regulation of its steel industry by voting to end quotas for the production of galvanized sheet at the beginning of 1987. However, at the urging of Eurofer, the association of large Western European steel companies, it delayed a decision on ending quotas on several other products. Eurofer asked that market regulation be continued while its members negotiate and implement a plan to cooperatively reduce excess capacity. The EEC estimated that despite over 30 million tons of capacity cutbacks that the EEC still had an excess of over 20 million tons of finished steel capacity.

Some EEC steel producers asked the EEC to strengthen its system of import protection. The steel producers requested that trade agreements be negotiated with several additional exporting countries and that antidumping and countervailing duty procedures be made more effective. Producers argued that currency revaluations and limitations on imports of steel into the United States were increasing the amount of steel imported to the EEC countries.

Finland.—Outokumpu Oy ordered a $100 million hot-strip mill for the stainless steel operation at its Tornio Works. The 220,000-ton-per-year capacity mill was expected to begin operation in early 1988.

France.—The Government of France strengthened cooperation between the two large state-owned steel groups by appointing a common chairperson for the two companies. Although the action was short of merging the companies, it ensured that long-range planning and restructuring of the companies would be coordinated.

Germany, Federal Republic of.—Mannesmann AG laid off 6,500, about one-quarter of the workers in its tube division, because of weak markets and excess capacity for pipe and tube.

The Nordferro DRI plant in Emden was sold to be dismantled and rebuilt in Bulgaria. The plant was built to produce merchant DRI for Europe, but was shut down after about only 1 year because unexpectedly high natural gas prices made the plant uneconomic.

Hungary.—Two Korf EOF steelmaking furnaces were ordered for installation in Ozki Kohaszati Uzemek plant at Osk. The two furnaces were to cost about $45 million installed in an existing open-hearth shop, and were to have a capacity of 900,000 tons per year.

Japan.—The higher value of the yen in international currency markets reduced the competitiveness of Japanese exports in the world market. Exports from Japan decreased, and producers were sometimes forced to accept lower prices to win orders. To reduce losses, some companies put workers on temporary leave under a Government program in which workers receive reduced salaries while on leave and for which the Government pays part of the salaries.

Major companies were also making plans for permanent shutdowns of unneeded capacity. Nippon Steel Corp., the largest steel company in the world, was preparing to present to its union a plan to shut down 4 of its 12 blast furnaces and to eliminate up to 30% of its jobs.

Libya.—Plans for commissioning the Misurata plant were delayed until mid-1987 because financing problems delayed work on some parts of the facility. The plant was to have two 600,000-ton-per-year Midrex direct-reduction units and three electric furnaces with a combined capacity of 1.3 million tons per year.

Mexico.—The Government of Mexico shut down the state-owned Fundidora Monterrey S.A. steel mill in Monterrey. It was the oldest of Mexico's steel mills and had not been profitable for several years. The integrated plant had a capacity of 1.7 million tons per year and employed 8,000.

Turkey.—Türkiye Demir ve Celik Isletmeleri Genel Müdürlügü, the state-owned steel company, was planning to build a 500,000-ton-per-year electric-furnace steel plant at Sivas. The plant was expected to begin producing bar late in 1987.

U.S.S.R.—The world's largest blast furnace was started at the Cherepovets steelworks. The furnace was expected to have a capacity of 3.9 million tons per year initially, and was to be upgraded to 5.0 million tons per year.

A 176-ton oxygen converter designed to melt 100% scrap began operation at Chelyabinsk. The furnace was built in cooperation with Krupp Industrietechnik GmbH of the Federal Republic of Germany, which developed the original technology.

[1]Physical scientist, Division of Ferrous Metals.

Table 2.—Pig iron produced and shipped in the United States in 1986, by State

State	Production (thousand short tons)	Shipped from furnaces: Quantity (thousand short tons)	Shipped from furnaces: Value (thousands)	Average value per ton at furnace
Alabama, Kentucky, Maryland	6,229	6,271	$1,144,043	$182.43
Illinois	2,382	2,379	356,490	149.85
Indiana	13,999	14,005	2,453,520	175.19
Michigan	4,657	4,656	803,855	172.65
Ohio	9,457	9,454	1,955,707	206.87
Pennsylvania	4,423	4,466	937,991	210.03
Texas, Utah, West Virginia	3,141	3,141	669,080	213.01
Total or average	[1]44,287	44,372	8,320,686	187.52

[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	1985[1]	1986[2]
Brazil	40	62
Canada	1,456	111
Venezuela	1,202	690
Other countries	92	27
Total	2,790	[3]889

[1]Excludes 9,798,277 tons used in making agglomerates.
[2]Excludes 8,392,815 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	Metalliferous materials consumed in blast furnaces: Iron and manganiferous ores: Foreign	Metalliferous materials consumed in blast furnaces: Agglomerates	Metalliferous materials consumed in blast furnaces: Net ores and agglomerates[1]	Metalliferous materials consumed in blast furnaces: Net scrap[2]	Metalliferous materials consumed in blast furnaces: Miscellaneous[3]	Metalliferous materials consumed in blast furnaces: 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]	Metalliferous materials consumed per ton of pig iron made (short tons): Net scrap[2]	Metalliferous materials consumed per ton of pig iron made (short tons): Miscellaneous[3]	Metalliferous materials consumed per ton of pig iron made (short tons): Net total[4]	Coke and fluxes consumed per ton of pig iron (short tons): Net coke	Coke and fluxes consumed per ton of pig iron (short tons): Fluxes
1985:																
Illinois	--	--	4,139	4,124	447	157	4,728	1,659	385	2,921	1.412	0.153	0.054	1.619	0.568	0.132
Indiana and Michigan	6	15	31,669	31,469	1,040	589	33,097	10,252	582	20,421	1.541	.051	.029	1.621	.502	.029
Ohio	2	1,372	13,410	14,687	308	592	15,587	5,229	969	9,259	1.586	.033	.064	1.683	.565	.105
Pennsylvania	48	1,031	8,949	9,961	293	333	10,586	3,563	581	6,473	1.539	.045	.051	1.635	.550	.090
Alabama, Kentucky, Maryland	--	312	9,983	10,239	97	252	10,588	3,666	351	6,745	1.518	.014	.037	1.570	.544	.052
Texas, Utah, West Virginia	91	60	6,368	6,464	195	100	6,759	2,195	264	4,143	1.560	.047	.024	1.631	.530	.064
Total[4] or average	147	2,790	74,519	76,944	2,381	2,023	81,346	26,564	[5]3,132	49,963	1.540	.048	.040	1.628	.532	.063
1986:																
Illinois	--	--	3,337	3,332	383	61	3,776	1,233	203	2,382	1.399	.161	.026	1.585	.518	.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	.016	.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	[6]2,247	44,287	1.500	.047	.034	1.581	.510	.051

[1]Net ores and agglomerates equal ore plus agglomerates plus flue dust used minus flue dust recovered.
[2]Excludes home scrap produced at blast furnaces.
[3]Does not include recycled material.
[4]Data may not add to totals shown because of independent rounding.
[5]Fluxes consisted of the following: 1,651,000 tons of limestone, 6,000 tons of burnt lime, 1,310,000 tons of dolomite, and 165,000 tons of other fluxes, excluding 2,417,000 tons of limestone, 15,000 tons of burnt lime, 1,663,000 tons of dolomite, and 28,000 tons of other fluxes used in agglomerating production at or near steel plants and an unknown quantity used in making agglomerates at mines.
[6]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 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	1985 Quantity (thousand short tons)	1985 Value Total (thousands)	1985 Value Average per ton	1986 Quantity (thousand short tons)	1986 Value Total (thousands)	1986 Value Average per ton
Basic	49,333	$9,990,377	$202.51	43,223	8,135,905	$188.23
Foundry	W	W	W	W	W	W
All other (not ferroalloys)	677	134,845	199.18	1,149	184,780	160.86
Total or average	50,010	10,125,222	202.46	44,372	[2]8,320,686	187.52

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	1985 In blast[1]	1985 Out of blast	1985 Total	1986 In blast[1]	1986 Out of blast	1986 Total
Alabama	2	3	5	3	1	4
Illinois	4	2	6	3	2	5
Indiana	11	7	18	11	7	18
Kentucky	2	--	2	2	--	2
Maryland	3	1	4	1	3	4
Michigan	6	3	9	6	3	9
Ohio	11	8	19	10	8	18
Pennsylvania	9	11	20	5	10	15
Texas	1	--	1	--	1	1
Utah	2	1	3	2	1	3
West Virginia	3	--	3	2	2	4
Total	54	36	90	45	38	83

[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]
1982	6,110	45,309	23,158	74,577
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

[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] Domestic	Iron ore[2] Foreign	Agglomerates[2] Domestic	Agglomerates[2] Foreign	Pig iron	Ferro-alloys[3]	Iron and steel scrap
1982	29	64	31	58	42,395	947	40,379
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	[r]50,002
1986	24	70	87	3	43,910	979	47,475

[r]Revised.
[1]Basic oxygen converter, open-hearth, and electric furnaces.
[2]Consumed in integrated steel plants only.
[3]Includes ferromanganese, spiegeleisen, silicomanganese, manganese metal, ferrosilicon, silicon metal, ferrochromium, chromium metal, and ferromolybdenum. Includes ferroalloys added to steel outside the furnace.

Table 9.—U.S. consumption of pig iron, by type of furnace or other use

Type of furnace or other use	1984		1985		1986	
	Thousand short tons	Percent of total	Thousand short tons	Percent of total	Thousand short tons	Percent of total
Basic oxygen converter	45,551	85.6	44,515	86.6	41,582	91.2
Open-hearth	5,720	10.7	4,737	9.2	2,325	5.1
Electric	368	.7	503	1.0	313	.7
Cupola	469	.9	501	1.0	428	.9
Air and other furnaces[1]	92	.2	56	.1	58	.1
Direct castings[2]	1,002	1.9	1,100	2.1	899	2.0
Total[3]	53,202	100.0	51,411	100.0	45,604	100.0

[1]Includes vacuum melting furnaces and miscellaneous melting processes.
[2]Castings made directly from blast furnace hot metal. Includes ingot molds and stools.
[3]Data 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	1985	1986
Connecticut	6	W
Georgia	2	--
Illinois	2,702	2,372
Indiana	16,016	14,044
Iowa	42	43
Kansas	8	6
Massachusetts	24	16
Michigan	5,088	4,929
Minnesota	17	13
Missouri	4	W
New Jersey	1	W
New York	16	12
Ohio	9,700	9,973
Oklahoma	W	--
Pennsylvania	6,775	4,702
Texas	525	62
Virginia	13	W
Wisconsin	51	45
Undistributed[2]	10,422	9,385
Total[3]	51,411	45,604

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 Alabama, California, Delaware (1985), Florida, Kentucky, Maine, Maryland, New Hampshire, North Carolina, Oregon, Rhode Island (1985), South Carolina, Tennessee, Utah, Washington, West Virginia, 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	1984 Quantity (short tons)	1984 Value (thousands)	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)
Steel mill products:						
Ingots, blooms, billets, slabs, sheet bars	73,536	$19,165	89,708	$28,000	58,885	$18,812
Wire rods	8,744	10,187	4,922	8,047	6,206	9,195
Structural shapes, 3 inches and over	29,049	18,366	41,633	40,461	31,698	21,275
Structural shapes, under 3 inches	11,231	9,655	7,139	7,897	6,995	7,463
Sheet piling	3,355	2,655	628	466	5,729	6,136
Plates	88,185	54,162	82,988	57,784	69,565	55,709
Rails and track accessories	15,225	11,370	10,937	10,844	9,447	11,057
Wheels and axles	3,854	13,377	2,493	14,875	3,685	18,796
Concrete reinforcing bars	9,889	4,678	7,409	3,553	14,197	4,907
Bars, carbon, hot-rolled	32,162	16,377	27,577	11,842	19,561	9,572
Bars, alloy, hot-rolled	49,969	39,773	34,871	37,298	25,862	33,900
Bars, cold-finished	28,125	24,796	20,854	28,182	13,491	22,291
Hollow drill steel	2,123	2,920	1,062	1,891	790	1,730
Pipe and tubing	207,428	325,800	199,258	285,182	121,050	188,212
Wire	19,440	37,747	18,758	31,215	26,081	37,574
Nails, brads, spikes, staples	7,161	24,199	5,445	21,670	5,862	31,659
Blackplate	38,781	9,779	32,754	7,704	70,488	22,178
Tinplate and terneplate	138,764	70,149	141,729	64,463	214,122	71,312
Sheets, hot-rolled	51,580	39,220	56,696	35,429	75,906	46,204
Sheets, cold-rolled	51,202	46,236	46,465	47,968	37,672	130,547
Strip, hot-rolled	11,563	14,254	12,482	13,742	13,683	17,386
Strip, cold-rolled	26,182	46,696	23,827	41,073	20,863	32,574
Plates, sheets, strip, galvanized, coated or clad	69,736	62,450	60,319	55,493	71,986	58,143
Total[1]	977,284	904,011	929,954	855,078	923,822	856,633
Other steel products:						
Plates and sheets, fabricated	11,371	22,955	13,677	27,214	11,133	18,023
Structural shapes, fabricated	86,854	141,849	46,770	93,396	34,098	67,121
Architectural and ornamental work	2,207	9,186	1,765	8,174	2,552	7,171
Sashes and frames	8,986	31,894	6,815	20,339	4,242	16,765
Pipe and tube fittings	11,426	98,915	16,362	126,336	18,645	155,183
Pipe and tubing, coated or lined	7,778	12,535	5,472	8,010	1,651	3,838
Bolts and nuts	86,897	127,017	58,944	106,094	44,186	100,502
Forgings	41,739	63,515	46,269	68,444	46,649	67,505
Cast-steel rolls	1,438	2,415	1,471	2,389	1,243	2,582
Railway track material	2,550	3,661	2,843	5,276	2,812	4,272
Total[1]	261,246	513,942	200,387	465,672	167,211	442,960
Iron products:						
Cast-iron pipes, tubes, fittings	51,682	99,252	41,523	64,236	65,307	69,253
Iron castings	122,375	110,084	94,419	90,994	40,473	34,909
Total[1]	174,057	209,336	135,942	155,230	105,780	104,161
Grand total[1]	1,412,587	1,627,289	1,266,283	1,475,980	1,196,813	1,403,755

[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	1984 Quantity (short tons)	1984 Value (thousands)	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)
Brazil	421,176	$43,703	130,762	$13,772	143,154	$15,472
Canada	171,708	29,638	166,291	29,920	112,607	20,324
China	--	--	1,968	330	6,041	1,129
France	1,704	253	7,241	1,219	--	--
South Africa, Republic of	31,489	4,593	30,504	4,936	32,944	5,434
Venezuela	54,274	3,815	--	--	--	--
Other	22,004	1,983	1,492	442	221	124
Total	702,355	83,985	338,258	50,619	294,967	[1]42,482

[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	1984		1985		1986	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Steel mill products:						
Ingots, blooms, billets, slabs, sheet bars	1,515,734	$332,664	1,878,953	$385,462	1,907,274	$391,269
Wire rods	1,594,437	540,315	1,479,749	501,994	1,367,221	472,387
Structural shapes, 3 inches and over	2,075,027	587,961	2,019,245	580,305	1,748,604	515,737
Structural shapes, under 3 inches	174,787	60,846	140,317	53,507	166,369	61,515
Sheet piling	80,709	30,862	102,790	37,837	107,013	40,047
Plates	1,880,297	539,927	2,303,682	628,335	1,477,017	399,082
Rails and track accessories	350,300	113,724	358,442	127,906	266,084	79,999
Wheels and axles	23,591	18,184	23,604	19,638	9,626	9,614
Concrete reinforcing bars	434,147	87,581	409,612	88,353	454,735	102,718
Bars, carbon, hot-rolled	540,302	184,926	445,001	152,544	419,699	135,123
Bars, alloy, hot-rolled	216,421	118,633	207,427	112,279	128,297	72,233
Bars, cold-finished	338,754	213,840	326,395	213,153	384,145	232,084
Hollow drill steel	1,811	2,310	1,260	1,383	1,378	1,530
Welded pipe and tubing	2,753,108	1,051,932	2,529,895	1,028,470	1,939,948	786,443
Other pipe and tubing	2,676,358	1,394,148	1,942,051	1,173,810	983,257	762,810
Wire	702,493	472,053	629,086	428,856	583,072	396,936
Wire nails	458,326	235,270	403,522	199,126	393,673	219,223
Wire fencing, galvanized	12,011	7,459	25,311	16,915	24,475	18,038
Blackplate	278,003	116,068	241,375	99,928	205,937	84,835
Tinplate and terneplate	373,277	203,147	419,242	222,114	380,268	199,484
Sheets, hot-rolled	2,690,721	782,510	2,433,705	708,727	2,101,876	594,816
Sheets, cold-rolled	3,672,456	1,499,599	2,803,532	1,208,379	2,627,755	989,605
Sheets, coated (including galvanized)	2,899,825	1,319,928	2,621,340	1,226,192	2,489,419	1,158,634
Strip, carbon, hot-rolled	79,592	25,373	62,154	19,353	43,557	15,486
Strip, carbon, cold-rolled	145,333	95,717	216,458	127,200	123,380	94,380
Strip, alloy, hot- or cold-rolled (including stainless)	51,604	86,441	67,849	105,585	49,846	81,192
Plates, sheets, strip, electrolytically coated (other than with tin, lead, or zinc)	149,624	79,656	186,485	98,291	131,379	69,596
Total	26,169,048	10,201,074	24,278,482	9,565,642	20,515,304	7,984,816
Other steel products:						
Plates, sheets, strip, fabricated	13,085	11,805	36,157	16,578	47,822	22,459
Structural shapes, fabricated	235,950	136,717	285,169	271,542	252,920	181,180
Pipe fittings	105,095	136,475	118,328	176,135	90,845	134,618
Rigid conduit	373	15,826	17,650	11,955	20,865	19,080
Bale ties made from strip	940	642	812	634	752	616
Nails, brads, spikes, staples, tacks, not of wire	48,662	61,217	45,801	60,298	50,823	70,083
Bolts, nuts, rivets, washers, etc.	684,761	753,707	638,314	724,509	647,002	748,820
Forgings	57,267	38,997	68,915	47,270	46,864	34,395
Total	1,146,133	1,155,386	1,211,146	1,308,921	1,157,893	1,211,251
Iron products:						
Cast-iron pipes, tubes, fittings	40,471	42,211	78,395	59,455	57,799	59,808
Iron castings	132,078	96,675	139,313	85,088	152,632	92,222
Total	172,549	138,886	217,708	144,543	[1]210,432	152,030
Grand total	27,487,730	11,495,346	25,707,336	11,019,106	21,883,629	9,348,097

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

Source: Bureau of the Census.

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

(Thousand short tons)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Algeria	1,209	1,213	[e]1,210	[e]1,210	1,200
Argentina[3]	2,090	2,052	1,983	2,102	[4]1,790
Australia	6,565	5,561	5,874	6,181	[4]6,492
Austria	3,434	3,660	4,128	4,083	3,700
Belgium	8,638	8,849	9,886	9,611	[4]8,863
Brazil[3]	11,935	14,269	18,960	20,911	[4]22,432
Bulgaria	1,717	1,789	1,739	1,876	1,900
Burma	14	17	9	([5])	--
Canada	8,818	9,443	10,629	10,654	10,200
Chile	500	595	655	634	[4]651
China	39,171	41,204	44,070	[e]48,100	55,300
Colombia	[r]228	266	278	258	[4]352
Czechoslovakia	10,500	10,434	10,539	[e]10,500	10,500
Egypt	125	216	248	175	220
Finland	2,157	2,092	2,242	[e]2,000	2,100
France	16,569	15,274	16,578	17,004	15,500
German Democratic Republic[6]	2,369	2,433	2,598	2,646	2,400
Germany, Federal Republic of	30,447	29,319	33,293	34,757	[4]31,987
Greece	121	152	152	[e]150	150
Hungary	2,404	2,256	2,310	2,309	[4]2,264
India	10,582	10,016	10,342	10,841	[4]11,584
Iran[e]	700	800	800	800	800
Italy	12,717	11,399	12,818	12,851	[4]13,122
Japan	85,603	80,398	88,629	88,812	[4]82,289
Korea, North[e]	5,800	6,100	6,300	6,400	6,400
Korea, Republic of	9,309	8,845	9,660	9,737	[4]9,940
Luxembourg[6]	2,852	2,553	3,051	3,037	[4]2,923
Mexico[3]	5,625	5,549	5,924	5,616	[4]5,566
Morocco[e]	13	17	17	17	17
Netherlands	3,987	[r]4,130	5,430	5,312	5,100
New Zealand[e 3]	165	170	190	190	220
Norway	503	623	602	670	690
Pakistan[e]	470	520	624	885	980
Peru[3]	225	154	68	228	[4]301
Poland	9,395	10,710	11,002	10,810	10,900
Portugal	237	391	411	457	[4]463
Romania	9,521	9,028	10,535	10,154	10,300
South Africa, Republic of	7,454	5,746	6,013	7,247	7,500
Spain	6,604	5,950	5,884	6,037	[4]5,291
Sweden[3]	2,076	2,328	2,561	2,811	2,900
Switzerland	11	11	60	73	72
Taiwan	2,971	3,764	3,704	3,780	4,100
Thailand	7	([7])	--	--	--
Trinidad and Tobago (sponge iron)	261	313	263	226	[4]371
Tunisia	107	162	165	165	165
Turkey	2,396	2,997	3,199	3,520	[4]4,041
U.S.S.R	[r]117,000	[r]121,000	121,600	120,600	120,600
United Kingdom	9,179	10,447	10,458	11,443	10,100
United States	43,342	48,770	51,961	49,963	[4]44,287
Venezuela[3]	2,598	2,476	3,511	3,391	3,700
Yugoslavia	2,980	3,136	3,147	3,439	3,400
Zimbabwe	527	[r]644	441	743	710
Total	[r]504,228	[r]510,241	546,751	555,416	546,833

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

[1]Table excludes ferroalloy production except where otherwise noted. Table includes data available through June 30, 1987.

[2]In addition to the countries listed, Vietnam and Zaire have facilities to produce pig iron and may have produced limited quantities during 1982-86, but output is not reported and available general information is not adequate to permit formulation of reliable estimates of output levels.

[3]Includes sponge iron output.

[4]Reported figure.

[5]Revised to zero.

[6]Includes blast furnace ferroalloys.

[7]Less than 1/2 unit.

Table 15.—Raw steel:[1] World production, by country[2]

(Thousand short tons)

Country[3]	1982	1983	1984	1985[p]	1986[e]
Algeria[e]	630	660	770	830	830
Angola[e]	11	11	11	11	11
Argentina	3,211	3,244	2,918	3,242	3,530
Australia	7,023	[r]6,236	6,948	7,251	[4]7,391
Austria	4,694	4,862	5,368	5,137	5,020
Bangladesh[5]	120	52	80	111	[4]106
Belgium	10,931	11,196	12,459	11,776	[4]10,741
Brazil	14,330	16,160	20,267	22,549	[4]23,406
Bulgaria	2,848	3,121	3,172	3,225	3,200
Canada	12,965	14,140	16,220	15,983	15,300
Chile	542	681	763	759	780
China	40,962	44,040	47,800	[e]51,500	57,400
Colombia	466	531	550	584	669
Cuba	[r]320	[r]388	358	442	[4]459
Czechoslovakia	16,526	16,561	16,348	16,574	16,500
Denmark	617	543	604	582	[4]697
Ecuador	31	25	20	20	20
Egypt	125	216	638	588	610
El Salvador	8	17	12	13	12
Finland	2,661	2,663	2,901	2,776	3,150
France	20,300	19,426	20,944	20,759	19,800
German Democratic Republic	7,902	7,958	8,348	8,656	8,710
Germany, Federal Republic of	39,551	39,384	43,419	44,640	[4]40,933
Greece	1,028	946	987	1,086	1,050
Hong Kong[e]	130	130	130	130	130
Hungary	4,081	3,986	4,134	4,019	[4]4,095
India[6]	11,811	11,359	11,402	12,185	12,230
Indonesia	551	882	1,100	1,323	1,650
Iran[e]	1,300	[r]1,300	1,300	1,300	1,300
Iraq[e]	50	--	--	--	--
Ireland	[r]67	[r]155	183	224	[4]229
Israel	132	165	[e]220	[e]170	170
Italy	26,434	23,891	26,484	26,173	[4]25,212
Japan	109,733	107,121	116,389	116,050	[4]108,330
Jordan[e]	[4]154	150	150	150	150
Kenya[e]	11	11	11	11	11
Korea, North[e]	6,400	6,700	7,200	7,200	7,200
Korea, Republic of	12,955	13,134	14,366	14,924	14,900
Luxembourg	3,869	3,631	4,395	4,349	[4]4,084
Malaysia[e]	230	390	390	390	830
Mexico	7,778	7,692	8,333	8,121	[4]7,904
Morocco[e]	7	7	7	7	7
Netherlands	4,791	4,935	6,326	6,081	5,400
New Zealand	278	257	302	250	316
Nigeria[e]	110	150	200	[4]280	220
Norway	847	987	1,014	[e]1,000	[4]922
Pakistan[e]	390	600	670	770	880
Peru	302	330	377	453	[4]534
Philippines	386	220	280	276	276
Poland	16,309	17,897	18,224	17,747	[4]18,850
Portugal	[r]553	[r]743	761	733	[4]780
Qatar	[r]546	526	527	588	[4]559
Romania	14,391	13,881	15,914	15,206	15,400
Saudi Arabia	([7])	[r]441	928	1,219	1,200
Singapore[e]	386	386	390	390	390
South Africa, Republic of	9,117	7,926	8,628	9,460	9,700
Spain	14,506	14,034	14,864	15,691	[4]13,201
Sweden	4,339	4,537	5,186	5,305	[4]5,192
Switzerland	[r]920	920	1,078	1,088	1,100
Syria	109	90	76	[e]76	76
Taiwan	4,495	5,530	5,758	5,871	6,300
Thailand	344	269	420	493	510
Trinidad and Tobago	197	231	219	192	[4]360
Tunisia	118	180	186	187	[4]200
Turkey	[r]3,509	[r4]4,226	4,773	5,456	[4]5,926
U.S.S.R	162,221	168,118	170,018	170,492	177,000
United Kingdom	15,106	16,519	16,668	17,331	[4]16,326
United States	74,577	84,615	92,528	88,259	[4]81,606
Uruguay	31	51	45	44	[4]44

See footnotes at end of table.

Table 15.—Raw steel:[1] World production, by country[2] —Continued

(Thousand short tons)

Country[3]	1982	1983	1984	1985[p]	1986[e]
Venezuela[6]	2,531	2,820	3,241	3,710	3,300
Vietnam[e]	130	110	110	[r]120	120
Yugoslavia	4,244	4,558	4,669	4,938	[4]4,981
Zimbabwe	582	741	431	[r e]510	540
Total	[r]709,860	[r]730,593	782,910	790,036	780,966

[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 June 30, 1987.

[3]In addition to the countries listed, Ghana, Libya, and Mozambique are known to have steelmaking plants, but available data are insufficient to make reliable production estimates. 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.

[7]Revised to zero.

Iron and Steel Scrap

By Raymond E. Brown[1]

Brokers, dealers, and other outside sources supplied domestic consumers in 1986 with 37.1 million short tons[2] of all types of ferrous scrap at a delivered value of approximately $2.69 billion, while exporting 11.7 million tons (excluding rerolling material and ships, boats, and other vessels for scrapping) valued at $1.05 billion. In 1985, domestic consumers received 37.4 million tons at a delivered value of approximately $2.94 billion, while exports totaled 9.95 million tons valued at $918 million.

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, 69% responded, representing an estimated 74% 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 1% for manufacturers of pig iron and raw steel and castings, 6% 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)

	1982	1983	1984	1985	1986
Stocks, Dec. 31:					
Scrap at consumer plants	6,418	5,807	5,261	5,104	4,344
Pig iron at consumer and supplier plants	622	345	304	266	188
Total	7,040	6,152	5,565	5,370	4,532
Consumption:					
Scrap	56,386	61,782	65,702	70,493	65,856
Pig iron	44,409	50,070	53,202	51,411	45,604
Exports:					
Scrap (excludes rerolling material and ships, boats, and other vessels for scrapping)	6,804	7,520	9,498	9,950	11,704
Value	$610,302	$636,723	$917,981	$918,186	$1,053,849
Imports for consumption:					
Scrap (includes tinplate and terneplate)	468	641	r577	r611	724
Value	$37,572	$48,219	r47,427	r$46,480	$49,073

rRevised.

Legislation and Government Programs.—On October 17, 1986, the President signed Public Law 99-499, Superfund Amendments and Reauthorization Act of 1986, which reauthorized and expanded the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund) toxic-waste cleanup program. The Superfund reauthorization will raise about $9 billion over 5 years and contained a number of new provisions on collecting and spending the revenues. Industrial taxes will be used to finance it. The Superfund law sets new standards for the removal of toxic wastes at dump sites and other areas. The Superfund gives the U.S. Government the authority to force private parties to clean up sites from which releases of hazardous substances into the environment might occur or have occurred. This could affect both suppliers and processors of scrap metal and other recycled materials.

A new policy statement on emissions trading was issued by the Environmental Protection Agency (EPA) on December 4, 1986.[3] The new policy replaces the EPA's original 1979 "bubble" policy and its 1982 interim emissions trading policy. The new version includes extensive tightening and clarification designed to assure the future environmental integrity of bubbles and other trading transactions. A bubble enables existing plants or groups of plants, such as those involved in the production of iron and steel, to increase emissions at one or more emission sources in exchange for compensating decreases in emissions at other emission sources.

Companion bills S. 2050 and H.R. 1309 were introduced in Congress on February 5 and July 17, respectively. They would have created a new Federal program to notify past and present employees in occupations deemed to be at risk from hazardous substances in the workplace and would require employers to conduct health monitoring of current at-risk employees. No action was taken on the Senate bill, and the House bill died on the floor.

There was much concern in 1986 about the decline of U.S. industrial competitiveness in world markets. Leaders from universities, businesses, and organized labor joined with members of Congress in an effort to identify areas that enhance or inhibit U.S. competitiveness.

Concerned that the July 17 bankruptcy filing by LTV Corp. would set a precedent for other steel companies, the administration established a task force to study the steel industry's problems. Ferrous scrap is a valuable resource to the U.S. steel industry. It is readily available, relatively inexpensive compared with hot metal, and the least expensive form of iron for producing steel. In the United States, electric arc furnaces (EAF) use over 90% scrap as their charged metallic, while basic oxygen furnaces charge about one-third scrap. Increased use of scrap to produce steel would make the United States more competitive in world markets.[4]

By resolution of the Commonwealth of Virginia's 1985 General Assembly, the State's solid waste commission was requested to conduct a study. The commission will assess the impacts of various contaminants on the recycling of metallic scrap.

AVAILABLE SUPPLY, CONSUMPTION, AND STOCKS

Steel producers continued a trend, which began in the 1980's, of maintaining smaller stocks of ferrous scrap. Iron and steel scrap stocks held by steel producers, which were at their highest level in January, declined throughout the year and reached their lowest level in December. Scrap processors continued to provide overnight delivery to certain customers. Although domestic demand for ferrous scrap in 1986 was down compared with that of 1985, an oversupply of ferrous scrap was offset somewhat owing to a banner year in exports. Domestic demand for ferrous scrap by the ferrous castings industry was down by a larger percentage than that for producers of pig iron and raw steel. Prices for most grades of iron and steel scrap remained depressed because of continued weak demand by the iron and steel industry, the major consumer of ferrous scrap. The domestic iron and steel industry continued to suffer from unfavorable economic conditions in 1986 brought on by foreign competition, declining demand, the high cost of domestic production, and overcapacity. These conditions led to restructuring, reorganizations, and changes in ownership throughout the iron and steel industry. USX Corp., the new name for United States Steel Corp. and this country's largest steel producer and ferrous scrap consumer, ceased operations indefinitely on August 1 because of a labor dispute. USX was also the target of takeover attempts and pressures to restructure to improve profitability. On July 17, LTV, the Nation's second largest steel producer, was the second U.S. steel producer that attempted to reorganize by filing for Chapter 11 bankruptcy. Wheeling-Pittsburgh Steel Corp. was the first U.S. steel producer to file for protection under Chapter 11 in April 1985. There were concerns that others might be forced to take the same route.

Raw steel production was 81.6 million tons in 1986 compared with 88.3 million tons in 1985. Raw steel capacity utilization was 63.8% in 1986 compared with 66.1% in 1985.

Steel mills accounted for 73.1% of all

scrap received from brokers, dealers, and other outside sources; steel foundries received 3.5%, and iron castings producers and miscellaneous users received 23.4%.

The apparent total domestic consumption of ferrous scrap in 1986, in million tons, was composed of 38.0 net receipts (total receipts minus shipments), 26.4 home scrap, and 0.8 withdrawals from stocks for a total of 65.2 million tons. This compares with an apparent total domestic consumption of 69.4 in 1985. Domestic consumption of ferrous scrap in 1986 was higher in the first half of the year than in the second half. A shift in U.S. demand for ferrous scrap from the Great Lakes, Midwest, and Northeast to the South, Southwest, and West, which had been occurring from 1981 to 1985, appeared to stabilize in 1986. Although total domestic ferrous scrap consumption in 1986 was down by about 7% compared with that of 1985, the total market for U.S. scrap (net receipts plus exports minus imports) increased slightly. The increase from 48.4 to 49.3 million tons was primarily the result of a record-high year for 1986 exports.

The 1984-86 status of U.S. manufacturing sectors that were major consumers of iron and steel products was as follows:

Appliances.—In 1986, 45.1 million units of major appliances were shipped from U.S. factories to domestic and foreign markets, a 7.9% increase from the 41.8 million units shipped in 1985. In 1984, 39.4 million units (revised) were shipped.

Automobiles.—In 1986, total U.S. passenger car production was 7.83 million units, down 4.3% from the 8.18 million units produced in 1985. The number of cars produced in 1984 was 7.77 million. The total number of recreational vehicles (less van conversions) shipped to retailers in 1986 was 198,000, a slight increase over the 194,000 units shipped to dealers in 1985. The number of recreational vehicles shipped to retailers in 1984 was 230,000.

Castings, iron.—Shipments totaled 7.63 million tons in 1986 compared with 9.09 million tons (revised) in 1985.

Castings, steel.—Shipments totaled 877,000 tons in 1986 compared with 940,000 tons (revised) in 1985.

Construction machinery (SIC 3531).—The value of shipments of construction machinery products, in billions, totaled $12.1 in 1986 compared with $11.8 (revised) in both 1985 and 1984.

Farm, wheeled tractors.—Unit retail sales in 1986 totaled 109,000 compared with 116,000 (revised) in 1985 and 118,000 (revised) in 1984.

Housing starts.—The number of private housing starts in 1986 totaled 1.81 million units compared with 1.74 and 1.75 million units for the years 1985 and 1984, respectively.

Materials handling.—The value of industrial materials handling equipment and systems shipments in 1986 was $4.12 billion compared with $4.27 billion (revised) in 1985 and $4.25 billion (revised) in 1984.

Mining machinery (SIC 3532).—The value of product shipments of mining machinery, in billions, totaled $1.50 in 1986 compared with $1.61 (revised) in 1985 and $1.58 (revised) in 1984.

Railroads (class 1 systems).—The total number of locomotives in service in 1985 was 22,900 compared with 24,500 in 1984. In 1985, there were 525 new locomotives compared with 428 in 1984. Rebuilt locomotives in 1985 totaled 144 compared with 252 in 1984.

The total number of freight cars in service in 1985 was 1.42 million compared with 1.49 million in 1984. New additions in 1985 consisted of 12,100 units compared with 12,400 units in 1984.

The total number of passenger train cars in service in 1985 was 2,500 compared with 2,580 in 1984, and 496,000 tons of new rail was laid in 1985 compared with 648,000 in 1984.

Service centers, steel.—Industrial steel products shipped by steel service centers, in million tons, were 21.7 in 1986, 21.5 (revised) in 1985, and 20.9 in 1984. Service centers generate about 5% scrap overall during the processing of steel mill products. About 1.1 million tons of ferrous scrap is generated annually by service centers. This estimation is based on a current level of approximately 21 million tons of industrial steel products shipped.

Shipbuilding.—The contract price for naval vessels totaled $3.03 billion for 16 ships in 1986 and $1.68 billion (revised) for 11 ships (revised) in 1985. In 1984, the total contract price for 11 naval vessels and 5 merchant vessels was $3.34 billion (revised).

Steel.—Shipments of all grades of finished steel mill products were 70.3 million tons in 1986 and 73.0 million tons in 1985.

Steel pipe and tubing.—Total shipments of pipe and tubing products were 2.84 million tons in 1986 and 4.10 million tons in 1985.

Ferrous scrap in stockpiles of domestic consumers totaled 4,344,000 tons at yearend 1986, down 760,000 tons from the 5,104,000 tons at yearend 1985. Stocks of ferrous scrap held by each of the three major consumers declined in 1986. Stocks held by steel mills were down by the largest quantity, whereas stocks held by steel castings manufacturers declined by the greatest percentage.

The Institute of Scrap Iron and Steel Inc. (ISIS) initiated a program to promote a "Design for Recycling" concept to help alleviate the hazardous waste problem. One aspect of the program focused on convincing manufacturers that it is a good business practice to design products to limit hazardous materials. Preventing the waste stream from the beginning is far more efficient than controlling it once it develops.

ISIS developed a list of materials that it designated as possible sources of hazardous and toxic wastes and recommended that its members refuse to purchase them as shredder feed material. Certain materials that were previously recycled freely and profitably may no longer be of interest to metallic scrap processors. ISIS released a news feature on recycling and hazardous waste that stressed its position that manufacturers who add hazardous materials to their products should take responsibility for their actions. Additionally, ISIS sent a written statement to the EPA, requesting that they withdraw the proposed listing of used oil as hazardous waste. ISIS indicated that the listing of used oil would have a catastrophic impact on the metals recycling industry. Also, ISIS asked the EPA to rule that wastes found nonhazardous under the agency's current testing procedure not be subjected to costly retesting for metals under the EPA's proposed new procedure. Undetected airbag canisters, charged with sodium azide in flattened automobile hulks, continued to be of major concern to scrap processors because of the potential of an explosion in the shredder during processing.

TRANSPORTATION

Shippers of ferrous scrap have asked the U.S. Interstate Commerce Commission (ICC) to reduce rail and motor carrier shipping rates so that they will be in line with falling fuel costs. ICC rules allow carriers to quickly pass on higher fuel prices to shippers but do not provide for a corresponding requirement for rate reductions.

The ICC denied a 1% increase in the published rate for carloads of scrap that the Consolidated Rail Corp. (Conrail) attempted to institute. The ICC rejected the increase on the basis that the railroads' operating costs and fuel costs had declined.

A decline in exports of iron and steel scrap in September coincided with a reported sharp increase in ocean freight rates of up to 60%.

PRICES

Based on average composite delivered prices per long ton quoted weekly and monthly by the American Metal Market (AMM) and Iron Age, No. 1 heavy melting steel scrap cost $74.17 in 1986, ranging from a low of $71.39 in June to a high of $75.97 in August as derived from AMM data, and based on Iron Age data, cost $73.41 in 1986, ranging from $70.90 in June to $75.50 in February. The average composite price for No. 1 heavy melting steel scrap in 1986 was slightly lower compared with that of 1985.

In 1986, the average price for total ferrous scrap exports decreased slightly compared with that of 1985 to $90.18 per ton, while that of total imports decreased by 11% to $67.82 per ton.

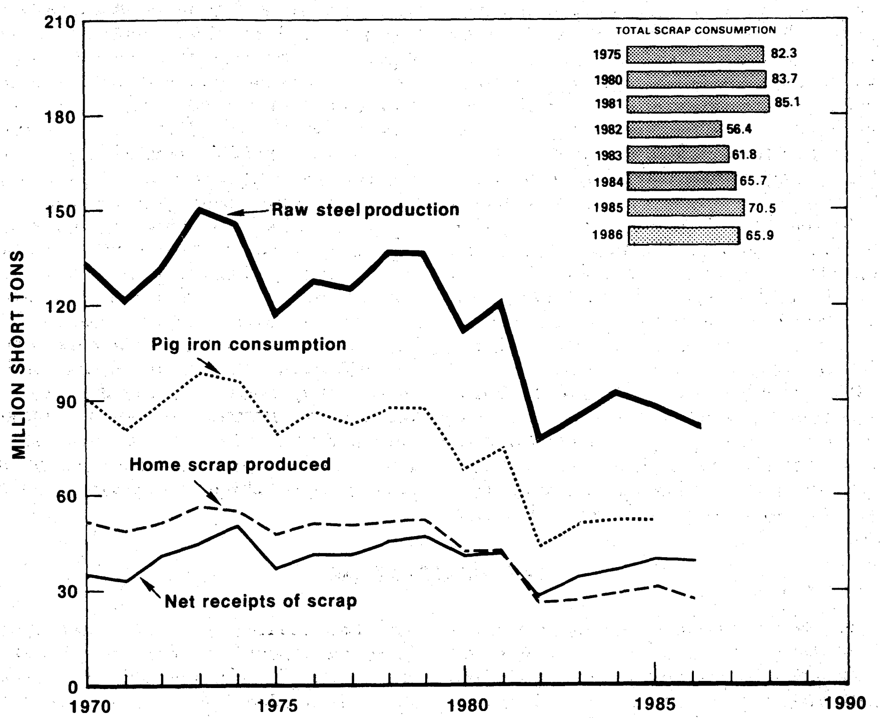

Figure 1.—Raw steel production (AISI), total iron and steel scrap consumption, pig iron consumption, home scrap production, and net scrap receipts.

FOREIGN TRADE

The trade surplus in 1986 for all classes of ferrous scrap (including rerolling material and ships, boats, and other vessels for scrapping) reached a record high of $1.03 billion in value and 11.3 million tons in quantity. This is an increase of 15% and 18% in value and quantity, respectively, over the 1985 surplus of $894 million and 9.58 million tons, respectively. The balance of trade for all U.S. goods in 1986 consisted of a record deficit of about $166 billion.

Exports of ferrous scrap (excluding rerolling material and ships, boats, and other vessels for scrapping) increased 18% from 9.95 million tons in 1985 to 11.7 million tons in 1986. In 1986, Canada, Japan, the Republic of Korea, Spain, Taiwan, Turkey, and Venezuela were the seven countries that received the largest tonnages of U.S. exports. Collectively, they received 8.32 million tons valued at $727 million, which averaged $87.35 per ton.

Exports of ferrous scrap (excluding rerolling material; ships, boats, and other vessels for scrapping; stainless steel; and alloy steel) totaled 11,379,000 tons valued at $933,760,000, which averaged $82.06 per ton.

Total U.S. exports of stainless steel scrap in 1986 went to 26 countries and consisted of 165,402 tons valued at $90,066,000 and averaging $544.53 per ton. Six countries received 84.5% of the total, of which the largest tonnages went to Japan, 52,860 tons; the Netherlands, 26,573 tons; Belgium-Luxembourg, 20,794 tons; Spain, 15,407 tons; Sweden, 13,668 tons; and the Republic of Korea, 10,457 tons. The value of stainless steel scrap exports to these six countries represented 82.1% of the total. Total U.S. alloy steel scrap (excluding stainless steel) exported to 36 countries in 1986 equaled

160,156 tons valued at $30,020,000, which averaged $187.44 per ton. Six countries received 66.1% of the total, of which the largest tonnages went to Taiwan, 32,058 tons; the United Kingdom, 17,788 tons; Canada, 17,200 tons; Mexico, 15,263 tons; Spain, 12,727 tons; and China, 10,820 tons. The value of alloy steel scrap exports to these six countries equaled 62.9% of the total.

Total imports for consumption of iron and steel scrap containing no dutiable alloys in 1986 consisted of 723,600 tons valued at $49,070,000 and averaging $67.81 per ton. In 1985, total imports were composed of 611,400 tons (revised) valued at $46,480,000 (revised), which averaged $76.02 (revised) per ton. The above-mentioned imports contained tinplate that totaled 4,210 tons valued at $441,000 in 1985 and 2,620 tons valued at $242,000 in 1986. Of the total quantity of imports in 1986, 77.8% was supplied by Canada and 9.7% came from Mexico. These two countries were also the leading suppliers of imports of ferrous scrap to the United States in 1985, with Canada's share representing 92.2% of the total and Mexico's share equaling 4.4%.

WORLD REVIEW

Total world demand for iron and steel scrap in 1986 was little changed from that of 1985. Overall demand for ferrous scrap in countries with centrally planned economies was up while that for market economy countries was down. Countries with the sharpest declines in demand, on a percentage basis, were Belgium, the Federal Republic of Germany, Japan, Spain, and the United States. Demand for ferrous scrap was up by the greatest percentage in industrializing countries. Among those were Brazil, China, the Republic of Korea, Turkey, and Yugoslavia.

The United States remained the leading exporting country of iron and steel scrap. The United Kingdom continued to rank second in ferrous scrap exports.

The number of oil tankers and combination carriers received worldwide for breaking in 1986 consisted of 169 vessels with a total deadweight of 14.8 million metric tons. This is down sharply from the 255 vessels weighing 31.3 million deadweight metric tons (dwmt) that were scrapped in 1985. Of the 169 vessels sold for demolition in 1986, Liberia provided the largest tonnage of 4.6 million dwmt. This was followed by Greece with 2.6 million dwmt, Japan with 1.7 million dwmt, and the U.S.S.R. with 1.2 million dwmt. In 1986, Taiwan, the world's leading shipbreaker, received 75 of the 169 vessels, which weighed 9.3 million dwmt. This represents 44% of the total number and 63% of the total tonnage of oil tankers and combination carrier vessels. Following Taiwan, the Republic of Korea and China were the second and third largest receivers in weight of vessels, respectively. However, China received 26 vessels while the Republic of Korea received 13.

China continued to expand its shipbreaking activities in 1986, scrapping 1.9 million dwmt of ships, 40% more than the total weight of ships scrapped in 1985. The annual shipbreaking capacity of China was estimated at 2.5 million dwmt.

TECHNOLOGY

Luria Brothers, a division of Avondale Industries Inc., Cleveland, OH, developed the "Clipress" scrap processing system to recycle sheet metal scrap clippings generated by automated stamping plants. The Clipress system is designed to replace the traditional scrap baling process. The Clipress system receives scrap clippings from a central conveyor system, continuously flattens the pieces (removing the draw bead and other convolutions), and loads an outgoing railcar or truck with the densified mass of sheet scrap. The flattening device consists of two large-diameter steel rolls, individually driven either hydraulically or mechanically, with a flattening force sustained through outboard hydraulic rams. The flattened scrap product is then conveyed directly to an outgoing railcar or truck where it is distributed and further densified by a pedestal-mounted hydraulic tamper with an attached electromagnet. The manufacturer claims installation of the system in a typical automated stamping plant will result in an immediate and substantial reduction in labor, maintenance, downtime, and freight costs, compared with the conventional scrap baling press.

At the beginning of the year, the Center for Metals Production (CMP), Pittsburgh, PA, completed a comprehensive study of EAF dust that involved reviewing 13 alternative technologies from a number of worldwide developers. In December, CMP awarded contracts for the two processes considered to be the most viable. The first technology consisted of a flame reactor proposed by St. Joe Minerals Corp. The reactor is to be tested at its Monaca, PA, facility. This system involves gasification of solid carbon fuel, either coal or coke, that then reacts with metal oxide compounds to form near-pure oxides of nonferrous metals. The process also produces an iron-bearing, nonhazardous slag. Under a cooperative agreement with St. Joe Minerals, the Bureau of Mines would conduct research into the parameters affecting the flame smelting process when used for the recovery of zinc from EAF dusts. The second technology, developed jointly by Bethlehem Steel Corp., Bethlehem, PA, and Tetronics Research and Development Co. Ltd., United Kingdom, entails an electrical transferred arc plasma furnace for the carbothermic reduction of dusts. During operation, zinc, lead, and cadmium compounds are selectively reduced, volatilized, and then collected as metallic elements. The remaining material is an iron-bearing slag. Testing of the technology will be done in Farrington, England. Financial support for both technologies will be provided by 23 steel companies and 1 industrial gas supplier. Matching funds and project management is being supplied by the Electrical Power Research Institute, Palo Alto, CA, through CMP.

In July, Weirton Steel Corp., Weirton, WV, was chosen by the U.S. Department of Energy to become the first U.S. steelmaker to implement the innovative Kohle-Reduktion (KR) process with the acceptance of its application for a $163 million KR process ironmaking demonstration plant. The KR process was designed by Korf Engineering GmbH of the Federal Republic of Germany. The process uses coal as a replacement for coke in the production of blast-furnace-quality iron and could reduce the demand for ferrous scrap.[5]

Successful operation of single electrode direct current arc furnaces at Florida Steel Corp.'s minimill in Tampa, FL, and Nucor Steel Corp.'s minimill in Darlington, SC, opened the way for major cost reductions in arc melting. Electrode consumption dropped from about 10 pounds per billet ton to about 4 pounds following the alternating current to direct current conversions. Other benefits include much quieter operation, reduced disturbance of the utility system, longer projected life of the secondary flexible cables, and less electrode breakage.[6] The direct current furnace could increase demand for ferrous scrap because of the possibility of a larger shift in steel production from basic oxygen furnaces to EAF.

Phoenix Metals Corp.'s new iron powder plant in Plymouth, MI, uses a patented process from Ford Motor Co. that produces powders by comminution grinding of scrap turnings. Phoenix holds a license with Ford until 1992. The comminution process cuts costs by removing the scrap melting step associated with the atomization process.[7]

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[1]Physical scientist, Division of Ferrous Metals.

[2]All quantities are in short tons unless otherwise specified.

[3]Federal Register. Environmental Protection Agency. Emissions Trading Policy Statement: General Principles for Creation, Banking and Use of Emission Reduction Credits. V. 51, No. 233, Dec. 4, 1986, pp. 43814-43859.

[4]Iron and Steel Society. Scrap Preheating and Melting in Steelmaking. Iron and Steel Society Inc., 410 Commonwealth Drive, Warrendale, PA 15086, 1986, 189 pp.

[5]Tony, W. A. Weirton Steel Awarded Federal Assistance To Build $163.1 Million Ironmaking Demonstration Plant. Iron & Steelmaker, v. 13, No. 10, Oct. 1986, pp. 15-19.

[6]Innace, J. J. DC Melting Mounts a Direct Assault on Costs. 33 Metal Prod., v. 25, No. 1, Jan. 1987, pp. 27-28.

[7]Metal Bulletin Monthly (London). Phoenix—Turning Scrap Into Powder. No. 187, July 1986, p. 15.

Table 2.—U.S. consumer receipts, production, consumption, shipments, and stocks of iron and steel scrap and pig iron in 1986, by grade

(Thousand short tons)

Grade	Receipts of scrap		Production of home scrap		Consumption of both purchased and home scrap (includes recirculating scrap)	Shipments of scrap	Ending stocks, Dec. 31
	From brokers, dealers, other outside sources	From other own-company plants	Recirculating scrap resulting from current operations	Obsolete scrap (includes ingot molds, stools, scrap from old equipment, buildings, etc.)			
MANUFACTURERS OF PIG IRON AND RAW STEEL AND CASTINGS							
Carbon steel:							
Low-phosphorus plate and punchings	362	1	2	(1)	361	--	22
Cut structural and plate	905	60	378	4	1,351	3	76
No. 1 heavy melting steel	7,558	714	6,502	123	14,525	849	939
No. 2 heavy melting steel	2,643	116	838	2	3,522	76	311
No. 1 and electric-furnace bundles	5,623	175	1,492	2	6,909	585	327
No. 2 and all other bundles	795	27	8	--	881	4	55
Electric furnace, 1 foot and under (not bundles)	58	115	26	(1)	193	4	15
Railroad rails	225	(1)	1	--	259	(1)	13
Turnings and borings	708	4	287	(1)	1,014	9	70
Slag scrap	496	119	1,883	1	2,147	386	194
Shredded or fragmentized	2,775	1,365	55	--	4,259	24	227
No. 1 busheling	1,407	43	163	(1)	1,576	99	65
All other carbon steel scrap	1,991	421	6,385	47	8,345	594	447
Stainless steel scrap	513	21	439	(1)	989	28	54
Alloy steel (except stainless)	113	104	954	18	1,146	175	179
Ingot mold and stool scrap	343	165	368	600	1,085	402	232
Machinery and cupola cast iron	1	4	6	--	6	13	1
Cast-iron borings	167	(1)	5	(1)	157	13	2
Motor blocks	8	--	--	--	9	--	--
Other iron scrap	164	58	259	1	430	80	97
Other mixed scrap	268	71	114	7	499	7	30
Total[2]	27,122	3,582	20,165	807	49,662	3,349	3,355
MANUFACTURERS OF STEEL CASTINGS							
Carbon steel:							
Low-phosphorus plate and punchings	438	(1)	102	(1)	489	(1)	36
Cut structural and plate	122	21	11	(1)	155	--	14
No. 1 heavy melting steel	76	1	58	2	139	--	7
No. 2 heavy melting steel	141	--	1	--	142	--	5
No. 1 and electric-furnace bundles	15	--	--	--	10	--	1
No. 2 and all other bundles	--	--	--	--	--	--	--
Electric furnace, 1 foot and under (not bundles)	45	1	5	--	52	1	1
Railroad rails	4	--	--	--	2	--	1
Turnings and borings	27	--	7	(1)	31	2	2
Slag scrap	--	--	--	--	--	--	--
Shredded or fragmentized	15	--	--	--	15	--	1
No. 1 busheling	13	--	--	--	8	(1)	2
All other carbon steel scrap	238	40	121	--	397	28	12
Stainless steel scrap	14	1	15	(1)	27	1	5
Alloy steel (except stainless)	60	--	121	(1)	181	(1)	45
Ingot mold and stool scrap	--	--	--	--	--	--	--
Machinery and cupola cast iron	1	--	1	--	1	--	--
Cast-iron borings	56	--	12	--	55	--	2
Motor blocks	--	--	--	--	(1)	--	--
Other iron scrap	49	--	60	(1)	112	5	17
Other mixed scrap	1	--	8	--	9	--	(1)
Total[2]	1,316	65	521	3	1,827	37	149

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 1986, 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	1,002	63	214	8	1,276	--	145
Cut structural and plate	1,133	30	123	(1)	1,275	1	78
No. 1 heavy melting steel	113	28	307	(1)	189	267	14
No. 2 heavy melting steel	315	--	29	(1)	334	8	10
No. 1 and electric-furnace bundles	127	232	39	--	394	1	10
No. 2 and all other bundles	151	--	--	--	161	--	20
Electric furnace, 1 foot and under (not bundles)	32	2	1	--	34	--	2
Railroad rails	122	1	8	(1)	131	3	8
Turnings and borings	226	3	4	5	258	4	17
Slag scrap	18	--	1	--	16	1	1
Shredded or fragmentized	1,083	92	--	--	1,290	3	66
No. 1 busheling	395	50	78	--	533	(1)	17
All other carbon steel scrap	440	2	121	(1)	553	2	38
Stainless steel scrap	25	--	4	(1)	27	2	2
Alloy steel (except stainless)	23	--	5	2	37	2	11
Ingot mold and stool scrap	105	--	162	--	288	2	26
Machinery and cupola cast iron	931	6	245	32	1,185	13	54
Cast-iron borings	805	304	79	(1)	1,142	36	68
Motor blocks	432	33	818	--	1,255	24	43
Other iron scrap	666	189	2,155	127	3,107	32	136
Other mixed scrap	541	19	334	(1)	883	31	75
Total[2]	8,685	1,053	4,724	175	14,367	433	840
TOTAL—ALL TYPES OF MANUFACTURERS[2]							
Carbon steel:							
Low-phosphorus plate and punchings	1,802	64	318	9	2,126	(1)	203
Cut structural and plate	2,160	111	511	4	2,781	4	168
No. 1 heavy melting steel	7,747	743	6,867	125	14,853	1,116	960
No. 2 heavy melting steel	3,099	116	868	2	3,998	84	325
No. 1 and electric-furnace bundles	5,765	407	1,531	2	7,313	586	337
No. 2 and all other bundles	946	27	8	--	1,041	4	75
Electric furnace, 1 foot and under (not bundles)	135	117	32	(1)	279	5	19
Railroad rails	351	1	9	(1)	392	3	21
Turnings and borings	960	7	298	5	1,302	15	89
Slag scrap	514	119	1,884	1	2,163	387	195
Shredded or fragmentized	3,872	1,458	55	--	5,563	27	294
No. 1 busheling	1,816	93	240	(1)	2,117	99	84
All other carbon steel scrap	2,670	463	6,627	47	9,295	624	496
Stainless steel scrap	552	22	457	(1)	1,043	31	60
Alloy steel (except stainless)	196	104	1,080	19	1,364	177	235
Ingot mold and stool scrap	448	165	530	600	1,372	404	258
Machinery and cupola cast iron	933	9	251	32	1,192	26	55
Cast-iron borings	1,028	304	95	(1)	1,353	50	71
Motor blocks	440	33	818	--	1,264	24	43
Other iron scrap	879	246	2,475	128	3,649	117	250
Other mixed scrap	810	90	456	7	1,391	38	105
Grand total[2]	37,123	4,700	25,410	984	65,856	3,819	4,344

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

Table 3.—U.S. consumer receipts, production, consumption, shipments, and stocks of pig iron and direct-reduced iron in 1986

(Thousand short tons)

	Receipts	Production	Consumption	Shipments	Stocks, Dec. 31
MANUFACTURERS OF PIG IRON AND RAW STEEL AND CASTINGS					
Pig iron	1,280	44,287	44,324	1,313	122
MANUFACTURERS OF STEEL CASTINGS					
Pig iron	54	--	53	--	3
IRON FOUNDRIES AND MISCELLANEOUS USERS					
Pig iron	1,285	--	1,227	60	63
TOTAL—ALL TYPES OF MANUFACTURERS					
Pig iron	2,619	44,287	45,604	1,373	188
Direct-reduced or prereduced iron	444	--	348	W	92

W Withheld to avoid disclosing company proprietary data.

Table 4.—Consumption of iron and steel scrap and pig iron in the United States in 1986, 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]	1,935	--	--	--	--	--	1,935	--
Basic oxygen process[3]	14,753	41,582	--	--	--	--	14,753	41,582
Open-hearth furnace	1,556	2,325	W	W	--	--	1,556	2,325
Electric furnace[3]	31,166	3	1,717	53	4,130	257	37,013	313
Cupola furnace	34	80	109	--	9,716	348	9,859	428
Other (including air furnace)[4]	218	37	4	--	522	20	740	58
Direct castings[5]	--	297	--	--	--	602	--	899
Total[1]	49,662	44,324	1,827	53	14,367	1,227	65,856	45,604

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]Includes vacuum melting furnaces and miscellaneous uses.
[5]Includes ingot molds and stools.

Table 5.—Proportion of iron and steel scrap and pig iron used in furnaces in the United States in 1986

(Percent)

Type of furnace	Scrap	Pig iron
Basic oxygen process	26.2	73.8
Open-hearth furnace	40.1	59.9
Electric furnace	99.2	.8
Cupola furnace	95.8	4.2
Other (including air furnace)	92.8	7.2

Table 6.—Iron and steel scrap supply[1] available for consumption in 1986, 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, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island	1,286	82	336	6	1,710	37	1,674
Pennsylvania	4,392	430	3,786	209	8,817	922	7,895
Total[2]	5,678	512	4,122	215	10,527	959	9,568
North Central:							
Illinois	3,843	623	2,186	38	6,690	179	6,511
Indiana	3,103	110	5,498	135	8,846	993	7,853
Iowa, Kansas, Michigan, Minnesota, Missouri	6,364	1,058	3,098	132	10,653	382	10,271
Ohio	5,149	915	4,078	244	10,387	828	9,559
Wisconsin	738	(4)	577	(4)	1,316	(4)	1,317
Total[2]	19,198	2,707	15,439	548	37,892	2,382	35,510
South Atlantic: Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia	4,198	352	2,452	126	7,128	228	6,900
South Central: Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas	5,766	1,016	2,637	65	9,484	204	9,280
Mountain and Pacific: Arizona, California, Colorado, Hawaii, Oregon, Utah, Washington	2,284	114	762	29	3,187	48	3,139
Grand total[2]	37,123	4,700	25,410	984	68,218	3,819	64,399

[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 1986, by region and State

(Thousand short tons)

Region and State	Pig iron and steel ingots and castings: Scrap	Pig iron and steel ingots and castings: Pig iron	Steel castings: Scrap	Steel castings: Pig iron	Iron foundries and miscellaneous users: Scrap	Iron foundries and miscellaneous users: Pig iron	Total[2]: Scrap	Total[2]: Pig iron
New England and Middle Atlantic:								
Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island	1,113	2	39	1	553	30	1,705	34
Pennsylvania	7,048	4,344	88	2	1,078	356	8,215	4,702
Total[2]	8,161	4,346	127	3	1,632	386	9,920	4,736
North Central:								
Illinois	5,351	2,245	163	--	1,095	127	6,609	2,372
Indiana	7,033	13,958	147	42	736	45	7,916	14,044
Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska	6,159	4,539	360	1	3,858	454	10,377	4,994

See footnotes at end of table.

Table 7.—U.S. consumption of iron and steel scrap and pig iron[1] in 1986, 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								
Ohio	7,241	9,898	218	4	2,455	71	9,914	9,973
Wisconsin	--	--	112	([3])	1,207	45	1,319	45
Total[2]	25,785	30,640	1,000	47	9,350	741	36,135	31,428
South Atlantic: Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia	5,750	W	9	W	1,222	32	6,981	32
South Central: Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas	7,492	[4]9,337	305	[4]3	1,849	56	9,645	[4]9,396
Mountain and Pacific: Arizona, California, Colorado, Hawaii, Oregon, Utah, Washington	2,474	W	386	W	313	11	3,175	11
Grand total[2]	49,662	44,324	1,827	53	14,367	1,227	65,856	45,604

W Withheld to avoid disclosing company proprietary data; included with "South Central" region.
[1]Includes molten pig iron used for ingot molds and direct castings.
[2]Data may not add to totals shown because of independent rounding.
[3]Less than 1/2 unit.
[4]Includes South Atlantic and Mountain and Pacific regions.

Table 8.—U.S. consumer stocks of iron and steel scrap and pig iron, December 31, 1986, 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, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island	111	8	29	25	3	175	2
Pennsylvania	456	33	102	102	14	707	46
Total[1]	567	41	130	126	17	882	48
North Central:							
Illinois	356	--	11	38	2	408	14
Indiana	321	1	10	114	12	458	21
Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska	403	1	7	99	27	537	28
Ohio	295	8	46	84	8	441	22
Wisconsin	9	2	--	11	--	21	7
Total[1]	1,383	12	74	347	48	1,865	92
South Atlantic: Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia	387	4	4	55	7	456	5
South Central: Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas	768	3	17	92	31	910	40
Mountain and Pacific: Arizona, California, Colorado, Hawaii, Oregon, Utah, Washington	162	([2])	9	58	1	231	3
Grand total[1]	3,267	60	235	678	105	4,344	188

[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 scrap in 1986

(Per long ton)

Month	Chicago	Pittsburgh	Philadelphia	Composite price[1]
January	$74.23	$74.50	$73.86	$74.20
February	76.89	76.79	74.00	75.89
March	74.05	74.00	74.00	74.02
April	74.00	74.00	74.00	74.00
May	74.00	70.95	73.43	72.79
June	71.00	70.17	73.00	71.39
July	71.00	72.50	73.00	72.17
August	76.71	76.50	74.71	75.97
September	73.14	76.12	75.00	74.75
October	70.87	76.41	75.00	74.09
November	73.00	77.39	75.00	75.13
December	73.00	79.07	75.00	75.69
Average 1986	73.49	74.87	74.17	74.17
Average 1985	72.89	[r]77.33	[r]74.59	[r]74.94

[r]Revised.
[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	1982		1983		1984		1985		1986	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Canada	307	21,006	539	39,717	779	59,521	446	38,445	365	31,436
China	1	109	1	177	227	21,190	387	32,793	340	28,506
Italy	12	2,972	65	4,395	306	27,038	307	30,250	286	26,177
Japan	1,530	145,083	2,600	218,337	2,680	264,857	2,110	199,135	1,725	170,015
Korea, Republic of	1,522	115,515	1,476	111,051	1,833	160,892	1,978	160,674	2,989	247,055
Mexico	380	33,822	419	36,017	484	47,663	597	57,535	318	29,981
Spain	868	61,616	356	22,734	608	55,228	910	72,312	673	51,771
Taiwan	352	57,213	499	75,638	405	54,515	414	45,163	667	74,387
Turkey	639	48,286	700	50,851	807	69,579	955	80,133	1,417	115,334
Venezuela	45	3,231	20	1,197	392	33,346	471	36,384	483	36,673
Other	[r]1,149	[r]121,450	[r]845	[r]76,608	[r]977	[r]124,151	[r]1,373	[r]165,360	2,441	242,514
Total[2]	6,804	610,302	7,520	636,723	9,498	917,981	9,950	918,186	11,704	1,053,849

[r]Revised.
[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	1982		1983		1984		1985		1986	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Exports:										
No. 1 heavy melting scrap	1,883	138,973	1,895	139,935	2,512	215,482	2,766	218,593	2,922	230,519
No. 2 heavy melting scrap	626	44,032	720	50,081	879	70,906	767	58,537	797	58,879
No. 1 bundles	115	8,619	206	16,486	77	8,258	185	17,172	155	13,876
No. 2 bundles	181	11,310	220	13,727	286	18,836	306	21,160	301	21,095
Stainless steel scrap	131	74,052	80	44,671	164	96,426	180	104,898	165	90,066
Shredded steel scrap	2,023	160,169	2,029	154,753	2,775	251,976	2,559	220,320	3,495	293,040
Borings, shovelings, turnings	577	28,923	532	28,277	800	49,664	875	56,314	731	43,955
Other steel scrap[1]	878	112,130	1,532	164,101	1,416	155,685	1,646	162,484	2,048	209,094
Iron scrap	389	32,096	306	24,692	590	50,748	666	58,707	1,091	93,325
Total[2]	6,804	610,302	7,520	636,723	9,498	917,981	9,950	918,186	11,704	1,053,849
Ships, boats, other vessels (for scrapping)	69	4,440	198	9,623	283	9,503	131	6,627	212	16,475
Rerolling material	53	7,969	34	4,194	58	10,918	110	15,604	78	11,302
Total exports[2]	6,925	622,711	7,752	650,540	9,840	938,402	10,191	940,416	11,994	1,081,626
Imports for consumption:										
Iron and steel scrap	468	37,572	641	48,219	[r]577	[r]47,427	[r]611	[r]46,480	724	49,073

[r]Revised.
[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	1982		1983		1984		1985		1986	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
China	--	--	--	--	--	--	19	2,497	--	--
Korea, Republic of	--	--	5	462	--	--	--	--	--	--
Mexico	33	5,290	28	3,579	57	8,248	90	12,511	77	11,186
Other	20	2,679	1	153	1	2,670	1	596	([1])	116
Total	53	7,969	34	4,194	58	10,918	110	15,604	[2]78	11,302

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

Table 13.—U.S. imports for consumption of iron and steel scrap,[1] by country

Country	1985		1986	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Austria	96	$306	58	$125
Belgium-Luxembourg	502	653	128	236
Canada	[r]563,581	[r]37,409	562,603	38,151
Germany, Federal Republic of	1,978	524	2,365	850
Japan	[r]6,651	[r]1,164	12,984	1,059
Mexico	[r]27,170	[r]4,290	69,929	6,158
Netherlands	[r]718	[r]235	816	247
Panama	56	26	--	--
Sweden	2	1	12	35
United Kingdom	2,931	973	22,462	311
Other	[r]7,673	[r]896	52,201	1,899
Total[2]	[r]611,358	[r]46,480	723,558	49,073

[r]Revised.
[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	1981	1982	1983	1984	1985
North America:					
Canada[2 3 4 5]	8,233	6,261	6,965	[e]7,000	7,905
United States[2 5 6]	85,097	56,386	61,782	65,702	70,493
Latin America:[7]					
Argentina	1,338	1,569	1,570	1,281	1,264
Brazil	6,052	5,625	6,137	6,971	7,714
Chile	[e]210	146	209	237	241
Colombia	[e]205	324	369	378	433
Ecuador	[e]25	33	26	21	21
Mexico	3,618	3,332	2,383	3,181	3,413
Peru	[e]180	120	186	343	256
Uruguay	[e]20	34	56	53	51
Venezuela	[e]1,090	1,027	457	1,292	1,195
Central America, not further detailed	[e]100	82	74	126	192
Europe:					
European Economic Community:					
Belgium[2]	4,133	4,566	[r]3,563	3,880	3,430
Denmark[8]	758	690	644	718	656
France[3 4 5]	8,040	7,076	7,197	7,135	7,109
Germany, Federal Republic of[5]	21,632	19,339	19,692	20,510	20,517
Greece[e]	300	300	275	300	300
Ireland[9]	41	76	174	208	254
Italy	17,799	16,944	15,861	[r]17,380	17,133
Luxembourg	1,458	1,450	1,508	[r]1,857	1,761
Netherlands	1,961	1,594	1,607	1,797	1,658
United Kingdom	11,424	11,535	10,569	10,578	7,712
European Free Trade Association:					
Austria	1,910	1,807	[3]1,797	[3]1,851	[3]1,681
Finland[3]	807	758	[r 10]786	831	[e]850

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	1981	1982	1983	1984	1985
Europe —Continued					
European Free Trade Association — Continued					
Norway[3 4]	559	537	577	638	e650
Portugal	486	522	r617	e600	e600
Sweden[2 3 5]	2,924	3,145	e3,395	e3,500	e3,500
Switzerland	[9]948	[9]915	e915	e915	e915
Council for Mutual Economic Assistance:					
Bulgaria[e]	830	830	820	850	850
Czechoslovakia[2 4 5]	8,244	8,186	8,665	r8,354	8,471
German Democratic Republic[2 3 4 5]	5,816	5,649	5,682	5,779	5,593
Hungary	2,425	2,446	2,445	2,705	2,754
Poland	9,598	[3]8,983	[3]9,796	[3]9,630	[3]9,490
Romania[e]	4,250	4,260	4,270	4,300	4,280
U.S.S.R.[e]	56,900	60,300	63,400	64,500	64,500
Other:					
Spain	9,933	10,042	10,795	r10,911	[9]11,769
Yugoslavia[3 4 5]	2,324	2,245	2,434	e2,500	e2,500
Africa: South Africa, Republic of[2]	[11]3,333	e3,060	e2,600	e3,000	e3,300
Asia:					
China[e]	9,000	9,400	10,100	10,900	11,700
India[e]	4,100	4,200	4,050	4,060	4,300
Japan[5]	44,616	42,832	44,269	47,934	48,685
Korea, Republic of[e]	2,700	3,300	3,350	3,600	3,700
Taiwan[e 12]	1,100	1,400	1,700	1,700	1,700
Turkey[9]	1,764	e1,900	r1,736	r1,863	2,127
Oceania:					
Australia[e]	2,480	2,070	1,820	2,050	2,100
New Zealand[e]	155	160	150	180	150
Total	350,916	317,456	r327,473	r344,099	349,873

eEstimated. rRevised.

[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 1985, v. 13, New York, 1986, 88 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]Except where individually specified as an estimate or as being derived from another source, data are from Instituto Latino Americano del Fierro y el Acero. Statistical Yearbook of Steel Making and Iron Ore Mining in Latin America, 1986. Santiago, 1987, 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]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.

[9]Organization for Economic Cooperation and Development. The Iron and Steel Industry in 1981, Paris, 1983, 40 pp.; 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.; and The Iron and Steel Industry in 1985, Paris, 1987, 52 pp.

[10]Excludes consumption, if any, in the production of pig iron.

[11]Iron and Steel Statistics Bureau (United Kingdom). International Steel Statistics, Republic of South Africa, 1981, p. 4.

[12]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	1981	1982	1983	1984	1985
North America:					
Canada	632	r627	r965	876	968
United States[2 3]	6,472	6,857	r7,554	r9,556	10,060
Latin America:					
Cuba	e40	e45	450	4159	e150
Mexico[2]	2	22	4	r17	18
Europe:					
European Economic Community:					
Belgium-Luxembourg	637	549	752	853	811
Denmark	204	130	193	258	298
France	3,510	3,397	3,557	4,525	4,366
Germany, Federal Republic of	3,756	3,160	3,282	3,602	3,756
Greece	1	1	1	1	1
Ireland	81	65	23	47	55
Italy	25	19	20	21	11
Netherlands	1,380	1,300	1,678	1,851	2,023
United Kingdom	3,712	3,387	4,182	4,758	4,982
European Free Trade Association:					
Austria	14	10	14	23	35
Finland	(5)	(5)	(5)	11	11
Iceland	3	4	r7	r12	7
Norway	35	35	40	23	10
Portugal	6	10	11	10	18
Sweden	15	20	23	24	24
Switzerland	141	116	r164	r118	110
Council for Mutual Economic Assistance:					
Bulgaria	87	63	42	53	42
Czechoslovakia[4]	113	107	137	r205	155
German Democratic Republic[4]	21	22	23	r40	29
Hungary	35	58	55	87	30
Poland[2]	88	284	161	194	88
Romania[4]	(5)	(5)	(5)	(5)	(5)
U.S.S.R.[2]	2,681	2,859	3,715	3,756	3,655
Other:					
Spain	21	1	1	4	1
Yugoslavia	265	70	78	157	191
Africa:					
Algeria[2]	48	62	61	r91	e100
Morocco[2]	56	57	r75	r101	89
South Africa, Republic of[4]	2	4	51	r51	e50
Asia:					
Bahrain[2]	1	3	7	e10	e10
Brunei	6	5	10	r12	e15
China[4]	161	108	40	r15	e25
Cyprus	(5)	8	9	15	16
Hong Kong[2]	371	327	363	331	332
India[2]	22	e20	e20	e20	e20
Indonesia[2]	--	(5)	1	1	1
Japan	206	193	128	161	183
Korea, North[4]	8	15	7	e10	e10
Korea, Republic of[2]	28	155	314	149	82
Kuwait	27	20	e20	136	e100
Malaysia[2]	13	7	r14	r22	24
Mongolia[4]	24	26	24	e25	e25
Philippines[2]	2	2	1	r2	1
Saudi Arabia	58	33	e35	e35	e35
Singapore[2]	2	9	132	120	184
Taiwan[2]	141	443	308	223	428
Thailand[2]	2	9	2	4	4
Turkey	--	--	--	3	e5
United Arab Emirates	4	7	e10	e10	e10
Oceania:					
Australia[2]	708	1,249	r574	409	555
New Zealand[2]	3	3	3	4	e10
Total	r25,670	r25,983	r28,941	r33,201	34,219

eEstimated. rRevised.
[1]Unless otherwise specified, source is United Nations Economic Commission for Europe. Annual Bulletin of Steel Statistics for Europe 1985, v. 13, New York, 1986, 88 pp.
[2]Official trade returns of subject country.
[3]Includes rerolling material.
[4]Partial figure; compiled from import statistics of trading partner countries.
[5]Less than 1/2 unit.

Table 16.—Iron and steel scrap imports, by selected countries[1]

(Thousand short tons)

Continent, country group, and country	1981	1982	1983	1984	1985
North America:					
Canada	924	505	737	[r]1,253	974
United States[2]	556	468	641	577	611
Latin America:					
Argentina[2]	2	2	8	[r]2	[e]5
Brazil[2]	8	8	(3)	34	[e]35
Chile	5	[e]10	[r]6	[e]10	[e]10
Colombia[2]	33	30	51	48	[e]50
Cuba	[e]100	[e]100	[4]107	[r] [4]106	[4]109
Mexico[2]	235	464	390	[r]696	711
Peru[2]	40	18	[e]20	[e]20	[e]20
Venezuela[2]	55	23	20	[r]400	547
Europe:					
European Economic Community:					
Belgium-Luxembourg	1,054	978	1,152	1,843	1,642
Denmark	198	97	74	146	53
France	383	304	338	449	508
Germany, Federal Republic of	1,473	1,421	1,424	1,935	1,776
Greece	317	478	573	362	345
Ireland	4	3	77	97	150
Italy	6,107	6,141	4,901	6,047	6,368
Netherlands	262	244	401	527	646
United Kingdom	23	41	12	37	55
European Free Trade Association:					
Austria	187	420	241	400	263
Finland	68	56	41	36	125
Norway	26	4	17	14	12
Portugal	94	138	119	132	116
Sweden	272	583	496	925	976
Switzerland	125	118	162	301	265
Council for Mutual Economic Assistance:					
Czechoslovakia[4]	278	81	173	[r]172	48
German Democratic Republic	764	502	741	1,141	977
Hungary	159	15	31	22	15
Poland	58	6	6	8	6
U.S.S.R.[5]	24	27	24	[r]49	28
Other:					
Spain	4,479	5,249	5,227	5,531	6,776
Yugoslavia	[2]528	560	812	861	804
Africa:					
Egypt[2]	15	14	[e]15	[r]1	2
Morocco[2]	2	3	3	[r]1	2
South Africa, Republic of[2]	14	31	8	[r]61	[e]50
Asia:					
Bahrain[2]	2	5	3	[e]3	[e]3
China[4]	(3)	3	2	[r]74	[e]75
Hong Kong[2]	104	71	30	31	22
India[2]	573	[e]500	[e]500	[e]500	[e]800
Indonesia[2]	69	250	284	[r]268	210
Japan	1,974	2,232	4,306	4,429	3,587
Korea, Republic of[2]	2,546	1,994	2,090	2,294	2,640
Malaysia[2]	60	28	[r]55	53	[e]55
Pakistan[2]	534	173	132	134	169
Philippines[2]	10	28	(3)	[r]1	1
Singapore[2]	86	103	104	87	72
Syria[2]	19	27	7	[e]15	[e]15
Taiwan[2]	971	718	811	637	766
Thailand[2]	460	430	707	545	725
Turkey	579	825	1,184	1,144	[2]1,323
Oceania:					
Australia	[2]1	[e]1	(6)	[r]13	[e]10
New Zealand[2]	5	6	3	3	3
Total	[r]26,865	[r]26,536	[r]29,266	[r]34,475	35,556

[e]Estimated. [r]Revised.
[1]Unless otherwise specified, source is United Nations Economic Commission for Europe. Annual Bulletin of Steel Statistics for Europe 1985, v. 13, New York, 1986, 88 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]Partial figure; compiled from incomplete returns of subject country and export statistics of trading partner countries.
[6]Revised to zero.

Kyanite and Related Materials

By Michael J. Potter[1]

Kyanite, andalusite, and sillimanite are anhydrous aluminum silicate minerals that are alike in both composition and use patterns and have the same chemical formula, $Al_2O_3 \bullet SiO_2$. Related materials include synthetic mullite, dumortierite, and topaz, also classified as aluminum silicates, although the last two additionally contain substantial proportions of boron and fluorine, respectively. All of these kyanite-group substances can serve as raw materials for manufacturing special high-performance, 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 1986 was estimated to have decreased compared with that of 1985 because of a similar decrease in steel shipments. The iron and steel industry has been the largest end user of kyanite, mullite, and synthetic mullite in its refractories.

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, of the three active mines canvassed, none responded. These mines were operated by two companies. An estimate of total production was made by the Bureau of Mines using last reported production levels adjusted by the trend of the minerals economy.

In the synthetic mullite survey, of the four canvassed operations, three, or 75%, responded and accounted for an estimated 87% of the total production data shown in table 1. The percentage of production that was estimated, 13%, was arrived at by using last reported production levels adjusted by the trend of the minerals economy.

Legislation and Government Programs.—The allowable depletion rates for kyanite, established by the Tax Reform Act of 1969 and unchanged through 1986, were 22% for domestic production and 14% for foreign operations.

DOMESTIC PRODUCTION

Kyanite was produced in the United States at three open pit mines, two in Virginia and one in Georgia. Kyanite Mining Corp. operated the Willis Mountain and East Ridge Mines in Buckingham County, VA. Pasco Mining Inc. operated the Graves Mountain Mine in Lincoln County, GA, until September 1986, when the facility was shut down permanently.

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 1986 was estimated to be largely of the high-temperature sintered variety, and the three producers of this material were believed to be C-E Minerals Inc. at Americus, GA, Didier Taylor Refractories Corp. at Greenup, KY, and Harbison-Walker Refractories Co. at Eufaula, AL. Electric-furnace-fused mullite was produced by Sohio Electro Minerals Co. at Niagara Falls, NY. In late 1986, Sohio was purchased by Washington Mills Abrasive Co. of North Grafton, MA. The new name of Sohio became Electro Minerals U.S. Inc. Another company, A. P. Green Refractories Co., announced plans to close out its operations, including synthetic mullite, at Philadelphia, PA, at the end of 1986.[2]

Table 1.—U.S. production of synthetic mullite

Year	Quantity (short tons)	Value (thousands)
1982	27,000	$5,950
1983[e]	23,000	4,700
1984[e]	27,000	5,300
1985[e]	27,000	5,450
1986[e]	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, 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

Engineering and Mining Journal, December 1986, listed prices for raw kyanite, f.o.b. Georgia, ranging from $92 to $144 per short ton for bulk shipments and $9 more per ton for bagged material. These prices were unchanged from those of 1985.

Prices in 1986, in British pounds, from Industrial Minerals (London) were the same as those of 1985. The price increases in U.S. dollars of 7% in table 2 reflect a corresponding increase in the value of the British pound against the U.S. dollar.[3]

Table 2.—Prices of kyanite and related materials

(Dollars per short ton)

	1985	1986
Andalusite, Transvaal, 52% to 54% Al_2O_3, bulk, c.i.f. main European port	89	95
Andalusite, Transvaal, 60% Al_2O_3, c.i.f. main European port	114	122
Sillimanite, South African, 70% Al_2O_3, bags, c.i.f. main European port	241	259
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	114-197	122-211
U.S. kyanite, f.o.b. plant, carlots:		
Calcined	123-172	123-172
Raw	70-137	70-137

Source: Industrial Minerals (London). No. 231, Dec. 1986, p. 87.

FOREIGN TRADE

Shipments of U.S. kyanite- and mullite-containing materials were made to destinations in Europe and Asia. Using updated information from mineral importers, imports of andalusite were estimated to be 7,500 tons in 1984, 3,000 tons in 1985, and 5,000 tons in 1986.

WORLD REVIEW

Australia.—Technical, market, and commercial evaluation work continued on the large industrial topaz deposit in Torrington, New South Wales. Two companies, Kingsway Group Ltd. and Pacific Copper Ltd., each controlled approximately 50% of the ore reserves in the area. The 440,000 tons of recoverable topaz may be doubled after further exploration. The host silexite rock contained 10% to 20% topaz in a quartz matrix. Calcination of topaz concentrates at approximately 2,370° F yielded a very pure, dense-grained refractory mullite containing 70% to 72% alumina and was said to be comparable to many of the highest grade synthetic mullites available from European, Japanese, and U.S. producers. Also of interest was fluosilicic acid, a calcination by-product, with potential for use in the production of fluorite, synthetic cryolite, and aluminum fluoride, as well as precipitated or fumed silica. Problems of conflicting land use may have an effect on development plans.[4]

South Africa, Republic of.—The andalusite mine formerly run by Andafrax (Pty.) Ltd. was acquired by the South African minerals import company, A. C. Nesbitt (Trading) (Pty.) Ltd. The new name of the operation was Purity Minerals (Pty.) Ltd. To reduce water consumption, emphasis was being placed on dry processing techniques. The andalusite occurs in metamorphosed shales containing 5% to 20% andalusite crystals. Reserves were estimated at 30 years at a production rate of 2,200 tons per month. Typical specifications of the final andalusite product were 0.7% ferric oxide and 59.5% alumina. Particle size was approximately plus or minus 0.12 inch and minus 0.04 inch for the fine grade.[5]

Sweden.—At the new kyanite operation of Svenska Kyanite AB the ore is ground to 80% finer than approximately 100 mesh. In the production process the grinding of the ore in rod and ball mills is immediately followed by flotation. The company had found that desliming the ore between grinding and flotation decreased recovery and complicated the processing. The final kyanite product contains a low level of acid-soluble iron, an important factor for use of the end product in the refractories industry.[6]

In late 1986, Svenska Kyanite became a wholly owned subsidiary of Svenska Mineral AB, one of Sweden's leading industrial mineral companies. Svenska Kyanite was originally a joint venture between Svenska Forshammer AB and Ulf Juvel AB.[7]

United Kingdom.—In 1985, imports of kyanite-group minerals totaled 54,500 tons; principal countries of origin and percentages supplied were the Republic of South Africa, 55%; France, 20%; and the United States, 14%.[8]

Table 3.—Kyanite: World production, by country[1]

(Short tons)

Country[2] and commodity	1982	1983	1984	1985[p]	1986[e]
Australia: Sillimanite[3]	863	133	559	[e]550	550
Brazil: Kyanite	466	473	1,422	[r e]1,540	1,650
China: Unspecified[e]	2,800	2,800	2,800	2,800	2,800
France: Andalusite	46,300	[r]46,187	57,300	[e]55,100	57,300
India:					
Andalusite	591	2,836	[e]3,000	556	550
Kyanite	37,425	42,226	40,812	33,590	30,860
Sillimanite	14,403	8,739	14,746	18,844	18,740
Kenya: Kyanite	--	[r]6	1	1	1
Korea, Republic of: Andalusite	36	319	230	46	55
South Africa, Republic of:					
Andalusite	171,655	128,503	157,967	214,612	203,900
Sillimanite	11,089	898	1,445	1,474	1,500
Spain: Andalusite	5,627	4,945	3,307	3,087	3,300
United States:					
Kyanite	W	W	W	W	W
Synthetic mullite[e]	[4]27,000	23,000	27,000	27,000	W
Zimbabwe: Kyanite	2,433	--	--	--	--

[e]Estimated. [p]Preliminary. [r]Revised. 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. 7, 1987.
[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]In addition, sillimanite clay (also called kaolinized sillimanite) is produced, but output is not reported quantitatively, and available information is inadequate for the formulation of reliable estimates of output levels.
[4]Reported figure.

TECHNOLOGY

A technical article discussed how rapid development of new permanent magnetic materials recently helped foster a breakthrough in new magnetic separation technology. The present state of the art in advancing magnetic separation technology was reviewed. Applications included a number of industrial minerals, including coarse particle andalusite.[9]

[1]Physical scientist, Division of Industrial Minerals.
[2]Industrial Minerals (London). A. P. Green in Two Plant Closure. No. 228, Sept. 1986, p. 18.
[3]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=US $1.50 for 1986.
[4]Breen, T. A. E. Recent Developments To Produce Synthetic Mullite & Fluorine By-Products From Australian Industrial Topaz. Proc. 7th Ind. Miner. Int. Congr., Monte Carlo, Apr. 1986, pp. 199-205.
[5]Industrial Minerals (London). Andafrax Buyout Creates Purity Minerals. No. 227, Aug. 1986, p. 10.
[6]Graesberg, M. Swedish Kyanite — New Source of Alumina for Refractories and Ceramics. Proc. 7th Ind. Miner. Int. Congr., Monte Carlo, Apr. 1986, p. 82.
[7]Industrial Minerals (London). Svenska Mineral Takes Kyanite Under Wing. No. 231, Dec. 1986, p. 9.
[8]———. United Kingdom Industrial Mineral Statistics. No. 224, May 1986, p. 65.
[9]Arvidson, B. R. Advances in Magnetic Separation. Ind. Miner. Process. Suppl., July 1986, pp. 4-6, 8-9, 11.

Lead

By William D. Woodbury[1]

One of the major domestic primary lead producers sold out to its partner, who in turn merged on an equity basis with the largest U.S. producer. The result was a new entity controlling about 55% of the U.S. lead mining and refining capacity.

Domestic mine output of recoverable lead was the lowest in a nonstrike year since 1968. Primary refinery output decreased significantly, and the primary metal inventory was at the lowest level since 1978. Secondary plants produced over 600,000 metric tons for the third consecutive year, but total domestic refinery output dropped below 1 million tons for the first time since 1968. The net imports of refined metal, and total net imports of contained lead in all forms, including scrap, increased. Although total domestic consumption of lead declined, mainly because of a drop in its use in gasoline additives, the storage battery sector achieved a record-high share of the total, a result of continuing growth in uninterruptible power supply systems (UPS) necessary for voltage control and emergency power in critical computer storage systems. Although the average U.S. producer sales price was severely depressed in the first half of the year owing to worldwide overproduction in 1985 and high 1985 year-end stock levels, significant price advances were made in the second half of 1986. At

Table 1.—Salient lead statistics

(Metric tons unless otherwise specified)

	1982	1983	1984	1985	1986
United States:					
Production:					
Domestic ores, recoverable lead content	512,516	449,295	322,677	413,955	339,793
Value thousands	$288,579	$214,745	$181,745	$174,008	$165,150
Primary lead (refined):					
From domestic ores and base bullion	459,865	459,328	330,168	416,091	344,176
From foreign ores and base bullion	52,295	55,227	65,409	71,353	22,071
Antimonial lead (primary lead content)	4,622	W	W	W	W
Secondary lead (lead content)	571,276	503,501	633,374	r615,695	614,886
Exports (lead content):					
Lead ore and concentrates	29,104	20,119	11,858	9,987	4,380
Lead materials excluding scrap	55,629	24,351	16,563	r37,322	19,778
Imports, general:					
Lead in ore and concentrates	35,807	47,516	68,870	42,665	86,747
Lead in base bullion	19	53	43	760	142
Lead in pigs, bars, reclaimed scrap	99,587	[1]179,485	167,868	136,697	143,511
Stocks, Dec. 31 (lead content):					
At primary smelters and refineries	125,537	106,661	135,079	127,950	87,049
At consumers and secondary smelters	97,209	100,771	97,077	93,130	83,824
Consumption of metal, primary and secondary	1,075,408	1,148,487	1,207,033	1,148,298	1,124,847
Price: Common lead, average, cents per pound[2]	25.54	21.68	25.55	19.07	22.05
World:					
Production:					
Mine thousand metric tons	r3,448.0	r3,358.3	3,252.5	p3,389.3	e3,239.3
Refinery[3] do	r3,171.7	r3,233.3	3,150.6	p3,359.9	e3,156.2
Secondary refinery do	r2,043.4	r2,024.5	2,293.9	p2,278.1	e2,278.0
Price: London Metal Exchange, pure lead, cash average, cents per pound	24.66	19.27	20.12	17.84	18.43

eEstimated. pPreliminary. rRevised. W Withheld to avoid disclosing company proprietary data.

[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]Metals Week. Transactions on a delivered basis.

[3]Primary metal production only. Includes secondary metal production where inseparably included in country total.

yearend, the domestic quotation range of 28 to 29 cents per pound was the highest since August 1984.

Recoverable world mine production, which represented 56% of estimated world demand in 1986, was estimated to have declined, and secondary sources supplied over 40% for the third consecutive year. World refinery production, including secondary lead, was estimated to have declined from that of 1985 and was significantly less than world demand, which increased slightly for the fourth consecutive year. The result was a precipitous drop in world metal stocks during the year.

The London Metal Exchange (LME) cash price for the year averaged 3.6 cents per pound less than that for the United States. This was marginally favorable for domestic importers, but in the last 3 months of 1986, the spread averaged about 5.9 cents per pound, which stimulated imports. The LME average for the year of 18.4 cents per pound was only 0.6 cent above that of 1985, which had been the lowest price since 1972.

In the United States, a Federal regulation lowering the permissible amount of lead contained in gasoline additives by 80% became effective on January 1, 1986. In June, amendments to the Safe Drinking Water Act were signed into law, significantly lowering the lead content of pipes and solders in municipal water systems.

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 286 consuming plants to which a survey request was sent, 267 responded, representing 93% of the total U.S. lead consumption shown in tables 1, 12, 13, 14, and 15. Of the 60 smelter-refineries to which a survey request was sent, 49 responded, representing 77% of the total refinery production of secondary lead recovered from scrap shown in tables 1, 8, 9, 10, and 11. Production and consumption for the nonrespondents were estimated using reported prior year levels adjusted for general industry trends.

Legislation and Government Programs.—On January 1, 1986, the permissible amount of lead additive in gasoline was reduced by the Environmental Protection Agency (EPA) from the July 1, 1985, standard of 0.5 gram per gallon to 0.1 gram per gallon. After the first quarter of 1986, the Occupational Safety and Health Administration (OSHA) ceased granting variances to the mandated 50 micrograms of lead per deciliter of blood level for employees at U.S. secondary lead-producing plants. Until then, OSHA had permitted a level of up to 60 micrograms per deciliter under certain conditions, under the law that originally became effective on March 1, 1983. On June 19, 1986, the President signed amendments to the Safe Drinking Water Act of December 16, 1974, prohibiting new pipes, fittings, or patches to existing pipes in municipal water systems from having a lead content exceeding 8%; the standard for lead in solders and fluxes was set at 0.2%. In October 1986, the U.S. Supreme Court rejected the U.S. primary and secondary producers joint challenge to EPA's final 1984 wastewater treatment standards. The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund) was reauthorized in October 1986, which continued the tax of $4.14 per short ton on lead oxide produced or imported.

DOMESTIC PRODUCTION

MINE PRODUCTION

Domestic mine production of recoverable lead was significantly lower than that of 1985 and was the lowest in a nonstrike year since 1968, 1 year before the Viburnum Trend operations in Missouri came fully onstream. The low output was attributed to the severely depressed lead prices during the first 5 months of the year carried over from 1985, in concert with the unusually high U.S. producer metal stocks on hand at yearend 1985. Seven Missouri lead mines, of which only six operated all year, together with eight 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 1986. Byproduct lead was recovered from mining in four other States during the year, accounting for less than 1,000 tons.

The St. Joe Lead Co. division of St. Joe Minerals Corp., Clayton, MO, operated two mine and mill complexes involving four mines in southeastern Missouri on the Viburnum Trend. According to parent Fluor Corp.'s annual Securities and Exchange (SEC) Form 10-K covering the fiscal year ending October 31, 1986, St. Joe hoisted 3.24 million tons of ore with an average grade of 5.57% lead. St. Joe's total lead in concentrate production for 1986 was 169,620 tons, an increase of over 14,000 tons from that of 1985, according to Fluor's Form 10-K. St. Joe was the largest U.S. lead mine producer during the year, accounting for nearly 50% of the total domestic production even though its Brushy Creek Unit in Missouri did not operate in 1986.

On November 1, 1986, St. Joe formed a partnership called The Doe Run Co. with Homestake Lead Co. of Missouri, a subsidiary of Homestake Mining Co. Each partner contributed its domestic lead business. St. Joe contributed its smelter-refinery, five mines, and three mills in Missouri. Homestake Lead contributed its Buick, MO, mine and mill, and Boss, MO, smelter-refinery. St. Joe retained a 57.5% interest and continued as operator of Doe Run under a services agreement. At yearend, Doe Run represented about 55% of the U.S. lead mining and refining capacity. The management of Doe Run estimated that, as of November 1, 1986, the new entity had proven ore reserves in Missouri of approximately 64.4 million tons with an average grade of 5.5% lead. Approximately 65% of the ore contained in Doe Run's ore bodies is on properties held under Federal mineral leases for terms of 10 to 20 years, renewable for 10 years. Doe Run pays the Bureau of Land Management, U.S. Department of the Interior, a royalty of 5% of the gross value of concentrates produced from these ore bodies.

The Magmont Mine, equally owned by Cominco American Incorporated and Dresser Industries Inc. and operated by Cominco, represented the second largest company output of mined lead in 1986. According to Cominco Ltd. of Canada's annual stockholders' report, the mine in Iron County, MO, produced 103,200 tons of lead concentrates averaging 77.0% lead content, or 79,500 tons contained. That production was lower than anticipated, however, because of a major ground fall in part of the mine that could affect remaining reserves, pending test mining in 1987. The integrated mill, one of the most modern in the world, treated 948,000 tons of ore, 93,000 tons less than that of 1985. The average grade of 8.6% lead was 1.1% higher than that of 1985, and therefore contained lead was slightly higher. In cooperation with the Bureau of Mines, an experimental pilot plant to extract cobalt by columnar flotation during the lead recovery became operational. The Magmont Mine was the Nation's largest lead-producing mine in 1986 and at yearend was estimated to have 4.8 million tons of measured and indicated ore reserves averaging 5.9% lead, a significant reduction from yearend 1985, according to Cominco. Magmont's concentrates were shipped to ASARCO Incorporated's smelter-refinery at Glover, MO, for processing on a toll basis for Dresser's 50% share and outright sale of Cominco's 50% share.

Asarco, according to its 1986 annual stockholders' report, produced 30,500 tons of lead in concentrates at its new West Fork Mine in Missouri during the first full year in production. A decision was made in July to bring the mine up to full production, 46,000 tons per year of lead in concentrates, by mid-1987, at an additional development cost of $3.3 million. In December 1986, Asarco purchased Ozark Lead Co.'s Milliken Mine and mill at Sweetwater, MO, from the parent Kennecott and renamed it the Sweetwater Unit. On care-and-maintenance status since March 1983, Sweetwater is capable of producing 90,000 tons of lead in concentrates per year, according to Asarco, and could be the Nation's second largest lead mine. Asarco paid $850,000 plus assumption of certain liabilities and will pay Kennecott 25% of future revenues of the Sweetwater Unit resulting from sales of lead at prices in excess of 29 cents per pound, adjusted for inflation. That condition would only be in effect for 10 years, beginning 2 years after production resumes, and limited to $10 million aggregate payments. Sweetwater and West Fork together could supply all of Asarco's feed requirements for their Glover, MO, smelter-refinery, but Asarco had no plans to reopen Sweetwater at yearend. As operator, Asarco also produced 6,800 tons of lead in concentrates at their 50%-owned Leadville Unit, a gold-silver-zinc-lead mine in Lake County, CO. Asarco was the third largest domestic lead mining company in 1986 and at yearend was one of only two fully integrated lead-producing companies, the other being Doe Run. West Fork's lead reserves at yearend were estimated by the company to be 10,245,000 tons of ore grading 7.13% lead, down only slightly in content from yearend 1985.

The Nation's largest capacity lead mine, the Buick Mine located in Iron County, MO, was shut down in mid-May by the operator, AMAX Inc., who sold its 50% share to its partner, Homestake Mining, for $10 million cash, including the smelter-refinery at Boss, MO, plus other net working capital items worth about $3 million. The mine's production to that point allowed it to finish 1986 as the second largest producing mine, but Homestake Mining did not reopen it during the year. Hecla Mining Co. shut down its Lucky Friday silver mine in Shoshone County, ID, a large lead producer, in mid-April owing to the depressed silver prices after record-high production levels in 1985. Domestic lead-producing mines operated at only 63% of capacity during 1986, owing to depressed prices, and the top 10 mines shown in table 6 produced over 99% of the total.

SMELTER AND REFINERY PRODUCTION

Primary.—According to Fluor Corp.'s annual SEC Form 10-K, the Doe Run smelter-refinery at Herculaneum, MO, the Nation's largest, produced 162,000 tons of refined lead, about the same as that reported in 1985, and which represented over 40% of 1986 primary production. The Doe Run plant at Boss, MO, which was shut down in mid-May with its captive Buick Mine, produced 53,500 tons of refined lead, according to Homestake's annual report.

Asarco's annual stockholders' report stated that its two smelters at East Helena, MT, and Glover, MO, produced 166,300 tons of lead bullion, and the smelter at El Paso, TX, did not operate during the year. The two refineries at Omaha, NE, and Glover, MO, produced 159,400 tons of refined lead and antimonial lead in 1986, a decrease of 45,440 tons from that reported in 1985. The lowered production was attributed to the virtual dearth of supply of foreign concentrates, owing to Peru's increase in its own smelting capacity, Australia's mine disruptions, and mine closures in Idaho's Coeur d'Alene silver mining district. The plant at Glover, MO, however, produced over its rated capacity for the second year in a row, owing to higher grades of domestic raw material feedstocks and uninterrupted operations with minimal downtime for repairs and maintenance. The U.S. primary refineries operated at 63% of capacity in 1986, compared with 82%, in 1985.

Secondary.—The U.S. secondary industry at yearend consisted essentially of 21 companies, which operated 29 plants with refined metal capacities ranging from 5,000 to 80,000 tons per year. There were also 28 small producers with 29 plants and annual capacities of 2,000 tons or less each, which produced specialty alloys for such uses as solders, brass or bronze ingots, and bearing metals. During the year, two plants in Oregon and Pennsylvania with a combined capacity of over 30,000 tons annually were closed. At yearend, nominal industry installed capacity was the same as yearend 1985, about 800,000 tons, owing to increases at some plants. Secondary capacity utilization for 1986 was 74%. In the last quarter of the year, strict Federal enforcement of regulations promulgated by the U.S. Department of Transportation concerning shipment of scrap lead-acid batteries over water bottled up exports primarily destined for Brazil and Taiwan. This improved what had been a mounting west coast battery scrap shortage. That relief may only be temporary, however, because about 110 million scrapped automotive batteries nationwide, excluding those exported, went unrecycled from 1980 through 1986, according to a Bureau of Mines estimate. This represented a drastically declining collection rate.

CONSUMPTION AND USES

Despite reported increases in the use of lead in traditional areas such as storage batteries, specifically industrial-traction types, and sheet lead or cable sheathing, overall consumption declined to the lowest level since 1982. This was attributed primarily to a marked decline in the use of lead for gasoline additives. There was also a significant decline in use for ammunition and other castings, and a drop in use in ceramics and glass, which had been increasing for television tubes. Other miscellaneous metal product uses, including type metal and terne metal, declined compared with those of 1985. All other end uses remained about level, with minor up or down variances, including automotive batteries and solder, which had declined for seven consecutive years.

According to statistics of the Battery Council International of domestic shipments plus units exported, production of automotive batteries, the largest specific end use for lead, increased by just under 1.3 million units from that of 1985, or 1.7%. However, this slight increase represented a lowering of materials in process and metal inventories, and not an increase in new metal demand for 1986. The Bureau of Mines estimated that the consumption of lead for grids and oxides in industrial and traction batteries increased by 21,600 tons, or 15%, to 167,400 tons, attaining a record high of just under 20% of that consumed for all lead-acid batteries. This sector has been the greatest growth area for lead consumption since 1982, expanding by nearly 100,000 tons compared with that year's figure, primarily for UPS systems.

The total use of lead to manufacture each automotive battery was estimated by the Bureau of Mines to be 20.0 pounds per unit, a drop of 0.6 pound per unit from that of 1984 and 1985. This was a reflection of continuing rapid technologic advances in design and manufacturing of batteries, as well as overall average vehicle downsizing. Exports of automotive batteries totaled 2,079,500 units, a decline of 153,500 units from those of 1985. The use of lead in storage batteries of all types attained a record high 76% of the reported domestic total consumption.

STOCKS

Metal stocks at domestic primary refineries decreased owing to the significantly decreased production levels at domestic mines and smelters, although raw material feedstocks increased to the highest level since 1980, a recessionary year. The latter condition reflected the indefinite shutdown of the Boss, MO, smelter-refinery in mid-May, which remained on standby through yearend. Refined pig lead stocks held by secondary producers and consumers at yearend were down slightly for the third consecutive year. Total stocks of contained lead in all forms, excluding scrap, held by all domestic producers and consumers, were down by 50,000 tons at yearend.

Stocks of lead and antimonial lead metal in the market economy countries reporting to the International Lead and Zinc Study Group (ILZSG) were approximately 400,000 tons at yearend, about 7% of 1986 total world demand, and 80,000 tons lower than at yearend 1985.[2] At yearend 1986, stocks in LME warehouses totaled 38,000 tons, a decrease of 23,000 tons from those of yearend 1985. Total ILZSG and LME stocks at yearend were the lowest since 1978, when they stood at 397,000 tons and 16,000 tons, respectively.

PRICES

At the start of the year, the U.S. producer price quotations range for lead published in Metals Week moved slightly downward, narrowing from 18.5 to 20.0 cents per pound listed on December 16, 1985, to 18.5 to 19.0 cents listed March 26, 1986, through April 24, 1986. That was the low point of the year, normally a slack sales period. Rising back to 18.5 to 20.0 cents per pound on April 25, the quotations rose gradually, but continuously, through yearend to 28.0 to 29.0 cents first listed on December 15. A normal spread of 1 to 2 cents per pound existed at the start of this period, until July 8, but then expanded to 2.5 to 3.0 cents through August before narrowing back to 0.5 to 1.0 cent per pound through yearend; on September 3, the quotation range was 23.0 to 24.0 cents per pound. In October, owing to the unbalancing merger in the domestic primary sector and the withholding of sales price data by the producers, the U.S. producer weekly and monthly weighted average transactions prices were replaced by Metals Week with the North American producer weekly and monthly mean U.S. list prices, sales-weighted.

On the LME, the monthly average cash price was virtually level for the first 4 months of the year, but had a gradually increasing differential with the U.S. producer average starting in March. Starting with May, the average cash price rose every month except July, which had four consecutive slight weekly setbacks, but at a slower rate than U.S. prices rose. As a result, a spread with North America of 7.0 cents per pound was reached during the first 2 weeks of November, the highest since August 1984 (7.1 cents), but narrowed for December 1986, to 5.2 cents per pound. Therefore, extremely high pig metal imports, almost 19,000 tons, were landed in the United States in November, and then tapered off to slightly under 12,000 tons during December, which was the monthly average for the year. The December average prices of 28.7 cents per pound in North America and 23.5 cents per pound on the LME were the highest since July 1984 and August 1982, respectively.

The domestic prices for lead oxides were based on the selling price for pig lead in a given period plus conversion charges. However, premium adjustments were also made by individual producers to reflect differences in manufacturing techniques, freight considerations, quality requirements, and other factors. The average total premium for carload lots, exclusive of containers, at plant, for litharge and red lead was 10.3 cents per pound above the average pig lead price, according to shipment values reported to the Bureau of Mines.

FOREIGN TRADE

Exports of contained lead in all forms, excluding scrap, were the lowest total since 1977. Scrap exports remained level. These conditions were attributed to the low domestic mine and primary metal production in the face of healthy demand, and the high capacity utilization in the U.S. secondary sector. Brazil and Taiwan received 64% 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%. Refined pig lead sent to the LME was virtually negligible in 1986. The United States had 90,000 tons net imports for consumption of lead in all forms, excluding chemicals, pigments, and oxides. Of the contained lead imported, 94% was refined pig lead, most of which came from Canada and Mexico, the traditional suppliers.

Imports of chrome yellow used for highway markings decreased for the first time in 5 years, but imports of litharge rebounded significantly from the low volume of 1985 as total imports of lead chemicals and compounds increased slightly. Mexico accounted for almost all of the U.S. imports of litharge and red lead, while Canada supplied 45% of all other categories, including over three-quarters of the chrome yellow. The Federal Republic of Germany, the Netherlands, and New Zealand accounted for most of the balance of chrome yellow. Argentina supplied about 90% of the lead acetate; Belgium and China equally supplied over 80% of the lead nitrate; the United Kingdom supplied over 90% of the lead arsenate; and Canada and the Netherlands supplied almost all of the other lead salts. Canada and Mexico accounted for over 80% of the total U.S. imports of lead chemicals and compounds, including oxides.

Table 2.—U.S. import duties for lead materials, January 1, 1986

(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	2.5% ad valorem	Free[1] or 2.3% ad valorem.	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 refined soft lead and antimonial lead in the market economy countries was 4.11 million tons, compared with 4.04 (revised) million tons in 1985, 4.00 million tons in 1984, and 3.80 million tons in 1983.[3] Estimated world consumption of lead in all forms during 1986 also increased for the fourth consecutive year to 5.60 million tons, the highest level since 1979 (5.73), compared with 5.56 (revised), 5.47 (revised), and 5.26 million tons in 1985, 1984, and 1983, respectively. However, estimated world primary refinery production decreased by 204,000 tons compared with that of 1985, owing primarily to significant indefinite shutdowns in Morocco, Spain, and the United States, and a concentrate shortage in Australia resulting from work stoppage because of disagreements between labor and management. The result was a world drawdown of metal stocks exceeding the buildup from the overproduction in 1985, and a steady rise in prices during the last 4 months of the year. Secondary lead production was over 40% of the world's total refinery output for the third consecutive year.

Four new lead-producing mines were opened during 1986, and two mines closed in previous years were reopened, including the large Faro open pit in Canada. Capacity that came into operation, including several small expansions of existing mines, totaled 150,000 tons. This was partly offset, however, by the closure of 11 mines, including the world's largest open pit lead mine in Morocco, totaling 108,000 tons. Several of these were silver mines, such as the Lucky Friday Mine in the United States that had a lead capacity of over 30,000 tons per year, and were not considered permanent closures. At yearend, world mine capacity for lead was estimated to be about 4.1 million tons per year, including those properties only temporarily shut down, about the same as that of yearend 1985. World mine production in 1986 was estimated to be 150,000 tons less than that of 1985.

A new electrolytic lead refinery was opened in the Republic of Korea and a new 12,000-ton-per-year primary smelter-refinery came on-stream in Peru. In Spain, there was a net loss of 30,000 tons of primary smelting and refining capacity owing to a closure only partially offset by an expansion. World primary refining capacity at yearend was 4.54 million tons compared with 4.34 million tons smelting capacity, about 1 million tons over the world's average lead mine production per year since 1969.

Australia.—The drop in mine production of lead resulted from labor-management disagreements from midyear through yearend, including a 2-month strike (May 26, 1986 to July 21, 1986) at the large Broken Hill, New South Wales, mines of Australia Mining & Smelting Ltd. (AM&S) and North Broken Hill Holdings Ltd. (NBHH). Mine production also declined slightly at Mount Isa, Queensland, and at Woodlawn, New South Wales, but increased at the AM&S CSA Mine at Cobar, New South Wales. Production from the NBHH mines on the west coast of Tasmania and at Elura, New South Wales, remained about the same as that of 1985. The decrease in total mine production in 1986 resulted in a nearly 50,000-ton decrease of metal from The Broken Hill Associated Smelters Pty. Ltd.'s (BHAS) smelter-refinery at Port Pirie, South Australia, the country's only primary refined lead producer.

A significant event during the year was the relinquishment of controlling interest held by Rio Tinto-Zinc Corp. PLC., a British company, to 49% of Conzinc Rio Tinto of Australia Holding Pty. (CRA), which had 100% ownership of AM&S. Control became domestic, as required by law, including that of the subsidiaries: New Broken Hill Consolidated Ltd. (NBHC), Zinc Corp. Ltd. (ZC), Cobar Mines Pty. Ltd., Sulphide Corp. Pty. Ltd., and BHAS, which is 30% owned by NBHH. NBHC and ZC intended to link their mines in Queensland and hoist through a refurbished NBHC shaft toward the end of 1987. The ZC shaft would be used in the interim. At yearend, CRA announced that the Woodlawn open pit mine at Tarago, New South Wales, scheduled for completion in early 1987, would go underground at 50% to 60% of the pit production rate for an additional 4 years, with similar grades. The extended ore body had been evaluated through exploratory workings since early 1985.

Development work continued at Mount Isa Mines Ltd.'s (MIM) Hilton silver-lead-zinc deposit 20 kilometers north of Mount Isa. Scheduled to come on-stream in 1987, the new mine could have a yearly production of about 2.5 million tons of ore by the mid-1990s, about that projected for the decline at Mount Isa. Exploratory drilling continued nearby at MIM's Hilton North property and through 1986 had outlined a probable reserve of 23 million tons averaging 6.4% lead and 12.4% zinc, plus another 30 million tons of possible ore averaging 5.8% lead and 11.5% zinc. Joint ventures composed of BHP Minerals Ltd.-Billiton Australia and BHP Minerals Ltd.-Cyprus Minerals Co. delineated zinc-lead-silver deposits at Cadjebut and Twelve Mile, respectively, in Western Australia. The Cadjebut reserves were 3.5 million tons grading 5% lead and 14% zinc.

At the Hellyer zinc-lead-silver prospect of Aberfoyle Ltd., 3 kilometers north of its Que River Mine on Tasmania, an exploration adit intersected the main ore body in May, and successful pilot milling of the ore in a converted tin mill led to a decision to develop the property and mill 250,000 tons of ore per year beginning in February 1987. A feasibility study to expand the operation with a new mill was scheduled for completion by late 1987. Aberfoyle was 43% owned by Cominco of Canada at yearend. Early in the year, Metallgesellschaft AG of the Federal Republic of Germany reportedly agreed to fund exploration of MIM's lead-zinc-copper find at Balcooma, Queensland, for a 35% interest within 2 years with the option of 50% at the end of the third year of exploration. Pancontinental Mining Ltd. (51%) entered into a joint venture with Outokumpu Oy (49%) of Finland to develop the Lady Loretta deposit in Queensland. Initial development, begun in May 1986, will extend through 1987 and include the sinking of a 470-meter-deep shaft. Published reserves at yearend were 9 million tons of ore averaging 6.5% lead and 14.8% zinc. Total in situ Australian reserves of lead at yearend were estimated by the Bureau of Mines to be about 17 million tons, about equal to that of the United States, including Alaska.

Canada.—Mine production of lead increased significantly in 1986 as a result of 6 month's production at capacity from Curragh Resources Corp.'s expanded Faro Mine in the Yukon Territory, and continued high grading at Pine Point Mines Ltd.'s operation at Yellowknife in the Northwest Territories. Cominco owns 51% of Pine Point. It's revised mine plan, which significantly lowered overall Canadian estimated lead reserves, was not expected to extend beyond the opening of Cominco's Red Dog Mine in Alaska in 1991. Total mine production increased about 45,000 tons over that of 1985, but at yearend, the Canadian Government's estimate of in situ proven and probable economically minable lead ore reserves was about 8 million tons, less than one-half of that for either the United States or Australia. Estimates for Canada, however, included only reserves for operating mines and deposits actually committed to production. Primary refined lead production in 1986 did not increase significantly over that of 1985 as most of the increase in total concentrate production was exported overseas through Skagway, Alaska, from the Faro Mine production.

Canadian Pacific Enterprises Ltd. sold 31% of its controlling interest (52%) in Cominco, Canada's largest lead and zinc producer, to a consortium consisting of Teck Corp. (50%), MIM Canada Inc. (25%), and Metallgesellschaft Canada Ltd. (25%). In another development, an Australian company, East-West Minerals NL, acquired ownership of Anaconda Canada Exploration Ltd. and Caribou-Chaleur Bay Mines Ltd. in order to develop their Caribou deposit in New Brunswick, which had over 6 million tons of estimated minable reserves averaging 4.5% lead and 9.5% zinc. Brunswick Mining and Smelting Corp. Ltd. of New Brunswick announced plans to deepen one of its shafts and install a new crusher, which will take over 3-1/2 years to complete, at its No. 12 Mine at Bathurst, Canada's largest zinc-lead mine and second largest lead producer. In western Canada, Westmin Resources Ltd. had a threefold increase in production at its H-W Mine at Myra Falls, British Columbia, which opened in 1984, as the new mill reached capacity in the fourth quarter. The improved efficiency reportedly reduced operating costs by nearly 50%.

Cominco announced in August that it would proceed with the modernization of its lead smelter at Trail, British Columbia, estimated to cost about $187 million, following offers from the Provincial and Federal Governments to invest $40 million and $57 million, respectively, over 5 years in redeemable preferred shares bearing interest at a floating rate tied to metal prices. The new smelter will have a capacity of 160,000 tons per year and will be the world's first to utilize the revolutionary Lurgi-GmbH-QSL process on a large production scale. The project was expected to be completed in 1989, and significantly improve in-plant and off-site environmental conditions at Trail as well as metallurgical efficiency. Refinery capacity will not be affected. During the year, Cominco instituted extended summer shutdowns at its prime feeder mine to Trail, The Sullivan, Canada's largest lead producer, as well as at the Trail Metallurgical complex and the Polaris Mine in the Northwest Territories, the nation's fourth largest lead producer.

China.—The Government announced plans to spend about $1.2 billion by 1990 at Baiyin City, known as the "copper city," in northwest China's Gansu Province. Five projects involving development of the nation's largest nonferrous metal producing area have been proposed with an annual metal output of 300,000 tons combined of copper, lead, zinc, and aluminum by 1988. The output in 1986 was 50,000 tons combined. The new QSL smelter under construction with an annual production capacity of

50,000 tons of lead was proposed for startup by 1990. A second stage expansion of the Changba open pit lead and zinc mine was scheduled to surpass 400,000 tons per year production of the four metals. The area's verified "reserves" are 10 million tons for lead and zinc. Additional "reserves" of 350,000 tons of lead and zinc were identified at an operating mine in eastern Inner Mongolia.

About $81 million was scheduled for investment by 1990 on modernization of the Fankou lead-zinc mine in Guandong Province to increase output by 50%. Lead production in 1985 was 30,000 tons, which was refined at the nearby Shaoguan smelter, which was also to expand its lead capacity by 15,000 tons by 1990 at a cost of $13.5 million. Tentative plans were being considered also for a new smelter at Shaoguan, which would increase total capacity to 180,000 tons combined lead and zinc. There was also a proposal to develop a new mine and metallurgical complex near the Burmese border at Lamping, which reportedly had 14 million tons of proven ore grading 10% combined lead and zinc. Chinese demand for lead reportedly reached 190,000 tons in 1985.

Germany, Federal Republic of.—Metallgesellschaft was considering the replacement of its primary lead smelter at Binsfeldhammer with an 80,000-ton-per-year QSL plant developed by its engineering subsidiary, Lurgi. The company's 1986 acquired share of Cominco of Canada, together with its Australian connection to MIM, was expected to give it more secure access to necessary raw materials and further demonstrate its QSL technology for sale worldwide.

Greenland.—In midyear, Vestgron Mines Ltd., then a subsidiary (62.5%) of Cominco, sold its interest in Greenex A/S, owner of the Black Angel zinc-lead-silver mine, to Boliden AB of Sweden. At yearend, Cominco divested itself completely of Vestgron as a cost-cutting measure.

Korea, Republic of.—A new 35,000-ton-per-year electrolytic lead refinery, owned by Korea Zinc Co. Ltd., came on-stream at Onsan in Kyoung Nam Province during the year.

Mexico.—Industria Minera México S.A. opened a lead-zinc mine, capacity 7,000 tons of lead per year, at Rosario, Sinaloa, and expanded a gold-silver mine to an additional 2,000 tons of lead per year byproduct at Charcas, San Luis Potosí. Cía Fresnillo S.A. de C.V. also opened a new silver-lead-zinc mine at Sultepec with a capacity of 1,000 tons of lead per year. These were offset, however, by closings at Industrias Peñoles S.A. de C.V. (PENOLES) mines at Ocampo, Coahuila, and Alamos, Sonora, totaling 12,000 tons of lead per year. However, PENOLES had underground development work going on at two new mines, one in Durango and one in Guerrero, plus an expansion in Queretaro. Cyprus Minerals and Minera Antares also continued development of mine projects in Chihuahua and Durango, respectively.

Morocco.—The world's largest open pit lead mine at Zaida, Khenifra, opened in 1972, was closed by Société de Développement Industriel et Minière de le Haute Moulouya, which resulted in about a 30% drop in Moroccan lead mine production in 1986. Typical recent production levels at Zaida had been nearly 50,000 tons per year.

Peru.—Expansion projects under way during 1986 at seven zinc-lead-silver mines were expected to add 8,000 tons more lead capacity in 1987 and an additional 5,000 tons in 1988. Empresa Minera del Centro del Perú completed a zinc-lead-copper mine expansion in 1986 at Casapalca, adding another 5,000 tons to Peru's lead mining capability during the year. However, this was offset by St. Joe Minerals closing in April of its El Madrigal Mine at Caylloma, Arequipa, which had a capacity of 6,000 tons of lead per year. Peru's first private lead smelter-refinery was started up in September with an annual capacity of 12,000 tons of metal. The operation, situated at Sayan, of Fundición de Concentrados S.A., was reportedly funded and set up by Ciá. Minera Santa Rita S.A. It will process 100% Minero Perú Comercial feed on toll until 1989, which then will be reduced to 30% until 1999.

Spain.—Empresa Nacional Adaro de Investigacíones Mineras S.A. permanently closed its underground lead-silver mine at Linares, Jaén, which had operated since 1949 with a capacity of 5,000 tons per year. This was partially offset by the new Troya zinc-lead mine opened in November at Besain, Guipuzcoa, by Exploración Minera Internacional España S.A. Spain's second largest primary lead producer, Compañia La Cruz S.A., indefinitely shut down its 50,000-ton-per-year custom smelter-refinery at Linares, Jaén, in the second half of the year. Spanish entry to the European Economic Community has meant that the internal metal price has been at less of a premium to the LME, thereby reducing the operating margin. Peñarroya S.A.-España, however, added 20,000 tons per year of capacity to its smelter-refinery at Cartagena, Murcia, the nation's largest. The new furnace was having technical difficulties at yearend, however.

Sweden.—Boliden Metall AB decided to sell its 50% share in the Preussag Boliden-Blei GmbH primary lead smelter-refinery at Nordenham in the Federal Republic of Germany as part of a cost-cutting plan. The company had also threatened to permanently close its smelter-refinery at Ronnskar if new stringent sulfur dioxide emission standards are rigidly enforced. It will reportedly not build a new plant, but could curtail production levels and make some modifications as an alternative strategy if its appeal to the Government is denied.

Tunisia.—Société Tunisienne d'Expansion Minière S.A. (SOTEMI) mine at Sidi Bou Aouane was closed in November, but this was more than offset by the completion of an expansion project at SOTEMI's Fej Hassen zinc-lead mine at Ghardimaou. The closed mine had originally opened in 1911; the Fej Hassen Mine opened in 1899.

TECHNOLOGY

A highly promising, revolutionary lead-acid battery system, patented and developed by Dunlop-Olympic-Australia, was introduced by Pacific Dunlop of Australia, which during the year acquired Chloride Incorporated, Tampa, FL, a leading U.S. battery producer. The innovative concept, known as the Pulsar Power Pak, consists of four distinct types of injection-molded plates welded together to form individual small 12-volt "batteries," instead of conventional 2-volt cells. When connected in parallel, a Power Pak of any desired capacity can be achieved. The construction process, utilizing automatically casted calcium alloy strip lead, is highly automated and continuous. Another significant advantage is that the design allows current to pass directly across the complete edge of a plate to the plate of opposite polarity, and with no cell buss bars impedance is very low. The battery weights are 20% to 60% lighter than the conventional lead-acid units delivering similar performance, the widest discrepancy being at the lower performance level. The Pulsar design lends itself to the proposed dualized system recently under much discussion in automotive circles, whereby each vehicle would have separate starting and auxiliary "key-off" and/or operating units, but charged through the same alternator circuit and available to assist one another if drawn down.[4]

Southern California Edison Co., in conjunction with the Electric Power Research Institute, the International Lead Zinc Research Organization, and Bechtel Ltd., announced plans in midyear to construct the world's largest lead-acid "battery," capable of storing enough electricity for 10,000 customers. When on-stream in 1988, it will be the first utility-side commercial load leveling plant in the United States, storing relatively inexpensive offpeak electricity for later feedback into the utility grid during periods of peak demand. The pilot plant, to be located at Edison's Chino, CA, substation, will utilize 2,300 tons of lead in battery banks covering about 1 acre and able to produce 10 megawatts of power. Estimated cost was about $10 million.[5]

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 were published in quarterly issues of Lead Abstracts, Lead Development Association, London, United Kingdom.

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[1]Physical scientist, Division of Nonferrous Metals.

[2]International Lead and Zinc Study Group (London). Lead and Zinc Statistics. ILZSG Mon. Bull., v. 27, No. 9, Sept. 1987, pp. 17-18.

[3]Work cited in footnote 2.

[4]Battery Man. V. 28, No. 9, Sept. 1986, pp. 15-20.

[5]Lead Industries Association Inc. 1986 Annual Report. P. 2.

The Wall Street Journal. July 28, 1986, sec. 2.

Table 3.—Mine production of recoverable lead in the United States, by State

(Metric tons)

State	1982	1983	1984	1985	1986
Alaska	W	W	--	--	--
Arizona	359	234	W	581	W
California	W	W	W	--	--
Colorado	W	W	W	W	W
Idaho	W	25,893	W	33,707	9,951
Illinois	W	W	W	W	W
Missouri	474,460	409,280	278,329	371,008	319,900
Montana	661	1,163	W	846	W
Nevada	W	14	W	(1)	--
New Mexico	W	258	--	W	10
New York	1,065	1,299	W	W	W
Oregon	--	W	--	--	--
Tennessee	--	--	W	W	--
Utah	W	--	W	--	--
Washington	W	--	--	--	--
Total	512,516	449,295	322,677	413,955	339,793

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	1985	1986
January	31,778	40,392
February	33,252	36,277
March	37,582	38,216
April	39,256	33,984
May	37,069	25,038
June	32,485	23,763
July	34,451	25,168
August	34,808	23,420
September	30,929	24,186
October	36,882	24,301
November	32,476	20,800
December	32,987	24,248
Total	413,955	339,793

Table 5.—Production of lead and zinc, in terms of recoverable metal, in the United States in 1986, 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
Arizona	--	--	--	--	--	--	--	--	--
Colorado	--	--	--	W	W	W	--	--	--
Idaho	--	--	--	--	--	--	--	--	--
Illinois	--	--	--	--	--	--	--	--	--
Missouri	3,335,823	229,432	26,086	--	--	--	705,431	50,718	10,147
Montana	--	--	--	--	--	--	--	--	--
New Jersey	--	--	--	W	--	W	--	--	--
New Mexico	--	--	--	--	--	--	--	--	--
New York	--	--	--	W	W	W	--	--	--
Tennessee	--	--	--	W	--	W	--	--	--
Total	3,335,823	229,432	26,086	4,152,848	(1)	156,400	705,431	50,718	10,147
Percent of total lead or zinc	XX	67	13	XX	(1)	77	XX	15	5

State	Copper-lead, copper-zinc, copper-lead-zinc ores			All other sources[2 3]			Total		
	Gross weight (dry basis)	Lead	Zinc	Gross weight (dry basis)	Lead	Zinc	Gross weight (dry basis)	Lead	Zinc
Arizona	--	--	--	W	W	--	W	W	--
Colorado	--	--	--	139,953	2,368	W	W	W	W
Idaho	--	--	--	487,077	9,951	351	487,077	9,951	351
Illinois	--	--	--	--	W	W	--	W	W
Missouri	1,054,193	39,750	1,686	--	--	--	5,095,447	319,900	37,919
Montana	--	--	--	W	W	--	W	W	--
New Jersey	--	--	--	--	--	--	W	--	W
New Mexico	--	--	--	17,387	10	--	17,387	10	--
New York	--	--	--	--	--	--	W	W	W
Tennessee	W	--	W	--	--	--	5,180,028	--	102,118
Total	(1)	39,750	(1)	13,911,456	19,893	10,350	22,105,558	339,793	202,983
Percent of total lead or zinc	XX	12	(1)	XX	6	5	XX	100	100

W Withheld to avoid disclosing company proprietary data; included in "Total." XX Not applicable.
[1]Included with "All other sources" to avoid disclosing company proprietary data.
[2]Includes lead and zinc recovered from copper, gold, gold-silver, and silver ores, from fluorspar and from mill tailings.
[3]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 1986, in order of output

Rank	Mine	County and State	Operator	Source of lead
1	Magmont	Iron, MO	Cominco American Incorporated	Lead ore.
2	Buick	do	The Doe Run Co	Lead-zinc ore.
3	Fletcher	Reynolds, MO	do	Lead ore.
4	Viburnum No. 29	Washington, MO	do	Do.
5	Casteel	Iron, MO	do	Copper-lead ore.
6	West Fork	Reynolds, MO	ASARCO Incorporated	Lead ore.
7	Viburnum No. 28	Iron, MO	The Doe Run Co	Do.
8	Lucky Friday	Shoshone, ID	Hecla Mining Co	Silver ore.
9	Leadville unit	Lake, CO	ASARCO Incorporated	Lead-zinc ore.
10	Sunnyside	San Juan, CO	Sunnyside Gold Corp	Gold ore.
11	Troy unit	Lincoln, MT	ASARCO Incorporated	Copper-silver ore.
12	Clayton	Custer, ID	Clayton Silver Mines	Silver ore.
13	Galena	Shoshone, ID	ASARCO Incorporated	Do.
14	Tiger	Pinal, AZ	McFarland & Hullinger	Gold tailings.
15	Rosiclare	Hardin and Pope, IL	Ozark-Mahoning Co	Fluorspar.
16	Black Pine	Granite, MT	Black Pine Mining Co	Silver ore.
17	Mission	Pima, AZ	ASARCO Incorporated	Copper ore.
18	Eisenhower	do	Eisenhower Mining Co	Do.
19	Coeur	Shoshone, ID	ASARCO Incorporated	Silver ore.
20	Balmat	St. Lawrence, NY	St. Joe Resources Co	Zinc ore.
21	San Xavier	Pima, AZ	ASARCO Incorporated	Copper ore.
22	St. Cloud	Sierra, NM	St. Cloud Mining Co	Gold-silver ore.
23	Gold Hill	Pinal, AZ	Little Hill Mines Inc	Copper ore.
24	Sunshine	Shoshone, ID	Sunshine Mining Co	Silver ore.
25	Pierrepont	St. Lawrence, NY	St. Joe Resources Co	Zinc ore.

Table 7.—Refined lead produced at primary refineries in the United States, by source material

(Metric tons unless otherwise specified)

Source material	1982	1983	1984	1985	1986
Refined lead:					
From primary sources:					
Domestic ores and base bullion	459,865	459,328	330,168	416,091	344,176
Foreign ores and base bullion	52,295	55,227	65,409	71,353	22,071
Total	512,160	514,555	395,577	487,444	366,247
Calculated value of primary refined lead[1] thousands	$288,377	$245,938	$222,821	r$204,932	$178,040

rRevised.
[1]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: New scrap	Consumption: Old scrap	Consumption: Total	Stocks, Dec. 31
1985						
Smelters, refiners, others:						
Soft lead[1]	1,448	31,156	--	31,128	31,128	1,476
Hard lead	1,622	14,352	--	15,280	15,280	694
Cable lead	1,250	3,278	--	3,908	3,908	620
Battery-lead platesr	29,767	669,406	--	672,362	672,362	26,811
Mixed common babbitt	285	1,623	--	1,610	1,610	298
Solder and tinny lead	2,137	20,656	--	19,937	19,937	2,856
Type metals	502	3,370	--	3,362	3,362	510
Drosses and residues	7,811	58,460	57,245	--	57,245	9,026
Total	r44,822	r802,301	57,245	r747,587	r804,832	r42,291

See footnotes at end of table.

Table 8.—Stocks and consumption of new and old lead scrap in the United States, by type of scrap —Continued

(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	674,845	--	680,154	680,154	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	802,023	66,024	746,840	812,864	31,450

[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
1985					
Refined pig lead	[r]260,337	--	--	--	[r]260,337
Remelt lead	13,361	--	--	--	13,361
Total	[r]273,698	--	--	--	[r]273,698
Refined pig tin[2]	--	1,302	--	--	1,302
Lead and tin alloys:					
Antimonial lead	[r]299,307	791	[r]10,112	524	[r]310,734
Lead-base babbitt	1,195	88	130	4	1,417
Solder	21,647	3,565	161	10	25,383
Type metals	1,912	122	281	3	2,318
Other alloys including cable lead	3,235	10	6	1	3,252
Total	[r]327,296	4,576	[r]10,690	542	[r]343,104
Tin content of chemical products	--	186	--	--	186
Grand total	[r]600,994	6,064	[r]10,690	542	[r]618,290
1986					
Refined pig lead	260,454	--	--	--	260,454
Remelt lead	20,020	--	--	--	20,020
Total	280,474	--	--	--	280,474
Refined pig tin[2]	--	1,134	--	--	1,134
Lead and tin alloys:					
Antimonial lead	290,129	891	9,950	621	301,591
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	319,444	4,847	10,451	641	335,383
Tin content of chemical products	--	W	--	--	W
Grand total	599,918	5,981	10,451	641	616,991

[r]Revised. 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.

Table 10.—Secondary lead recovered in the United States

(Metric tons unless otherwise specified)

	1982	1983	1984	1985[r]	1986
As metal:					
In soft lead	240,476	189,602	263,431	273,698	280,474
In antimonial lead	284,367	271,638	327,803	299,307	290,129
In other alloys	46,433	42,261	42,140	42,690	44,283
Total:					
Quantity	571,276	503,501	633,374	615,695	614,886
Value[1] thousands	$321,663	$240,655	$266,284	$258,851	$298,908

[r]Revised.
[1]Value based on average quoted price of common lead.

Table 11.—Lead recovered from scrap processed in the United States, by kind of scrap and form of recovery

(Metric tons)

	1985[r]	1986
KIND OF SCRAP		
New scrap:		
Lead-base	39,715	45,854
Copper-base	6,243	3,000
Tin-base	5	5
Total	45,963	48,859
Old scrap:		
Battery-lead plates	492,377	493,743
All other lead-base	68,861	60,284
Copper-base	8,493	12,000
Tin-base	1	--
Total	569,732	566,027
Grand total	615,695	614,886
FORM OF RECOVERY		
As soft lead	273,698	280,474
In antimonial lead	299,307	290,129
In other lead alloys	27,949	29,278
In copper-base alloys	14,736	15,000
In tin-base alloys	5	5
Total	615,695	614,886

[r]Revised.

Table 12.—U.S. consumption of lead, by product

(Metric tons)

SIC code	Product	1985	1986
	Metal products:		
3482	Ammunition: Shot and bullets	50,233	44,382
	Bearing metals:		
35	Machinery except electrical	332	581
36	Electrical and electronic equipment	249	268
371	Motor vehicles and equipment	3,875	3,787
37	Other transportation equipment	936	889
	Total bearing metals	5,392	5,525
3351	Brass and bronze: Billets and ingots	7,823	8,383
36	Cable covering: Power and communication	15,501	17,061
15	Calking lead: Building construction	2,288	1,833
	Casting metals:		
36	Electrical machinery and equipment	1,842	1,198
371	Motor vehicles and equipment	1,020	1,357
37	Other transportation and equipment	11,145	6,790
3443	Nuclear radiation shielding	5,407	923
	Total casting metals	19,414	10,268
	Pipes, traps, other extruded products:		
15	Building construction	11,457	11,900
3443	Storage tanks, process vessels, etc	398	642
	Total pipes, traps, other extruded products	11,855	12,542
	Sheet lead:		
15	Building construction	11,396	12,572
3443	Storage tanks, process vessels, etc	1,602	2,038
3693	Medical radiation shielding	1,833	2,665
	Total sheet lead	14,831	17,275
	Solder:		
15	Building construction	4,469	4,513
341	Metal cans and shipping containers	2,894	2,048
367	Electronic components and accessories	4,187	4,333
36	Other electrical machinery and equipment	2,597	2,196
371	Motor vehicles and equipment	7,227	8,212
	Total solder	21,374	21,302
	Storage batteries:		
3691	Storage battery grids, post, etc	468,746	488,932
3691	Storage battery oxides	372,194	364,878
	Total storage batteries	840,940	853,810
371	Terne metal: Motor vehicles and equipment	5,088	3,497
27	Type metal: Printing and allied industries	1,623	306
34	Other metal products[1]	5,570	3,678
	Total metal products	1,001,932	999,862
	Other oxides:		
285	Paints	14,056	14,400
32	Glass and ceramic products	44,146	40,781
28	Other pigments and chemicals	14,561	14,346
	Total other oxides	72,763	69,527
2911	Gasoline additives	45,694	28,541
	Miscellaneous uses	27,909	26,917
	Grand total	1,148,298	1,124,847

[1]Includes lead consumed in foil, collapsible tubes, annealing, galvanizing, plating, and fishing weights.

Table 13.—U.S. consumption of lead, by month[1]

(Metric tons)

Month	1985	1986
January	95,761	100,745
February	102,639	88,946
March	101,880	82,919
April	91,322	94,628
May	93,091	89,732
June	83,348	87,662
July	72,971	73,787
August	111,165	98,816
September	108,911	105,839
October	107,582	110,397
November	96,299	94,804
December	83,329	96,572
Total[2]	1,148,298	1,124,847

[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 14.—U.S. consumption of lead in 1986, by State[1]

(Metric tons)

State	Refined soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
California	47,569	36,480	11,047	--	95,096
Colorado	506	167	21	--	694
Connecticut	3,916	3,408	--	145	7,469
District of Columbia	5	--	--	--	5
Florida	9,039	7,018	945	--	17,002
Georgia	20,331	7,445	3,467	--	31,243
Illinois	28,330	38,546	2,539	813	70,228
Indiana	194,711	33,102	10,545	565	238,923
Kansas	11,158	6,675	4,608	--	22,441
Kentucky	8,851	9,942	1,792	--	20,585
Maryland	69	--	--	--	69
Massachusetts	580	108	59	122	869
Michigan	14,464	11,693	374	--	26,531
Missouri	10,653	17,661	--	--	28,314
Nebraska	5	--	247	575	827
New Jersey	42,212	22	822	218	43,274
New York	13,125	6,122	10,180	--	29,427
Ohio	17,357	13,674	3,830	206	35,067
Pennsylvania	100,894	33,367	33,952	1,380	169,593
Rhode Island	1,707	--	13	--	1,720
Tennessee	1,261	3,100	2,038	--	6,399
Washington	12,493	663	--	--	13,156
Wisconsin	933	--	27	54	1,014
Alabama and Mississippi	9,933	4,676	2,258	1,575	18,442
Arkansas and Oklahoma	1,913	444	28	--	2,385
Hawaii and Oregon	4,395	9,070	829	--	14,294
Iowa and Minnesota	16,730	15,261	5,488	--	37,479
Louisiana and Texas	69,464	19,643	5,126	--	94,233
Montana and Idaho	32	--	--	--	32
New Hampshire, Maine, Vermont, Delaware	14,385	13,385	--	23	27,793
North Carolina and South Carolina	38,414	24,013	5,172	--	67,599
Utah, Nevada, Arizona	202	26	176	--	404
Virginia and West Virginia	41	381	1,818	--	2,240
Total	695,678	316,092	107,401	5,676	1,124,847

[1]Includes lead that went directly from scrap to fabricated products and lead contained in leaded zinc oxide.

Table 15.—U.S. consumption of lead in 1986, 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	61,765	49,545	29,066	5,676	146,052
Storage batteries	514,874	265,803	73,133	--	853,810
Other oxides	69,527	--	--	--	69,527
Gasoline additives	28,541	--	--	--	28,541
Miscellaneous	20,971	744	5,202	--	26,917
Total	695,678	316,092	107,401	5,676	1,124,847

[1]Includes lead that went directly from scrap to fabricated products and lead contained in leaded zinc oxide.

Table 16.—Production and shipments of lead pigments[1] and oxides in the United States

Product	1985			1986		
	Production (metric tons)	Shipments		Production (metric tons)	Shipments	
		Metric tons	Value[2]		Metric tons	Value[2]
White lead, dry	477	483	$793,506	470	587	$794,640
Litharge and red lead	98,815	98,026	61,071,171	72,810	70,836	55,556,500
Leady oxide	380,440	NA	NA	376,382	NA	NA

NA Not available.
[1]Excludes basic lead sulfate; withheld to avoid disclosing company proprietary data.
[2]At plant, exclusive of container.

Table 17.—Lead content of lead pigments[1] and oxides produced by domestic manufacturers

(Metric tons)

Product	Lead in pigments from pig lead	
	1985	1986
White lead	382	376
Litharge and red lead	91,628	67,507
Leady oxide	361,419	357,564
Total	453,429	425,447

[1]Excludes basic lead sulfate; withheld to avoid disclosing company proprietary data.

Table 18.—U.S. imports for consumption of lead pigments and compounds, by kind

Kind	1985		1986	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
White lead	315	$426	540	$598
Red lead	710	340	534	257
Litharge	9,955	4,074	11,270	4,810
Chrome yellow	2,886	4,426	1,934	3,061
Other lead pigments	536	1,138	4,811	1,551
Other lead compounds	1,870	2,064	2,181	2,655
Total	16,272	12,468	21,270	12,932

Source: Bureau of the Census.

Table 19.—Stocks of lead at primary smelters and refineries in the United States, December 31

(Metric tons)

Stocks	1982	1983	1984	1985	1986
Refined pig lead	73,455	58,267	47,696	83,857	20,029
Lead-base bullion	4,252	5,557	5,837	2,945	4,476
Lead in ore and matte	47,830	42,837	81,546	41,148	62,544
Total	125,537	106,661	135,079	127,950	87,049

Table 20.—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
1982	51,036	40,118	5,346	709	97,209
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

Table 21.—Average monthly and annual quoted prices of lead[1]

(Cents per pound)

Month	1985		1986	
	U.S. producer	London Metal Exchange	U.S. producer	London Metal Exchange
January	19.09	19.03	18.35	16.69
February	18.82	16.69	17.79	16.64
March	17.68	15.95	18.20	16.64
April	19.92	17.65	18.73	16.74
May	20.11	17.04	19.38	17.06
June	19.05	17.64	22.07	18.96
July	18.88	18.27	21.94	17.21
August	19.10	18.74	22.42	17.77
September	19.20	18.15	23.43	18.45
October	18.93	17.83	[2]25.55	19.69
November	19.05	17.86	[2]28.01	21.45
December	18.97	17.67	[2]28.68	23.48
Average	19.07	17.84	22.05	18.43

[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 quotation (weighted) from October.

Table 22.—U.S. exports of lead, by country

Country	1985 Quantity (metric tons)	1985 Value (thousands)	1986 Quantity (metric tons)	1986 Value (thousands)
Ore and concentrates (lead content):				
Australia	--	--	182	$68
Canada	7,529	$2,986	693	208
Germany, Federal Republic of	642	734	308	237
India	--	--	14	14
Japan	1,438	365	--	--
Mexico	23	7	3,146	942
Netherlands	354	410	--	--
Taiwan	--	--	24	12
United Kingdom	--	--	2	1
Other	1	1	11	9
Total	9,987	4,503	4,380	1,491
Drosses and residues including flue dust (lead content):				
Belgium-Luxembourg	1,894	557	218	1,504
Brazil	1,831	359	--	--
Canada	3,527	1,186	6,088	1,794
India	--	--	31	9
Finland	91	50	--	--
France	35	25	49	296
Germany, Federal Republic of	161	195	--	--
Japan	60	224	--	--
Netherlands	102	63	--	--
Thailand	--	--	73	12
United Kingdom	2,210	2,929	707	1,253
Other	67	144	11	4
Total	9,978	5,732	7,177	4,872
Unwrought lead and lead alloys (lead content):				
Australia	1	1	37	55
Belgium-Luxembourg	206	1,177	415	2,681
Brazil	r1,500	421	1,993	392
Canada	1,783	1,006	3,225	2,058
Chile	385	630	164	173
China	1	26	84	94
Dominican Republic	67	60	148	90
Egypt	346	274	33	64
France	3	9	--	--
Germany, Federal Republic of	14	52	842	1,058
Ghana	1	5	--	--
Haiti	128	119	38	25
Honduras	--	--	2	3
India	--	--	243	54
Israel	544	216	51	23
Italy	--	--	22	37
Japan	71	90	14	51
Korea, Republic of	761	1,052	466	407
Malaysia	--	--	35	234
Mexico	364	230	1,194	569
Netherlands	15,511	8,428	19	264
Netherlands Antilles	34	24	--	--
Nigeria	310	195	--	--
Panama	56	51	--	--
Peru	90	109	--	--
Philippines	27	20	--	--
Saudi Arabia	16	51	5	12
Singapore	7	8	1	3
Sudan	--	--	79	54
Taiwan	687	316	1,917	862
United Kingdom	2,298	1,381	80	84
Venezuela	27	32	2	7
Other	142	217	81	228
Total	r25,380	16,200	11,190	9,582
Wrought lead and lead alloys (lead content):				
Australia	4	14	3	28
Barbados	39	43	8	58
Belgium-Luxembourg	--	2	2	75
Brazil	22	30	16	24
Canada	367	656	211	163
Ecuador	5	11	1	44
France	3	36	20	29
Germany, Federal Republic of	41	178	8	23
Honduras	5	12	7	18
Hong Kong	5	36	5	14
India	2	2	1	3
Ireland	--	--	18	25

See footnotes at end of table.

Table 22.—U.S. exports of lead, by country —Continued

Country	1985 Quantity (metric tons)	1985 Value (thousands)	1986 Quantity (metric tons)	1986 Value (thousands)
Wrought lead and lead alloys (lead content) —Continued				
Israel	2	$8	9	$49
Italy	1	1	([1])	2
Jamaica	--	--	27	39
Japan	26	41	111	286
Korea, Republic of	18	159	15	75
Mexico	670	2,861	834	3,065
Netherlands	1	7	1	14
Panama	1	7	11	23
Philippines	--	--	2	4
Saudi Arabia	6	36	([1])	5
Singapore	41	34	20	35
Spain	--	--	22	34
Taiwan	543	236	6	36
United Kingdom	63	98	8	17
Venezuela	60	69	15	68
Other	39	200	30	159
Total	1,964	4,777	1,411	4,415
Scrap (gross weight):				
Australia	18	8	--	--
Belgium-Luxembourg	383	176	29	99
Brazil	14,475	2,920	16,137	4,008
Canada	3,634	917	2,640	762
Colombia	6,185	882	--	--
Denmark	--	--	1	1
Ecuador	2	7	--	--
Germany, Federal Republic of	1,525	266	770	333
Hong Kong	15	7	--	--
India	450	88	1,423	813
Ireland	273	77	644	193
Italy	3,528	495	20	17
Japan	1,540	1,002	625	409
Korea, Republic of	3,053	978	5,570	1,521
Mexico	1,832	346	2,529	430
Netherlands	182	143	485	314
Portugal	--	--	99	28
Spain	18	2	14	2
Switzerland	68	20	--	--
Taiwan	17,262	2,477	21,688	2,914
Thailand	--	--	179	51
Trinidad and Tobago	68	20	--	--
United Kingdom	1,633	891	3,025	2,075
Venezuela	3,738	1,067	3,051	918
Other	67	174	69	33
Total	59,949	12,963	58,998	14,921
Grand total	r107,258	44,175	83,156	35,281

rRevised.
[1]Less than 1/2 unit.

Source: Bureau of the Census.

Table 23.—U.S. exports of lead

Year	Blocks, pigs, anodes, etc.: Unwrought Quantity (metric tons)	Unwrought Value (thousands)	Unwrought alloys Quantity (metric tons)	Unwrought alloys Value (thousands)	Wrought lead and lead alloys: 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 (gross weight) Quantity (metric tons)	Scrap (gross weight) Value (thousands)	Drosses, etc. Quantity (metric tons)	Drosses, etc. Value (thousands)
1984	3,732	$4,849	1,228	$2,820	2,156	$7,058	329	$487	45,097	$11,575	9,118	$5,352
1985	23,468	14,050	r1,912	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

rRevised.

Source: Bureau of the Census.

Table 24.—U.S. imports[1] of lead, by country

(Lead content)

Country	1984 Quantity (metric tons)	1984 Value (thousands)	1985 Quantity (metric tons)	1985 Value (thousands)	1986 Quantity (metric tons)	1986 Value (thousands)
Ore and concentrates:[2]						
Australia	17,024	$5,689	12,260	$2,407	11,497	$2,246
Bolivia	816	390	--	--	--	--
Canada	14,127	5,242	5,195	1,246	62,900	7,325
Chile	904	189	765	106	3,106	914
Honduras	5,370	2,889	1,568	757	--	--
Italy	5,103	1,664	--	--	--	--
Mexico	2,803	1,630	4,321	1,356	827	287
Peru	22,718	8,671	15,176	4,017	8,417	1,174
South Africa, Republic of	--	--	3,381	1,316	--	--
Other	5	2	--	--	--	--
Total	68,870	26,366	[3]42,665	11,205	86,747	11,946
Base bullion:						
Canada	19	10	713	375	121	67
France	18	8	--	--	--	--
Mexico	6	37	48	23	21	47
Other	([4])	2	--	--	--	--
Total	43	57	[3]760	398	142	114
Pigs and bars:						
Australia	10,884	5,187	3,627	1,758	--	--
Belgium-Luxembourg	231	282	15	13	--	--
Canada	94,893	50,103	90,056	33,783	105,281	44,080
China	--	--	--	--	77	31
Denmark	11	4	--	--	--	--
France	--	--	20	9	--	--
Germany, Federal Republic of	1,528	4,205	542	3,080	496	658
Italy	418	316	--	--	--	--
Mexico	39,502	19,158	33,771	13,271	29,532	11,617
Netherlands	116	92	10	23	--	--
Panama	--	--	--	--	47	19
Peru	9,205	4,349	5,150	1,770	1,053	449
South Africa, Republic of	496	275	--	--	--	--
Spain	3,184	1,635	--	--	--	--
Sweden	--	--	--	--	2,773	1,055
U.S.S.R	--	--	--	--	262	96
United Kingdom	974	943	337	807	679	1,153
Other	123	58	--	--	21	14
Total	161,565	86,607	[3]133,529	54,514	140,221	59,172
Reclaimed scrap, including drosses:[5]						
Australia	1,302	359	--	--	--	--
Canada	2,311	1,099	1,118	454	1,444	383
Mexico	2,638	864	2,035	720	1,831	1,060
United Kingdom	48	23	--	--	--	--
Other	3	13	15	34	15	28
Total	[3]6,303	2,358	3,168	1,208	3,290	1,471
Grand total	236,781	115,388	180,122	67,325	230,400	72,703

[1]Data are "general imports"; that is, they 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]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 25.—U.S. imports for consumption of lead, by country

Country	1984		1985		1986	
	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	1,843	$477	--	--	--	--
Chile	--	--	765	$106	2,052	677
Honduras	4,121	2,201	1,568	757	--	--
Italy	1,569	467	--	--	--	--
Mexico	2,654	1,550	317	116	827	287
Peru	19,695	7,226	--	--	--	--
Other	5	2	--	--	--	--
Total[2]	29,888	11,923	2,649	979	4,604	1,344
Base bullion (lead content):						
Canada	19	10	713	375	121	67
France	18	8	--	--	--	--
Mexico	6	37	48	23	21	47
Other	([3])	2	--	--	--	--
Total[2]	43	57	760	398	142	114
Pigs and bars (lead content):						
Australia	9,978	4,364	91	443	--	--
Belgium-Luxembourg	231	282	15	14	--	--
Canada	94,815	50,062	90,056	33,783	105,281	44,080
China	--	--	--	--	77	31
Denmark	11	4	--	--	--	--
France	--	--	20	9	--	--
Germany, Federal Republic of	1,528	4,205	542	3,080	496	658
India	907	447	1,361	664	--	--
Italy	419	316	--	--	--	--
Mexico	39,502	19,158	33,771	13,271	29,532	11,617
Netherlands	116	92	10	23	--	--
Peru	9,205	4,349	5,150	1,770	1,053	449
South Africa, Republic of	496	275	--	--	--	--
Spain	3,184	1,635	--	--	--	--
Sweden	--	--	--	--	2,773	1,055
U.S.S.R	--	--	--	--	262	96
United Kingdom	974	943	337	807	679	1,153
Other	121	58	--	--	68	33
Total[2]	161,489	86,189	131,353	53,864	140,221	59,172
Reclaimed scrap, etc. (lead content):[4]						
Australia	27	30	--	--	--	--
Canada	2,311	1,099	1,118	454	1,444	383
Mexico	2,638	864	2,035	720	1,831	1,060
United Kingdom	48	23	--	--	--	--
Other	3	13	15	38	15	28
Total[2]	5,026	2,029	3,168	1,212	3,290	1,471
Sheets, pipe, shot, other forms:						
Belgium-Luxembourg	90	107	44	57	454	418
Canada	471	837	419	627	299	293
Germany, Federal Republic of	315	1,693	149	576	132	422
Italy	([3])	2	1	13	18	40
Mexico	669	853	164	147	43	22
Peru	--	--	121	61	100	45
Spain	--	--	36	11	13	11
United Kingdom	51	128	1,027	809	228	255
Other	72	424	20	216	57	319
Total[2]	1,667	4,044	1,981	2,517	1,344	1,825
Grand total[2]	198,108	104,241	139,911	58,970	149,601	63,926

[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]Less than 1/2 unit.
[4]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 26.—U.S. imports for consumption of lead

(Thousand metric tons and thousand dollars)

Year	Ore and concentrate (lead content)		Base bullion (lead content)		Pigs and bars (lead content)		Sheets, plates, strip, other forms	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1982	19	8,784	(1)	28	95	58,633	(1)	646
1983	20	5,712	(1)	23	[2]176	[2]81,170	1	1,628
1984	30	11,923	(1)	57	161	86,189	2	3,720
1985	3	979	1	398	131	53,864	2	2,394
1986	5	1,344	(1)	114	140	59,172	1	1,701

Year	Waste and scrap (lead content)		Dross, skimmings, residues, n.s.p.f. (lead content)		Powder and flakes		Total value
	Quantity	Value	Quantity	Value	Quantity	Value	
1982	4	1,473	1	282	(1)	48	69,894
1983	3	980	1	360	(1)	4	89,877
1984	4	1,665	1	363	(1)	324	104,241
1985	2	1,068	1	144	(1)	123	58,970
1986	2	1,306	1	165	(1)	124	63,926

[1]Less than 1/2 unit.
[2]Includes Bureau of Mines estimate of 42,000 metric tons of U.S. brands returned from the London Metal Exchange with an estimated value of $16,945,000.

Source: Bureau of the Census.

Table 27.—U.S. imports for consumption of miscellaneous products containing lead[1]

Year	Gross weight (metric tons)	Lead content (metric tons)	Value (thousands)
1983	2,312	1,131	$13,720
1984	2,671	1,363	17,299
1985	3,377	1,453	22,124
1986	1,016	517	3,810

[1]Babbitt metal, solder, white metal, and other lead-containing combinations.

Source: Bureau of the Census.

Table 28.—Lead: World mine production of lead in concentrates, by country[1]

(Thousand metric tons)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Algeria[e]	5.0	3.0	4.0	[r]3.8	3.6
Argentina	[r]32.8	31.7	28.5	28.6	28.6
Australia	455.3	480.6	440.6	498.0	434.5
Austria	4.1	4.3	4.2	7.5	6.0
Bolivia	12.4	11.8	7.4	6.2	3.4
Brazil	19.4	18.8	16.7	19.2	19.5
Bulgaria[e]	95.0	95.0	95.0	95.0	95.0
Burma	16.1	23.1	21.9	21.9	[3]18.1
Canada	341.2	251.5	264.3	268.3	[3]303.5
Chile	1.6	1.7	4.3	2.5	[3]1.5
China[e]	160.0	160.0	160.0	160.0	160.0
Colombia	.2	.2	.1	.1	.1
Congo (Brazzaville)	4.1	[r e]4.0	1.7	1.5	1.4
Czechoslovakia	3.1	3.2	3.1	[e]3.2	3.2
Ecuador	.2	.2	.2	[e].2	.2
Finland	1.9	2.1	2.5	[e]2.4	2.4
France	5.9	1.5	2.3	2.5	[3]2.5
Germany, Federal Republic of	23.5	23.5	21.0	20.5	[3]16.7
Greece[e]	19.0	20.0	22.0	[r]19.4	20.0
Greenland	26.5	[r]21.6	17.7	17.8	20.0
Honduras	15.1	19.3	20.5	21.3	19.0
Hungary[e]	.6	.7	.7	.7	.4
India	[e]16.6	[e]25.7	24.8	27.1	30.0
Iran[e]	25.0	[3]26.0	[r]28.0	[r]28.0	28.0
Ireland	36.0	33.6	37.2	34.6	[3]36.4
Italy	16.2	23.6	20.8	15.6	[3]11.1
Japan	45.9	46.9	48.7	50.0	[3]40.3
Korea, North[e]	95.0	75.0	110.0	110.0	110.0
Korea, Republic of	12.2	12.2	10.8	9.7	10.0
Mexico	170.2	184.3	202.6	197.5	200.0
Morocco	103.6	97.9	100.7	106.8	[3]76.2
Namibia	32.9	38.5	33.3	34.6	[3]37.1
Nigeria[e]	.3	.3	[r].2	.3	.1
Norway	4.0	4.1	4.0	[r e]3.8	3.7
Peru	[r]197.6	[r]207.4	193.7	201.5	[3]194.4
Poland	45.3	47.0	52.8	51.3	52.0
Romania[e]	27.0	30.0	30.0	28.0	28.0
South Africa, Republic of	90.3	87.5	94.8	98.4	[3]97.8
Spain	73.3	82.0	96.6	85.6	[3]79.6
Sweden	[r]80.8	[r]79.5	80.8	75.9	88.0
Thailand	[r]18.5	21.0	16.7	19.7	18.0
Tunisia	5.0	4.6	4.1	2.5	2.5
Turkey	10.7	9.1	14.6	14.4	14.5
U.S.S.R.[e]	430.0	435.0	440.0	440.0	440.0
United Kingdom	4.0	3.8	2.4	4.0	4.0
United States	530.3	465.6	334.5	424.4	[3]353.1
Yugoslavia	113.1	114.0	113.6	[e]110.0	110.0
Zambia	21.2	25.9	18.1	15.0	[3]14.9
Total	[r]3,448.0	[r]3,358.3	3,252.5	3,389.3	3,239.3

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through June 23, 1987.
[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.

Table 29.—Lead: World smelter production, by country[1]

(Thousand metric tons)

Country	1982	1983	1984	1985[p]	1986[e]
Argentina:					
Primary (refined)	[r]15.9	[r]15.2	16.3	15.1	15.0
Secondary (refined)	14.6	[r]16.0	15.0	13.6	14.0
Total	[r]30.5	[r]31.2	31.3	28.7	29.0
Australia:					
Primary:					
Bullion for export	181.6	182.6	179.5	183.2	[2]188.3
Refined	218.8	196.3	198.8	200.1	[2]151.5
Secondary (refined)[e]	28.3	27.0	21.5	[r]15.6	16.7
Total[e]	428.7	405.9	399.8	[r]398.9	356.5
Austria:					
Primary	3.4	4.2	1.7	1.9	2.0
Secondary	14.5	12.9	16.5	15.6	16.0
Total	17.9	17.1	18.2	17.5	18.0
Belgium:					
Primary[e 3]	52.9	54.4	71.5	[2]67.0	70.0
Secondary[4]	28.0	30.0	30.0	8.3	10.0
Total	80.9	84.4	101.5	75.3	80.0
Brazil:					
Primary	21.9	20.6	26.0	29.9	30.0
Secondary	26.3	28.9	37.7	43.1	45.0
Total	48.2	49.5	63.7	73.0	75.0
Bulgaria:[e]					
Primary	114.0	112.0	112.0	112.0	110.0
Secondary[4]	4.0	4.0	4.0	4.0	5.0
Total	118.0	116.0	116.0	116.0	115.0
Burma: Primary (refined)	7.8	7.6	7.0	9.6	[2]5.4
Canada:					
Primary (refined)	174.3	178.1	173.0	[e]172.7	180.0
Secondary (refined)	64.6	63.9	79.0	[e]66.8	70.0
Total	238.9	242.0	252.0	[e]239.5	250.0
China:[e]					
Primary (refined)	155.0	165.0	165.0	165.0	165.0
Secondary (refined)	20.0	30.0	30.0	30.0	30.0
Total	175.0	195.0	195.0	195.0	195.0
Colombia: Secondary (refined)[e]	3.0	3.0	3.0	3.0	4.0
Cyprus: Secondary (refined)[e]	2.5	2.5	2.5	2.0	2.0
Czechoslovakia: Secondary (refined)	21.0	21.0	21.1	[e]21.5	20.0
Denmark: Secondary (refined)	15.9	10.0	13.0	4.5	[2].6
Finland: Secondary (refined)	4.4	6.0	4.5	[e]4.4	4.5
France:					
Primary (refined)	122.7	114.9	117.9	133.6	140.0
Secondary	[r]17.7	[r]13.6	13.5	12.2	12.5
Total	[r]140.4	[r]128.5	131.4	145.8	152.5
German Democratic Republic: Secondary[e]	[r]20.0	[r]20.0	[r]22.0	[r]20.0	20.0
Germany, Federal Republic of:					
Primary	110.7	116.2	102.3	109.7	[2]111.1
Secondary	239.7	236.3	254.9	246.6	254.8
Total	350.4	352.5	357.2	356.3	[2]365.9
Greece: Primary (refined)	[r]4.2	--	--	[e]15.0	16.0
Guatemala: Secondary (refined)	.1	.1	.1	[e].1	.1
Hungary: Secondary (refined)[e]	.1	.1	.1	.1	.1
India:					
Primary (refined)	[e]14.4	15.0	15.2	15.6	19.0
Secondary (refined)[e]	8.8	[2]6.6	10.0	10.0	10.0
Total[e]	23.2	[2]21.6	25.2	25.6	[2]29.0

See footnotes at end of table.

Table 29.—Lead: World smelter production, by country[1] —Continued

(Thousand metric tons)

Country	1982	1983	1984	1985[p]	1986[e]
Ireland: Secondary (refined)	10.0	8.0	9.1	9.0	8.0
Italy:					
Primary (refined)	36.4	37.0	37.6	29.5	[2]29.3
Secondary (refined)	97.3	89.4	102.9	96.7	[2]101.7
Total	133.7	126.4	140.5	126.2	[2]131.0
Jamaica: Secondary (refined)[e]	1.0	1.0	1.0	1.0	1.0
Japan:					
Primary	192.8	198.9	207.9	218.3	[2]219.1
Secondary (refined)	119.1	118.3	129.2	133.3	[2]128.9
Total	311.9	317.2	337.1	351.6	[2]348.0
Korea, North: Primary (refined)[e]	60.0	60.0	95.0	95.0	95.0
Korea, Republic of:[e]					
Primary (refined)	9.5	10.5	12.0	14.5	10.0
Secondary (refined)	6.6	7.3	8.3	7.9	12.9
Total	16.1	17.8	20.3	22.4	22.9
Malaysia: Secondary (refined)[e]	[2]3.0	4.0	9.0	[r]10.0	9.6
Mexico:					
Primary	145.4	166.8	174.8	203.0	200.0
Secondary (refined)[e]	34.0	[r]31.0	[r]30.0	[r]31.0	32.0
Total[e]	179.4	[r]197.8	[r]204.8	[r]234.0	232.0
Morocco:					
Primary (refined)	56.5	55.2	46.1	59.5	60.0
Secondary (refined)[e]	2.0	2.0	2.0	2.0	2.0
Total[e]	58.5	57.2	48.1	[r]61.5	62.0
Namibia: Primary (refined)	40.6	35.4	28.9	38.5	[2]40.0
Netherlands:					
Primary[e]	2.5	2.5	2.5	3.0	3.0
Secondary (refined)	27.7	23.6	33.6	37.3	37.5
Total[e]	30.2	26.1	36.1	[r]40.3	40.5
New Zealand: Secondary (refined)[e]	6.0	6.0	6.0	6.0	6.0
Nigeria: Secondary	.4	.4	.6	.8	1.0
Pakistan: Secondary[e]	([5])	([5])	([5])	([5])	--
Peru:					
Primary (refined)	[r]68.8	67.7	70.2	81.8	66.3
Secondary (refined)[e]	5.0	5.0	5.0	5.0	5.0
Total[e]	[r]73.8	72.7	[r]75.2	[r]86.8	71.3
Philippines: Secondary (refined)	6.0	6.0	4.0	7.0	7.2
Poland:[e]					
Primary (refined)	55.0	56.5	58.4	61.1	60.0
Secondary (refined)[4]	23.8	24.5	25.0	26.2	25.0
Total	78.8	81.0	83.4	[2]87.3	85.0
Portugal: Secondary (refined)	4.0	6.0	6.0	7.0	6.5
Romania:					
Primary (refined)[e]	40.5	40.0	[r]35.9	[r]38.6	36.0
Secondary (refined)[e]	5.2	9.3	10.0	10.0	10.0
Total	45.7	49.3	45.9	48.6	46.0
South Africa, Republic of: Secondary (refined)	30.4	23.6	30.8	32.8	[2]40.5
Spain:					
Primary (refined)[3]	99.5	107.8	110.1	112.8	101.0
Secondary (refined)	32.1	36.0	49.9	43.3	32.0
Total	131.6	143.8	160.0	156.1	[2]133.0
Sweden:					
Primary	63.7	[r]60.8	65.6	58.8	65.0
Secondary	[r]19.9	[r]15.2	27.7	25.9	30.0
Total	[r]83.6	[r]76.0	93.3	84.7	95.0

See footnotes at end of table.

Table 29.—Lead: World smelter production, by country[1] —Continued

(Thousand metric tons)

Country	1982	1983	1984	1985[p]	1986[e]
Switzerland: Secondary (refined)	3.0	2.0	2.0	2.0	2.2
Taiwan: Secondary (refined)[e]	35.0	38.0	44.3	44.4	45.0
Thailand: Secondary (refined)	.9	3.2	6.2	7.5	7.0
Trinidad and Tobago: Secondary (refined)[e]	2.0	2.0	2.0	2.0	2.0
Tunisia:					
Primary (refined)	15.3	10.4	8.4	2.0	2.0
Secondary (refined)[e]	.5	.5	.5	.5	.5
Total[e]	15.8	10.9	8.9	[2]2.5	2.5
Turkey:[e]					
Primary (refined)	[r]2.0	[r]2.0	([5])	([5])	--
Secondary (refined)	4.5	5.5	9.0	10.0	10.0
Total	6.5	7.5	9.0	10.0	10.0
U.S.S.R.:[e]					
Primary (refined)	485.0	490.0	495.0	[r]500.0	500.0
Secondary (refined)	245.0	255.0	260.0	265.0	270.0
Total	730.0	745.0	755.0	[r]765.0	770.0
United Kingdom:					
Primary	34.1	40.7	36.1	36.0	39.0
Secondary (refined)[6]	175.2	185.3	191.3	179.1	161.0
Total	209.3	226.0	227.4	215.1	200.0
United States:					
Primary (refined)	516.8	514.6	395.6	487.4	[2]366.2
Secondary (refined)	571.3	503.5	633.4	615.7	[2]614.9
Total	1,088.1	1,018.1	1,029.0	1,103.1	[2]981.1
Venezuela: Secondary (refined)	15.0	15.0	17.0	[e]18.0	16.0
Yugoslavia:					
Primary	74.0	93.1	[e]95.0	[e]110.0	110.0
Secondary	35.0	34.0	35.0	[e]40.0	40.0
Total	109.0	127.1	[e]130.0	[e]150.0	150.0
Zambia: Primary (refined)	14.6	14.6	8.8	8.9	[2]6.6
Grand total	[r]5,265.0	[r]5,239.1	5,439.3	5,586.9	5,412.5
Of which:					
Primary	[r]3,210.6	[r]3,246.6	3,170.1	3,389.1	3,211.8
Secondary	[r]2,054.4	[r]1,992.5	2,269.2	2,197.8	2,200.7

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

[1]Table includes data available through June 23, 1987. 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 insufficient information is 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 30.—Lead: World refinery production, by country[1]

(Thousand metric tons)

Country	1982	1983	1984	1985[p]	1986[e]
Argentina:					
Primary	[r]15.9	[r]15.2	16.3	15.1	15.0
Secondary	14.6	[r]16.0	15.0	13.6	14.0
Total	[r]30.5	[r]31.2	31.3	28.7	29.0
Australia:					
Primary	218.8	196.3	198.8	200.1	[2]151.5
Secondary[e]	28.3	27.0	21.5	[r]15.6	16.7
Total[e]	247.1	223.3	220.3	[r]215.7	168.2
Austria:					
Primary	10.4	12.0	10.0	10.0	6.5
Secondary	11.1	11.5	16.2	15.5	13.5
Total	21.5	23.5	26.2	25.5	20.0
Belgium:					
Primary	66.0	96.3	89.6	84.3	65.0
Secondary	33.7	37.8	38.1	30.0	26.0
Total	99.7	134.1	127.7	114.3	91.0
Brazil:					
Primary	21.9	21.0	26.0	28.8	[2]32.7
Secondary	26.3	29.0	37.7	43.1	[2]38.9
Total	48.2	50.0	63.7	71.9	[2]71.6
Bulgaria:[e]					
Primary	100.3	98.6	98.6	98.0	97.0
Secondary	17.7	17.4	17.4	18.0	17.0
Total	118.0	116.0	116.0	116.0	114.0
Burma: Primary	7.8	7.6	7.0	9.6	[2]5.4
Canada:					
Primary	174.3	178.1	173.0	[e]172.7	180.0
Secondary	64.6	63.9	79.0	[e]66.8	70.0
Total	238.9	242.0	252.0	[e]239.5	250.0
China:[e]					
Primary	155.0	165.0	165.0	165.0	165.0
Secondary	20.0	30.0	30.0	30.0	30.0
Total	175.0	195.0	195.0	195.0	195.0
Colombia: Secondary[e]	3.0	3.0	3.0	3.0	4.0
Cyprus: Secondary[e]	2.5	2.5	2.5	2.0	2.0
Czechoslovakia: Secondary	21.0	21.0	21.1	[e]21.5	21.0
Denmark: Secondary	15.9	10.0	13.0	4.5	[2].6
Finland: Secondary	4.4	6.0	4.5	[e]4.4	4.4
France:					
Primary	122.7	115.0	117.9	133.6	140.0
Secondary	85.9	99.4	88.8	90.0	90.0
Total	208.6	214.4	206.7	223.6	230.0
German Democratic Republic: Secondary[e]	38.0	36.0	35.0	[r]55.0	50.0
Germany, Federal Republic of:					
Primary	201.6	217.0	191.9	181.0	160.0
Secondary	148.9	135.5	165.3	175.3	200.0
Total	350.5	352.5	357.2	356.3	360.0
Greece: Primary	[r]4.2	--	--	[e]15.0	16.0
Guatemala: Secondary	.1	.1	.1	.1	.1
Hungary: Secondary[e]	.1	.1	.1	.1	.1
India:					
Primary	[e]14.4	15.0	15.2	15.6	19.0
Secondary	[e]8.8	6.6	[e]10.0	[e]10.0	10.0
Total	[e]23.2	21.6	[e]25.2	25.6	[2]29.0
Ireland: Secondary[e]	10.0	[r]8.0	[r]9.1	[r]9.0	8.0

See footnotes at end of table.

Table 30.—Lead: World refinery production, by country[1] —Continued

(Thousand metric tons)

Country	1982	1983	1984	1985[p]	1986[e]
Italy:					
Primary	36.4	37.0	37.6	29.5	[2]29.3
Secondary	97.3	89.4	102.9	96.7	[2]101.7
Total	133.7	126.4	140.5	126.2	[2]131.0
Jamaica: Secondary[e]	1.0	1.0	1.0	1.0	1.0
Japan:					
Primary	183.1	203.3	233.8	233.7	[2]232.7
Secondary	119.1	118.3	129.2	133.3	[2]128.9
Total	302.2	321.6	363.0	367.0	[2]361.6
Korea, North: Primary[e]	60.0	60.0	95.0	95.0	95.0
Korea, Republic of:[e]					
Primary	9.5	10.5	12.0	14.5	10.0
Secondary	6.6	7.3	8.3	7.9	12.9
Total	16.1	17.8	20.3	22.4	22.9
Malaysia: Secondary[e]	[2]3.0	4.0	9.0	[r]10.0	9.6
Mexico:					
Primary	137.2	162.5	163.2	193.5	187.0
Secondary[e]	34.0	[r]31.0	[r]30.0	[r]31.0	32.0
Total[e]	171.2	[r]193.5	[r]193.2	[r]224.5	219.0
Morocco:					
Primary	56.5	55.2	46.1	59.5	60.0
Secondary[e]	2.0	2.0	2.0	2.0	2.0
Total[e]	58.5	57.2	48.1	[r]61.5	62.0
Namibia: Primary	40.6	35.4	28.9	38.5	[2]40.0
Netherlands:					
Primary	4.8	2.0	--	--	--
Secondary	27.7	23.6	33.6	37.3	37.5
Total	32.5	25.6	33.6	37.3	37.5
New Zealand: Secondary[e]	6.0	6.0	6.0	6.0	6.0
Nigeria: Secondary[e]	2.0	2.0	2.0	3.0	3.5
Pakistan: Secondary[e]	1.0	1.0	1.0	1.0	1.0
Peru:					
Primary	[r]68.8	67.7	70.2	81.8	66.3
Secondary[e]	5.0	5.0	5.0	5.0	5.0
Total[e]	[r]73.8	72.7	[r]75.2	[r]86.8	71.3
Philippines: Secondary	6.0	6.0	4.0	7.0	7.2
Poland:					
Primary[e]	55.2	56.7	58.4	61.1	60.0
Secondary[e]	23.6	24.3	25.0	26.2	26.0
Total	78.8	81.0	83.4	[2]87.3	86.0
Portugal: Secondary	4.0	6.0	6.0	7.0	6.5
Romania:					
Primary[e]	40.5	40.0	[r]35.9	[r]38.6	36.0
Secondary[e]	5.2	9.3	10.0	10.0	10.0
Total	45.7	49.3	45.9	48.6	46.0
South Africa, Republic of: Secondary	30.4	23.6	30.8	32.8	[2]40.5
Spain:					
Primary	99.5	107.8	110.1	112.8	101.0
Secondary	32.1	36.0	49.9	43.3	32.0
Total	131.6	143.8	160.0	156.1	[2]133.0
Sweden:					
Primary	29.6	34.8	49.8	43.2	50.0
Secondary	19.9	[r]15.2	27.7	25.9	30.0
Total	49.5	[r]50.0	77.5	69.1	80.0
Switzerland: Secondary	3.0	2.0	2.0	2.0	2.0
Taiwan: Secondary[e]	35.0	38.0	44.3	44.4	45.0

See footnotes at end of table.

Table 30.—Lead: World refinery production, by country[1] —Continued

(Thousand metric tons)

Country	1982	1983	1984	1985[p]	1986[e]
Thailand: Secondary	.9	3.2	6.2	7.5	7.0
Trinidad and Tobago: Secondary[e]	2.0	2.0	2.0	2.0	2.0
Tunisia:					
Primary	15.3	10.4	8.4	[r] [e]2.0	2.0
Secondary[e]	.5	.5	.5	.5	.5
Total[e]	15.8	10.9	8.9	[r]2.5	2.5
Turkey:[e]					
Primary	[r]2.0	[r]2.0	([3])	([3])	--
Secondary	4.5	5.5	9.0	10.0	10.0
Total	6.5	7.5	9.0	10.0	10.0
U.S.S.R.:[e]					
Primary	485.0	490.0	495.0	[r]500.0	500.0
Secondary	245.0	255.0	260.0	265.0	270.0
Total	730.0	745.0	755.0	[r]765.0	770.0
United Kingdom:					
Primary	131.0	136.9	147.1	148.1	146.0
Secondary	175.2	185.3	191.3	179.1	161.0
Total	306.2	322.2	338.4	327.2	307.0
United States:					
Primary	516.8	514.6	395.6	487.4	366.2
Secondary	571.3	503.5	633.4	615.7	614.9
Total	1,088.1	1,018.1	1,029.0	1,103.1	981.1
Venezuela: Secondary	15.0	15.0	17.0	[e]18.0	16.0
Yugoslavia:					
Primary	72.0	54.8	45.4	[e]83.0	115.0
Secondary	10.2	42.7	37.4	[e]40.0	40.0
Total	82.2	97.5	82.8	[e]123.0	155.0
Zambia: Primary	14.6	14.6	8.8	8.9	[2]6.6
Grand total	[r]5,215.1	[r]5,257.8	5,444.5	5,638.0	5,435.2
Of which:					
Primary	[r]3,171.7	[r]3,233.3	3,150.6	3,359.9	3,156.2
Secondary	[r]2,043.4	[r]2,024.5	2,293.9	2,278.1	2,278.0

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

[1]Table includes data available through June 23, 1987. 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.

[3]Revised to zero.

Lime

By Lawrence Pelham[1]

Lime sold or used by producers, including that for Puerto Rico, decreased 8% from that of 1985 to 14.5 million short tons valued at $761 million.

Agricultural lime decreased 39%, chemical and industrial lime decreased 9%, construction lime was essentially unchanged, and refractory lime increased 12%.

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 117 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)

	1982	1983	1984	1985	1986
United States:[1]					
Number of plants	147	139	129	115	116
Sold or used by producers:					
Quicklime	11,701	12,383	13,134	12,997	11,850
Hydrated lime	2,037	2,066	2,302	2,314	2,199
Dead-burned dolomite	337	418	487	378	424
Total[2]	14,075	14,867	15,922	15,690	14,474
Value[3] thousands	$696,207	$757,611	$811,183	$809,000	$757,867
Average value per ton	$49.46	$50.96	$50.95	r$51.56	$52.36
Lime sold	10,856	12,083	13,064	13,409	12,097
Lime used	3,219	2,784	2,858	2,281	2,377
Exports[4]	23	28	25	19	16
Imports for consumption[4]	348	283	247	194	201
Consumption[5]	14,400	15,122	16,144	r15,885	14,658
World: Production	r120,273	r121,455	125,619	p123,496	e121,831

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]Measured 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 ($CaO \cdot MgO$); (4) two types of dolomitic hydrate, type N ($Ca(OH)_2 \cdot MgO$ and type S ($Ca(OH)_2 \cdot Mg(OH)_2$); 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, including that of Puerto Rico, from limestone decreased 8% to 14.5 million tons in 1986. Commercial lime, sold by the producer, decreased 10% to 12.1 million tons. Captive lime, used by the producer, was essentially unchanged at 2.4 million tons.

Production of quicklime decreased 9% to 11.9 million tons, hydrated lime decreased 5% to 2.2 million tons, and dead-burned dolomite increased 12% to 424,000 tons. The decrease in total lime production was primarily caused by the closure of the Allied Corp. soda ash plant in New York, and decreased lime consumption by the steel industry.

Seventy-three 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, Pennsylvania, and Utah; USG Corp. with one plant each in Louisiana, Ohio, Texas, and Virginia; Martin Marietta Corp. in Ohio; Chemstar Inc. with two plants each in California and Nevada and one each in Arizona and Utah; Bethlehem Steel Corp. with two plants in Pennsylvania; Allied Products Co. with two plants in Alabama; LTV Steel Co. in Ohio; and Chemical Lime Inc. in Texas. These 10 companies operated 29 plants and accounted for 57% of the total lime production.

The number of plants producing lime in the United States and Puerto Rico increased from 116 in 1985 to 117 in 1986. Leading individual plants, in descending order, were Mississippi Lime's Ste. Genevieve plant in Missouri, Dravo Lime's Maysville plant in Kentucky, and Martin Marietta Chemical Div.'s Woodville plant in Ohio.

New Plants, Expansions, and Changes.—Imasco Ltd., a Canadian conglomerate, acquired Genstar Corp. in August.[2] On December 4, Imasco sold Genstar Lime Co., San Mateo, CA, to Chemical Lime Inc., Ft. Worth, TX, and the Lhoist Group of Belgium. Genstar Lime, with plants in Arizona, California, Nevada, and Utah, changed its name to Chemstar.[3]

M. J. Stavola Industries, Anthony, FL, acquired Dixie Lime & Stone Co., Sumterville, FL.[4]

Dravo Corp., Pittsburgh, PA, purchased on April 22 a lime plant and underground limestone mine near Carntown, KY, from Black River Mine, a joint venture of Armco Inc. and LTV. Reportedly, the mine contains 150 million tons of recoverable limestone. The lime production plant has a capacity of 660,000 tons per year. The acquisition increased Dravo Lime's overall annual capacity by 40% to 2.3 million tons.[5]

Table 2.—Lime sold or used by producers in the United States, by State[1]

State	1985					1986				
	Plants	Hydrated (thousand short tons)	Quicklime (thousand short tons)	Total[2] (thousand short tons)	Value (thousands)	Plants	Hydrated (thousand short tons)	Quicklime (thousand short tons)	Total[2] (thousand short tons)	Value (thousands)
Alabama	5	113	1,103	1,216	$52,295	5	96	1,084	1,180	$50,377
Arizona	3	W	W	W	W	3	W	W	505	21,016
Arkansas, Louisiana, Oklahoma	4	219	117	335	17,551	4	227	110	337	21,962
California	10	W	W	367	24,733	11	W	W	371	24,187
Colorado, Nevada, Wyoming	6	W	W	188	15,398	8	W	W	211	16,648
Florida	2	W	W	W	W	1	W	W	W	W
Hawaii, Oregon, Washington	5	W	W	356	24,318	5	W	W	371	24,629
Idaho	3	--	93	93	5,803	3	--	89	89	4,729
Illinois, Indiana, Missouri	8	436	2,848	3,283	160,121	8	402	2,514	2,916	142,133
Iowa, Nebraska, South Dakota	4	W	W	W	W	5	W	W	W	W
Kentucky, New York (1985), Tennessee, West Virginia (1985)	6	W	W	2,490	122,643	4	W	W	W	W
Maryland	1	6	3	10	608	1	3	6	10	546
Massachusetts	2	15	144	159	10,935	2	16	W	W	W
Michigan	8	W	W	535	24,790	8	W	W	556	27,257
Minnesota and Montana	6	--	179	179	10,724	7	10	261	271	15,494
North Dakota	3	--	56	56	5,562	3	--	74	74	7,359
Ohio	9	W	W	1,730	84,142	9	W	W	1,648	81,103
Pennsylvania	9	344	1,148	1,492	85,269	10	319	1,098	1,417	81,234
Puerto Rico	1	23	--	23	3,249	1	24	--	24	3,291
Texas	7	587	605	1,192	65,927	7	611	563	1,173	62,670
Utah	4	W	W	225	11,912	3	W	W	232	13,079
Virginia	5	127	506	633	28,103	4	68	556	624	27,362
Wisconsin	5	99	243	341	19,001	5	117	233	350	19,715
Other[3]	([4])	[r]368	[r]6,331	[r]808	[r]39,165	([4])	330	5,686	2,139	116,369
Total[2]	116	2,337	13,376	15,713	812,249	117	2,223	12,274	14,498	761,158

[r]Revised. 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]Includes data indicated by symbol W.
[4]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	1985			1986		
	Plants	Quantity (thousand short tons)	Percent of total	Plants	Quantity (thousand short tons)	Percent of total
Less than 10,000 tons	9	54	(2)	14	92	1
10,000 to 25,000 tons	24	409	3	23	340	2
25,000 to 50,000 tons	16	625	4	13	477	3
50,000 to 100,000 tons	18	1,292	8	22	1,671	11
100,000 to 200,000 tons	26	3,774	24	25	3,561	25
200,000 to 400,000 tons	16	4,320	28	16	4,612	32
More than 400,000 tons	7	5,239	33	4	3,745	26
Total	116	15,713	100	117	14,498	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, 87%; construction, 10%; refractories, 3%; and a small amount for agriculture. Captive lime was used mainly in the production of steel in basic oxygen furnaces, 36%; and sugar refining, 26%.

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 used to make tar-bonded refractory bricks used in basic oxygen furnaces. Lime consumption for raw steel production decreased 13% to 4.7 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 recovery, 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 wastewater 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 was used to raise the pH of the product stream, causing colloidal impurities to precipitate. 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, e.g., 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 mix to act as an anti-stripping agent and to improve durability, in plaster and stucco, and in mortar. Other applications of lime included agricultural uses, leather tanning, plastics manufacture, and pigments.

The Nevada State Highway Department began requiring in 1986 that hydrated lime be used as an antistripping agent in hot-mix asphalt for highway surfacing. Nevada joined Georgia, New Mexico, and Wyoming in this requirement.[6]

Table 4.—Destination of shipments of lime sold or used by producers in the United States, by State[1]

(Thousand short tons)

State	1985			1986		
	Quicklime	Hydrated lime	Total[2]	Quicklime	Hydrated lime	Total[2]
Alabama	437	50	487	426	45	472
Alaska	(3)	1	1	(3)	1	1
Arizona	211	61	272	234	64	298
Arkansas	79	32	111	87	24	111
California	383	87	470	406	96	501
Colorado	63	17	80	72	9	82
Connecticut	30	10	40	15	10	25
Delaware	30	5	35	32	6	37
District of Columbia	17	33	50	22	26	48
Florida	375	41	416	361	34	395
Georgia	233	59	292	228	47	275
Hawaii	5	1	6	2	4	6
Idaho	99	3	102	97	3	100
Illinois	519	137	655	491	133	624
Indiana	1,483	36	1,518	1,322	33	1,356
Iowa	75	17	92	78	15	93
Kansas	62	20	82	62	17	79
Kentucky	534	22	556	489	18	508
Louisiana	243	118	361	245	96	341
Maine	14	3	17	13	1	13
Maryland	266	18	284	284	15	299
Massachusetts	62	10	72	39	15	54
Michigan	993	33	1,026	940	35	976
Minnesota	183	17	200	229	18	247
Mississippi	126	28	154	110	12	123
Missouri	141	48	189	125	49	174
Montana	33	13	46	42	8	50
Nebraska	35	6	41	51	6	57
Nevada	86	5	91	100	18	118
New Hampshire	2	(3)	2	2	(3)	2
New Jersey	111	52	163	107	54	160
New Mexico	133	31	164	156	38	194
New York	634	39	673	65	39	104
North Carolina	204	30	234	248	41	289
North Dakota	106	4	110	155	7	162
Ohio	1,504	121	1,625	1,287	118	1,404
Oklahoma	110	14	124	78	13	91
Oregon	104	12	116	77	12	90
Pennsylvania	1,558	210	1,768	1,416	203	1,619
Rhode Island	5	2	7	3	2	5
South Carolina	108	19	128	109	21	130
South Dakota	25	3	28	14	1	15
Tennessee	121	120	241	194	67	261
Texas	595	571	1,166	560	589	1,149
Utah	210	11	220	178	10	189
Vermont	(3)	1	1	(3)	1	1
Virginia	193	21	215	159	14	173
Washington	251	12	263	265	13	277
West Virginia	406	36	441	437	22	459
Wisconsin	99	46	146	97	47	144
Wyoming	56	18	74	39	22	62
Other[4]	1	--	1	--	--	--
Total[2]	13,354	2,302	15,657	12,250	2,191	14,441
Exports:						
Canada	18	8	26	19	8	28
Other countries	4	25	29	5	24	29
Total[2]	22	33	55	24	33	57
Grand total[2]	13,376	2,337	15,713	12,274	2,223	14,498

[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 Puerto Rico and U.S. possessions.

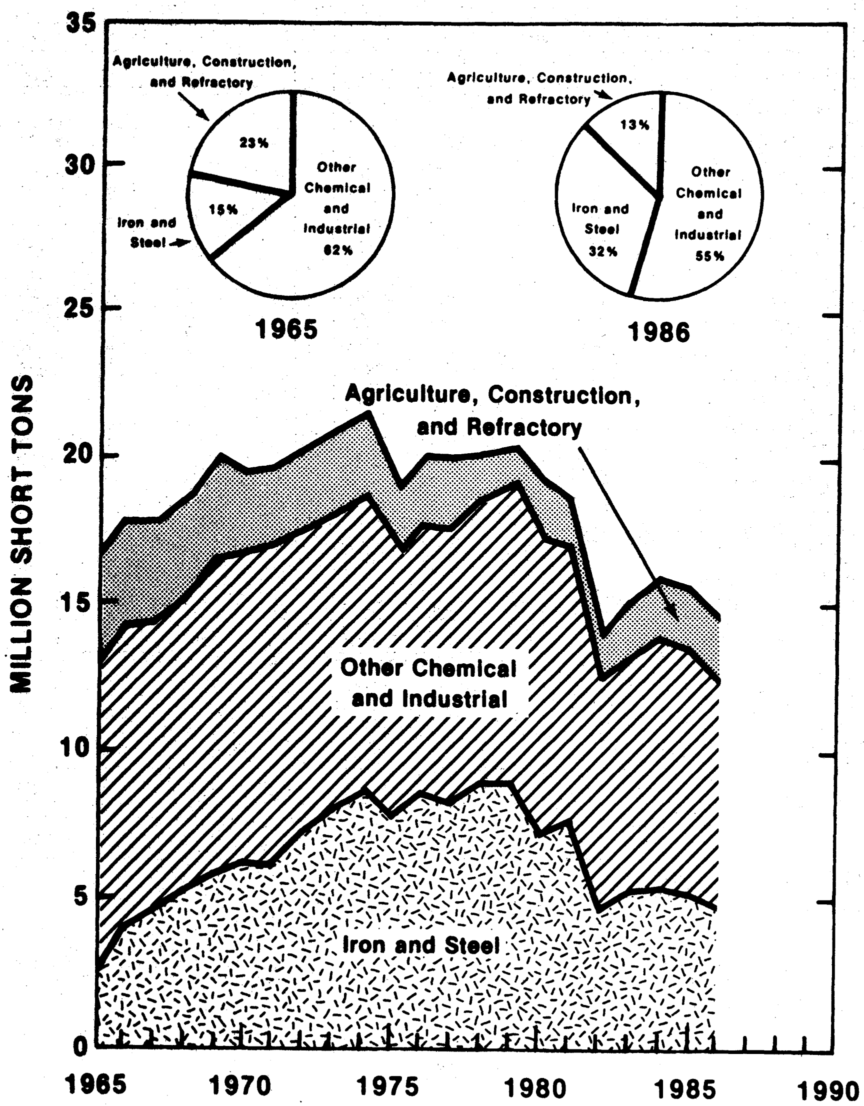

Figure 1.—Trends in major uses of lime.

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

(Thousand short tons and thousand dollars)

Use	1985 Sold	1985 Used	1985 Total[2]	1985 Value	1986 Sold	1986 Used	1986 Total[2]	1986 Value
Agriculture	83	--	83	5,524	51	([3])	51	3,169
Chemical and industrial:								
Steel, BOF	3,369	804	4,173	207,795	2,817	863	3,680	175,332
Water purification	W	W	1,509	75,273	W	W	1,610	83,003
Sulfur removal from stack gases	1,317	--	1,317	65,587	1,341	--	1,341	69,947
Paper and pulp	W	W	1,112	55,354	W	W	1,198	58,331
Steel, electric	W	W	945	47,057	W	W	883	41,527
Sewage treatment	W	W	848	42,491	W	W	540	29,567
Alkalies	W	W	645	32,121	W	W	118	7,015
Sugar refining	42	514	557	27,778	68	621	689	42,667
Magnesia from seawater or brine	W	W	408	10,673	W	W	398	19,574
Copper ore concentration	W	W	307	15,282	W	W	335	13,978
Acid water, mine or plant	W	W	283	14,098	W	W	286	14,715
Steel, open-hearth	W	W	252	12,534	W	W	122	5,939
Calcium carbide	W	W	229	11,418	W	W	W	W
Glass	130	--	130	6,463	142	--	142	7,020
Aluminum and bauxite	112	--	112	5,600	174	--	174	7,752
Precipitated calcium carbonate	W	--	W	6,367	W	W	W	W
Ore concentration, other	82	--	82	4,106	130	--	130	6,155
Oil and grease	49	--	49	2,619	W	--	W	W
Tanning	40	--	40	2,010	22	--	22	1,377
Petroleum refining	29	--	29	1,437	10	--	10	587
Food products, animal or human	24	--	24	1,209	17	--	17	878
Oil well drilling	16	--	16	1,797	11	--	11	902
Metallurgy	10	--	10	513	W	W	10	467
Fertilizer	6	--	6	302	5	--	5	351
Brick, sand-lime	3	--	3	186	W	--	W	W
Paint	1	--	1	62	2	--	2	179
Other[4]	6,224	1,098	783	41,527	5,643	762	906	50,490
Total[2]	11,454	2,416	13,870	691,660	10,383	2,246	12,629	637,753
Construction:								
Road stabilization	601	--	601	39,437	481	--	481	28,345
Soil stabilization	263	--	263	17,275	417	--	417	24,154
Finishing lime	204	--	204	13,403	221	--	221	20,899
Mason's lime	W	W	259	16,987	W	W	214	15,610
Other[5]	53	--	53	3,509	61	--	61	3,440
Total[2]	W	W	1,381	90,611	W	W	1,394	92,448
Refractory dolomite	W	W	378	24,454	W	W	424	27,788
Grand total[2]	13,119	2,594	15,713	812,249	12,121	2,377	14,498	761,158

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, chrome, citric acid (1985), commercial hydrators, desiccants, explosives, ferroalloys, fiberglass, glue, insecticides, ladle desulfurizing, magnesium metal, manganese, pelletizing, petrochemicals, pharmaceuticals, rubber, silica brick, soap, wire drawing, 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 on an f.o.b.-plant basis, was essentially unchanged at $52.50 per ton. Values were $50.50 for chemical and industrial lime, $65.54 for refractory dolomite, $66.32 for construction lime, and $62.14 for lime used in agriculture.

The average value of quicklime sold increased 4% to $48.50 per ton. Values were $47.91 for chemical lime, $31.75 for lime used in agriculture, $54.35 for construction lime, and $61.55 for refractory dead-burned dolomite.

The average value of hydrated lime sold increased 11% to $74.95 per ton. Values were $81.24 for chemical lime, $61.93 for lime used in agriculture, and $69.60 for construction lime.

FOREIGN TRADE

U.S. exports of lime decreased 15% to 16,400 tons. Of the total, Canada received 81%, the Bahamas, 7%; and Mexico, 6%. The remaining 6% went to 26 countries.

Imports, principally from Canada (94%) and Mexico (6%), were essentially unchanged at 200,707 tons.

Table 6.—U.S. exports of lime

	Quantity (short tons)	Value (thousands)
1983	28,154	$4,815
1984	24,714	6,805
1985	19,383	5,155
1986	16,448	4,500

Source: Bureau of the Census.

Table 7.—U.S. imports for consumption of lime

	Hydrated lime		Other lime		Total	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1983	58,811	$3,431	223,752	$11,345	282,563	$14,776
1984	59,906	3,669	187,579	9,722	[1]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

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

Source: Bureau of the Census.

WORLD REVIEW[7]

Austria.—In 1985, lime used for construction projects and environmental protection was 289,999 tons, a 10% decrease from that of 1984. Industrial lime consumption increased 19% to 384,000 tons, primarily because of increased consumption by the steel industry.

France.—Lime production in 1985 was 3.4 million tons, virtually the same as in 1984. Lime consumption by the steel industry decreased 5%; consumption for all uses other than iron and steel production increased slightly. Oil products and natural gas represented 17% and 63%, respectively, of fuel consumption by lime kilns. Operating costs decreased significantly because of reduced prices for these fuels.

Germany, Federal Republic of.—Sales of lime in 1985 increased 3% to 6.7 million tons, with 39% to the steel industry, 51% to chemical and other industries, and 10% for building materials. Small quantities were used for environmental and agricultural purposes.

Japan.—Total sales of lime decreased 3.7% in 1985 compared with those of 1984. The demand for lime by the steel industry decreased 6% and accounted for 53% of total sales. This decrease resulted from decreases in production of crude steel, 0.3%, and converter steel, 2.1%, and the continued decrease in the ratio of quicklime required per ton of converter steel produced. Lime demand by the chemical industry and for agriculture was essentially unchanged. Lime demand decreased for masonry and plaster and for water treatment, but increased for soil stabilization, autoclaved lightweight concrete, and environmental protection.

South Africa, Republic of.—Lime sales increased slightly in 1985 to 2.2 million tons and included signficant export sales. The lime industry operated at 55% to 60% of capacity.

United Kingdom.—Estimated usage of lime for 1984 was agriculture, 30,000 tons; iron and steel, 1,494,000 tons; chemical use, 1,399,000 tons; building materials, 234,000 tons; and other uses, 7,000 tons.

Table 8.—Quicklime and hydrated lime, including dead-burned dolomite: World production, by country[1]

(Thousand short tons)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Algeria[e]	45	45	45	45	45
Australia[e] [3]	1,045	[4]1,120	1,100	1,100	1,200
Austria	1,132	1,257	1,391	[e]1,430	1,380
Belgium	1,683	1,951	2,392	1,997	1,980
Brazil[e]	5,500	5,500	5,500	5,500	5,700
Bulgaria	1,958	1,801	1,682	1,467	1,500
Burundi	([5])	([5])	([5])	1	1
Canada	2,422	2,460	2,498	2,438	2,600
Chile	711	797	858	[e]880	880
Colombia[e]	1,430	1,430	1,430	1,430	1,430
Costa Rica[e]	10	11	11	11	11
Cuba	161	169	166	187	200
Cyprus	12	9	8	9	9
Czechoslovakia	3,404	3,417	3,436	3,557	3,530
Denmark (sales)	109	119	141	142	155
Dominican Republic[e]	44	44	44	[r]37	37
Egypt[e]	105	[4]103	107	107	105
Fiji Islands[e]	[4]4	3	3	3	3
Finland	396	379	[e]390	[e]390	390
France	3,300	3,247	3,450	3,417	[4]3,200
German Democratic Republic	3,869	3,812	3,965	3,932	3,900
Germany, Federal Republic of	7,604	7,574	7,651	7,545	7,820
Guatemala	[e]27	30	56	68	68
Hungary	932	906	907	883	[4]868
India[e]	440	440	550	550	550
Iran[e]	600	700	700	700	700
Ireland	51	[e]65	75	93	[4]97
Israel	55	45	[e]55	[e]55	55
Italy	2,389	2,228	2,648	2,509	2,300
Jamaica	126	134	127	95	100
Japan (quicklime only)	8,573	8,197	8,547	8,217	[4]7,404
Jordan	66	294	247	[e]247	247
Kenya	24	38	23	31	33
Korea, Republic of[e]	220	220	220	220	220
Kuwait	11	[e]15	17	58	58
Lebanon[e]	55	22	11	11	11
Libya	248	287	[r] [e]290	[r] [e]290	290
Malawi	2	2	2	[e]2	2
Malta	8	6	[e]6	[e]6	6
Martinique[e]	6	6	6	6	6
Mauritius[e]	[4]8	8	8	8	8
Mexico[e]	4,400	4,000	4,400	4,400	4,400
Mongolia[e]	65	70	72	80	80
Mozambique[e]	11	11	11	11	11
Nepal	[e]11	[e]11	8	[e]8	[4]1
New Zealand[e]	190	180	165	175	175
Nicaragua	[e]6	5	[e]3	4	3
Norway[e]	145	145	145	110	110
Paraguay	59	81	94	88	88
Peru[e]	40	40	40	40	40
Philippines	73	56	56	52	50
Poland	4,476	4,543	4,686	4,546	4,500
Portugal[e]	275	250	[r]230	[r]220	220
Romania	4,180	3,994	4,242	4,097	4,100
Saudi Arabia[e]	190	10	[4]13	13	13
South Africa, Republic of (sales)	2,232	2,085	2,325	2,220	[4]2,143
Spain[e]	1,200	1,100	[4]1,199	1,200	1,300
Sweden	[r]640	[r]672	714	[r] [e]770	770
Switzerland	51	47	45	41	45
Taiwan	152	145	130	116	120
Tanzania[e]	7	[4]3	3	3	3
Tunisia	550	640	660	660	720
Turkey	1,000	1,100	[e]1,100	[e]1,100	1,200
Uganda	[r]([5])	[r]([5])	[r] [e]1	[r] [e]1	1
U.S.S.R	31,636	32,520	32,520	32,190	32,190
United Arab Emirates[e]	45	50	50	50	50
United Kingdom[e]	2,750	2,750	2,750	2,750	2,750
United States including Puerto Rico (sold or used by producers)	14,112	14,902	15,956	15,713	[4]14,498
Uruguay	15	11	9	10	11
Venezuela[e]	[4]2	2	2	2	2

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]	1982	1983	1984	1985[p]	1986[e]
Yugoslavia	2,657	2,810	[e]2,850	[e]2,750	2,750
Zaire	114	118	121	[r e]120	120
Zambia	204	213	256	282	[4]268
Total	[r]120,273	[r]121,455	125,619	123,496	121,831

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through June 23, 1987.
[2]Lime is produced in many other countries besides 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 years 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

Over the last 5 years, 18 of the 162 lime installations worldwide that use annular shaft kilns have converted to pulverized-coal firing. Reportedly, fuel consumption in the annular shaft kiln is typically 3.2 to 3.5 million British thermal units per short ton, or about one-half the rate of fuel consumption in a rotary kiln. On-line operating of equipment is reported to be 98% to 99% with 4 to 5 years between shutdowns. Pulverized-fuel firing of the annular shaft kiln on a commercial scale was developed jointly by the Beckenbachs, who invented the annular shaft kiln, for Warmestelle Steine und Erden and Rheinische Westfälische Kalkenwerke AG, both of the Federal Republic of Germany. Fuller Co., a licensee of the Beckenbach annular shaft kiln, has built a large-scale pilot plant at its research facility in Catasaugua, PA, to test coal firing and evaluate various types of fuel and their effect on product quality.[8]

Successful performance and fuel economies have been reported for a new kiln insulation material by three rotary kiln operators in the United States and one in Spain. According to Lydall Inc., the manufacturer, the insulation saves fuel and increases the life of the refractory in the insulated (hot) zone of the rotary kiln. Reportedly, it is the first high-efficiency insulating product specifically designed for rotary kiln applications. The insulating material is made of high-purity ceramic fibers combined with a unique blend of binder materials. A cladding of fiberglass cloth material has been applied to each side of the product.[9]

[1]Physical scientist, Division of Industrial Minerals.
[2]Rock Products. V. 89, No. 11, 1986, p. 9.
[3]———. V. 90, No. 2, 1987, p. 9.
[4]Work cited in footnote 3.
[5]Rock Products. V. 89, No. 6, 1986, p. 9.
[6]———. V. 89, No. 9, 1986, p. 17.
[7]From reports presented at the International Lime Association Congress, London, England, June 12-13, 1986.
[8]Dorman, W. D., and S. M. Cohen. Coal-Fired Annual Shaft Kiln Finds Growing Acceptance. Pit & Quarry, v. 78, No. 11, 1986, pp. 29-31.
[9]Rock Products. V. 78, No. 11, 1986, pp. 32-33.

Lithium

By Joyce A. Ober[1]

The United States continued to be the leading producer of lithium minerals and chemicals worldwide, despite a decrease in domestic production. A large increase in imports of lithium ores for the ceramics and glass industry caused a slight increase in estimated consumption. Imports of other lithium compounds also increased significantly because of decreased domestic production. Demand for lithium carbonate for the aluminum industry decreased once again. Exports decreased and producers' stocks remained about the same. World production experienced little change with only slight increases in production of lithium ores for use in the ceramics and glass industry.

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.

Table 1.—Salient lithium statistics

(Short tons of contained lithium)

	1982	1983	1984	1985	1986
United States:					
Production[1]	W	W	W	W	W
Producers' stock changes[1]	W	W	W	W	W
Imports[2]	30	35	90	410	700
Shipments of Government stockpile surplus[3]	2	1	1	1	2
Supply[1] [4]	5,000	6,000	6,600	5,500	4,100
Supply[e] [5]	4,300	4,800	6,100	5,000	3,500
Exports[e] [6]	2,300	2,600	2,900	2,500	2,000
Consumption:					
Apparent	W	W	W	W	W
Estimated	2,000	2,200	3,200	2,500	2,600
Rest of world: Production[e] [1]	2,600	2,600	3,300	3,600	3,700

[e]Estimated. 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.

Legislation and Government Programs.—The General Services Administration reported sales of 24,800 pounds of lithium hydroxide monohydrate valued at $37,520 from excess stocks in the National Defense Stockpile. This material was excess from a 1960's nuclear weapons program. 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 material remaining in the stockpile was classified into two separate accounts. Sales in 1986 disposed of all the material in one account, while the remaining account contained 79,918,000 pounds of material.

DOMESTIC PRODUCTION

Two companies continued to produce lithium products in the United States. Foote Mineral Co., 87.5% owned by Newmont Mining Corp., was up for sale in 1986. Foote announced the temporary closing of its lithium carbonate operation at Kings Mountain, NC, where lithium ore was mined from pegmatite dikes. The plant remained on standby until such time in the future as market conditions become more favorable. Foote also produced lithium compounds from subsurface brines in Silver Peak, NV. Lithium Corp. of America (Lithco), a subsidiary of FMC Corp., continued to mine lithium ore from pegmatite dikes at Bessemer City, NC.

Foote reported total domestic production of 7,191 tons of lithium carbonate equivalent, or 1,352 tons of contained lithium, a decrease of about 22%.[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. Domestic consumption of lithium compounds increased slightly in 1986, although U.S. production decreased. Imported lithium ores replaced lithium carbonate in some applications in the ceramics and glass industry.

Despite the continued depression of the aluminum industry, the largest end use for lithium was in the addition of lithium carbonate to the cryolite bath in aluminum potlines. The lithium carbonate is converted to lithium fluoride, which lowers the melting point of the bath, allowing a lower operating temperature for the pot and increasing the electrical conductivity of the bath. Operators can use these factors to either increase production, reduce power consumption, or increase current efficiency.

The second largest end use, the addition of lithium chemicals and ores to ceramics and glass manufacturing processes, nearly surpassed the largest end use in terms of quantity of lithium material consumed. The lithium additive lowers process melting points, reduces the coefficient of thermal expansion and the viscosity, and eliminates the use of toxic chemicals. The manufacture of thermal-shock-resistant cookware was the largest use of lithium in the ceramics industry. Use of low-iron petalite and spodumene increased as a source of lithium used in the improvement of the physical properties of container and bottle glass, as well as a source of alumina (Al_2O_3), another important component of the glass.

The third largest end use for lithium in 1986 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. They were being used increasingly in military, industrial, automotive, aircraft, and marine applications.

Aircraft manufacturers in several countries have built experimental aircraft with wing and fuselage skins made of aluminum-lithium alloys. Use of the alloys has reduced aircraft weight by more than 10%, thus allowing for a significant fuel savings over the life of the aircraft. The lithium metal necessary for the production of these alloys is made by the electrolysis of molten anhydrous lithium chloride. The alloys, which are 2% to 3% lithium by weight, are of interest to the aircraft and aerospace industry because of their reduced density, higher elastic modulus, and superior corrosion resistance compared with that of conventional aluminum alloys. Major aluminum producers have overcome the problems with alloy casting and brittleness and were marketing the aluminum-lithium alloys to companies that sought to take advantage of their improved physical properties. However, the cost of these alloys remained a major drawback to their commercial application, and they faced direct competition from composite materials that consist of boron, graphite, or aramid fibers imbedded in plastic.

Lithium batteries were another end use for lithium metal with potential to increase dramatically. Eastman Kodak Co., which had recently entered the battery market, announced the availability of a 9-volt lithium-manganese dioxide battery for consumer use.[3] Safety problems with lithium batteries have been effectively overcome, and their use was becoming more common. Lithium batteries were being used increasingly in electronic watches, microcomputers, and cameras. Large lithium batteries have been used for some time in military applications. These batteries possess improved properties over more conventional alkaline batteries, although at increased cost. The major battery manufacturers were continuing research related to both primary lithium batteries and secondary, rechargeable batteries.

Small quantities of other lithium compounds were important to many industries. Butyllithium was used as a catalyst in the synthetic rubber industry. 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 disorder were prescribed medication containing a pharmaceutical-grade of lithium carbonate. Lithium metal was used as a scavenger for impurities in molten 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 individual lithium compounds differed from those of 1985, but the total amount of lithium contained in those stocks remained about the same.

PRICES

Prices of large-volume products such as lithium carbonate and lithium hydroxide monohydrate remained unchanged throughout the year, while prices for most other lithium products increased.

Table 2.—Domestic yearend producers' prices of lithium and lithium compounds

(Dollars per pound)

	1985	1986
Lithium bromide, 54% brine: 2,268-pound lots, delivered in drums	3.92	4.24
Lithium carbonate, technical: Truckload lots, delivered	1.50	1.50
Lithium chloride, anhydrous, technical: Truckload lots, delivered	3.32	3.49
Lithium fluoride	4.96	5.12
Lithium hydroxide monohydrate: Truckload lots, delivered	1.93	1.93
Lithium metal ingot, battery-grade: 1,000-pound lots, f.o.b	32.50	35.10
Lithium metal ingot, standard-grade: 1,000-pound lots, f.o.b	24.20	24.20
Lithium sulfate, anhydrous	3.21	3.21
N-butyllithium in n-hexane (15%): 3,000-pound lots, delivered	15.10	15.88

Source: U.S. lithium producers.

FOREIGN TRADE

U.S. exports of lithium carbonate, lithium hydroxide, and other lithium compounds decreased 17%, 19%, and 45%, respectively. U.S. imports for consumption of lithium ores increased by 183% over the figures reported in 1985, and imports of lithium compounds increased by 49%. The Bureau of the Census reported no imports of lithium salts in 1985, but imports reportedly resumed in 1986. Imports of lithium metal decreased by almost 90% because of an increase in domestic production in 1986. The only lithium metal imported was from the Federal Republic of Germany.

Table 3.—U.S. exports of lithium chemicals, by compound and country

Compound and country	1985 Gross weight (pounds)	1985 Value	1986 Gross weight (pounds)	1986 Value
Lithium carbonate:				
Australia	--	--	72,220	$88,784
Brazil	264,475	$341,203	440	3,498
Canada	1,898,790	2,964,347	1,470,149	2,391,197
Colombia	2,000	4,240	--	--
France	39,600	97,218	118,646	170,441
Germany, Federal Republic of	3,921,495	4,862,449	5,367,455	6,766,826
Hong Kong	--	--	38,801	51,764
India	25,866	40,465	25,877	72,943
Japan	5,611,356	7,709,487	2,180,837	3,129,384
Korea, Republic of	210,937	239,644	141,680	212,927
Mexico	377,181	548,249	371,011	547,580
Netherlands	153,974	199,590	455,875	657,101
New Zealand	26,409	55,075	1,100	5,071
South Africa, Republic of	80,609	129,384	46,300	69,210
Taiwan	204,250	276,050	361,518	484,501
United Arab Emirates	40,000	65,200	--	--
United Kingdom	22,000	29,260	918,601	1,314,335
Venezuela	1,037,414	1,444,475	8,800	12,341
Total	13,916,356	19,006,336	11,579,310	15,977,903
Lithium hydroxide:				
Argentina	67,813	123,412	386,916	668,863
Australia	319,380	608,218	204,883	350,940
Austria	--	--	950	1,030
Bahamas	926	1,250	--	--
Belgium	165,440	297,792	791	3,713
Brazil	855,313	1,535,846	953,925	1,626,832
Canada	5,622	9,899	19,481	31,630
Chile	29,544	54,053	39,457	75,396
Colombia	140,275	257,198	12,400	24,012
Ecuador	4,409	8,112	17,623	32,160
France	86,857	156,940	44,000	77,400
Germany, Federal Republic of	1,356,448	2,162,298	923,425	1,609,230
Honduras	2,075	4,510	6,600	13,530
India	331,778	555,031	503,498	842,238
Indonesia	75,000	158,529	92,000	187,264
Iran	4,409	8,025	--	--
Israel	12,043	21,219	40,344	70,373
Italy	--	--	6,614	12,831
Japan	1,741,088	3,044,939	1,459,124	2,600,737
Kenya	18,238	54,330	59,774	110,147
Korea, Republic of	116,582	216,221	203,987	338,728
Malaysia	4,200	7,686	--	--
Mexico	534,586	970,551	56,753	190,591
Netherlands	341,230	602,616	145,200	240,457
New Zealand	6,614	13,170	13,219	25,029
Nigeria	9,240	16,203	--	--
Pakistan	25,312	41,321	46,026	83,840
Peru	26,738	43,384	15,465	28,557
Philippines	75,633	136,322	45,000	74,360
Saudi Arabia	11,000	20,500	--	--
Singapore	118,948	216,297	88,148	160,264
South Africa, Republic of	259,678	460,063	139,360	246,716
Spain	156,200	262,108	44,000	79,200
Taiwan	74,996	134,082	79,421	125,798
Thailand	16,066	26,839	17,931	32,573
Turkey	--	--	85,800	149,292
United Arab Emirates	8,576	15,750	5,292	9,633
United Kingdom	731,748	1,249,180	569,277	909,676
Uruguay	--	--	882	1,800
Venezuela	88,559	160,032	44,092	79,360
Yugoslavia	30,864	55,560	16,000	26,651
Total	7,853,428	13,709,486	6,387,658	11,140,851
Other:				
Argentina	6,118	22,961	124	2,632
Australia	10,222	24,194	27,480	66,771
Austria	24,428	42,750	--	--
Belgium	530	64,224	39,379	34,353
Bermuda	--	--	9,813	40,856
Bolivia	--	--	2,200	2,073
Brazil	51,221	86,941	40,610	122,174
Canada	940,596	1,910,884	472,303	912,150
Chile	3,968	8,478	--	--
China	27,143	47,500	1,200	1,428

Table 3.—U.S. exports of lithium chemicals, by compound and country —Continued

Compound and country	1985 Gross weight (pounds)	1985 Value	1986 Gross weight (pounds)	1986 Value
Other —Continued				
Colombia	7,584	$12,637	4,792	$14,825
Costa Rica	527	1,130	1,000	1,520
Denmark	5,830	4,628	--	--
Finland	--	--	9,211	16,120
France	42,822	171,826	122,773	291,491
Germany, Federal Republic of	883,906	1,241,254	338,142	1,466,270
Hong Kong	--	--	140	9,600
India	1,096	1,700	3,388	17,035
Israel	1,687	46,075	2,432	49,095
Italy	6,157	12,085	1,512	1,036
Jamaica	--	--	14,890	36,422
Japan	530,978	1,653,141	114,892	888,108
Jordan	15,000	15,000	--	--
Korea, Republic of	83,768	118,083	172,728	223,734
Liberia	10,079	11,631	--	--
Libya	5,270	7,300	--	--
Mexico	324,759	684,533	181,155	420,718
Netherlands	181,357	242,981	321,200	488,612
Pakistan	52,575	89,530	20,041	41,157
Saudi Arabia	8,000	15,488	75	12,588
Singapore	11,983	31,827	27,829	56,470
South Africa, Republic of	5,675	9,309	21,287	50,962
Switzerland	6,500	834,000	156	3,588
Taiwan	3,647	31,740	8,927	43,404
United Arab Emirates	6,360	5,049	--	--
United Kingdom	2,338,742	4,878,809	1,126,018	2,657,074
Venezuela	9,640	52,334	5,978	11,861
Yugoslavia	215	73,000	551	75,742
Total	5,608,383	12,453,022	3,092,226	8,059,869

Source: Bureau of the Census.

Table 4.—U.S. imports for consumption of lithium-bearing materials, by commodity and country

Commodity and country	1985 Gross weight (pounds)	1985 Value (thousands) Customs	1985 Value (thousands) C.i.f.	1986 Gross weight (pounds)	1986 Value (thousands) Customs	1986 Value (thousands) C.i.f.
Lithium ores:						
Australia[1]	164,794	$20	$23	2,273,967	$247	$325
Canada[1]	2,596,545	314	314	2,892,257	306	306
Zimbabwe	6,670,868	841	940	21,488,181	2,639	2,985
Total	9,432,207	1,175	1,277	26,654,405	3,192	3,616
Lithium compounds:						
Belgium	4,933	4	4	--	--	--
Chile	2,713,783	3,468	3,655	4,125,042	5,239	5,525
China	18	1	2	5	2	2
France	13,820	1,712	1,722	12,200	3,161	3,178
Germany, Federal Republic of	45,503	150	160	51,787	330	342
Japan	3,379	137	141	228	66	69
United Kingdom	21,923	85	90	381	49	50
Total	2,803,359	5,557	5,774	4,189,643	8,847	9,166
Lithium salts:						
France	--	--	--	220	8	9
Germany, Federal Republic of	--	--	--	4,409	24	28
Japan	--	--	--	50	2	2
United Kingdom	--	--	--	90	4	4
Total	--	--	--	4,769	38	43
Lithium metal:						
Germany, Federal Republic of	100	4	4	4,333	24	25
United Kingdom	41,503	456	466	--	--	--
Total	41,603	460	470	4,333	24	25

[1]Spodumene concentrate.

Source: Bureau of the Census as adjusted by the Bureau of Mines.

WORLD REVIEW

Argentina.—Exploration and development proceeded at two separate brine deposits for lithium in conjunction with magnesium and potassium salts. Party Sasimagi was planning a 6,000-ton-per-year chemical plant to treat the salts from the Salar del Rincón, Puna.[4] Production was expected to begin at yearend 1987. Government officials signed an agreement on an international call for tender for the exploration and development of the salts from the Salar del Hombre Muerto, Catamarca.[5] This deposit could support production worth up to $200 million annually.

Australia.—Greenbushes Ltd. began producing a high-grade spodumene concentrate on a commercial scale in January.[6] The concentrate contains 7.5% lithia (Li_2O) and a maximum of 0.10% iron oxide (Fe_2O_3). The company also began production of glass-grade spodumene intended for use in the container glass industry. Plant trials on a commercial scale were completed in Europe and Australia. Greenbushes planned to increase annual sales of this 4.5% to 5.0% Li_2O concentrate to 50,000 tons per year over the next 5 years. This concentrate could replace nepheline syenite, sodium carbonate, or feldspar as raw material for the container glass industry and thereby reduce the cost of the glass product. Greenbushes created a subsidiary, Lithium Australia Ltd., to take over the lithium assets of its operation in Western Australia and to develop the production and sale of lithium products. Plans for constructing a lithium carbonate plant with Metallgesellschaft AG and C. Itoh & Co. Ltd. were deferred, and production was considered unlikely to begin before 1990.[7]

Bolivia.—Servicio Geológico de Bolivia, the Bolivian Geological Survey, was expected to receive aid from the Italian Government to explore mineral deposits in western Bolivia.[8] Plans for the study included preliminary work on the Salar de Uyuni, which is believed to contain one of the world's largest lithium deposits.[9]

Canada.—Tantalum Mining Corp. of Canada Ltd. completed construction of a spodumene concentration plant at Bernic Lake, Manitoba.[10] The company began producing glass-grade spodumene concentrate on a commercial scale at a capacity of 12,000 tons per year.

Chile.—A cooperative study continued among the Government-owned Corporación de Fomento de la Producción , Molibdenos y Metales S.A. (a private Chilean firm), and AMAX Inc. (a multinational U.S. firm). The study addressed the feasibility of developing a second production site at the Salar de Atacama.[11] Pending a positive evaluation, initial production was projected at 2,800 tons per year of lithium metal equivalents.

China.—Geologists from the National Salt Lake Research Institute estimated the Quaidam Salt Basin, in northwest China's Qinghai Province, to contain one of the world's largest deposits of lithium, as well as magnesium and boron.[12]

France.—A prototype of a French fighter plane with some of its fuselage skin made of an aluminum-lithium alloy made its maiden voyage in 1986.[13] The alloy was manufactured by Pechiney. Pechiney reported that it had overcome the problems it had been experiencing in producing the thick plate products that will be required for these alloys to gain widespread use.[14] This was the first time that Avions Marcel Dassault-Breguet Aviation has constructed a plane using the superlight alloy. The new material made the plane significantly lighter than other comparable aircraft.

Mali.—Lithium deposits were identified in Mali by the Direction Nationale de la Géologie et des Mines.[15] The lithium occurs in outcrops of large pegmatites with spodumene in the Birrimian greenstone belts near the Ivory Coast border.

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[1]Physical scientist, Division of Industrial Minerals.

[2]Foote Mineral Co. 1986 10-K Report. FMC Corp., the owner of Lithco, did not report specific lithium data in its 1986 10-K report.

[3]Jones, S. R. Two Bold Entrants in the Market for Batteries. Chem. Week, v. 138, No. 24, 1986, pp. 8-11.

[4]Mining Journal (London). Argentinian Salts Project. V. 306, No. 7868, 1986, p. 408.

[5]———. Argentina Evaporites Agreement. V. 306, No. 7852, 1986, p. 116.

[6]Vultan Minerals Ltd. (Australia). Annual Report 1986. Pp. 23-26. Greenbushes Ltd. is owned by Vultan Minerals Ltd.

[7]Industrial Minerals (London). More on Greenbushes Glass Grade Spodumene. No. 231, 1986, p. 8.

[8]Mining Magazine. Italian Aid for Bolivia. V. 55, No. 4, 1986, p. 303.

[9]Bleiwas, D. S., and J. S. Coffman. Lithium Availability—Market Economy Countries. A Minerals Availability Appraisal. BuMines IC 9102, 1986, p. 15.

[10]Energy, Mines and Resources Canada. Lithium, an Imported Commodity. Miner. Bull. MR 212, 1986, p. 11.

[11]Industrial Minerals (London). Enter Minsal in the Salar. No. 222, 1986, p. 16.

[12]Mining Magazine. China Finds Lithium. V. 55, No. 4, 1986, p. 303.

[13]French Advances in Science and Technology. Rafale Takes New Materials Into the Skies. V. 1, No. 2, 1986, p. 1.

[14]Metal Bulletin (London). Pechiney Alloy Breakthrough. No. 7118, 1986, p. 17.

[15]Mining Journal (London). Recent Discoveries in Mali. V. 306, No. 7865, 1986, p. 353.

Table 5.—Lithium minerals and brine: World production, by country[1]

(Short tons)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Argentina (minerals not specified)	125	168	24	22	22
Australia, spodumene[3]	[e]90	1,100	7,200	12,300	12,100
Brazil:					
Amblygonite	73	125	54	[e]83	165
Lepidolite	82	1	--	--	--
Petalite	2,528	2,086	526	[e]550	940
Spodumene	376	128	317	[e]330	550
Canada, spodumene[e 4]	--	--	90	[r]330	550
Chile (carbonate from subsurface brine)	--	--	2,326	4,969	4,960
China (minerals not specified)[e 5]	15,400	16,500	16,500	16,500	16,500
Namibia (minerals not specified)	1,146	860	970	2,160	2,200
Portugal, lepidolite	998	601	1,086	[r e]880	830
U.S.S.R. (minerals not specified)[e 5]	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)	10,788	21,157	25,270	30,765	31,000

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Table includes data available through May 19, 1987.

[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]Data are for years ending June 30 of that stated.

[4]Estimates from U.S. imports from Canada.

[5]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.

Magnesium

By Deborah A. Kramer[1]

U.S. production of primary magnesium decreased from that of 1985 chiefly because one producer operated at reduced capacity for the second half of 1986. Consumption of primary magnesium also declined even though consumption for aluminum alloying, the dominant end use, was about the same as that of 1985, and consumption for structural uses increased. The United States remained a net exporter of magnesium as exports increased, and imports remained about the same.

Capacity expansions in Brazil and Canada were announced, and new primary magnesium plants were scheduled to be constructed in Canada and Norway. The expansions and new plants would increase annual world capacity by about 125,000 short tons in the next few years, compared with existing capacity of 414,000 tons at yearend 1985.

Developments in rapid solidification (RS) technology, high-purity magnesium alloys with improved physical properties, and the continued penetration of magnesium into automotive applications indicated a potential to increase domestic magnesium consumption significantly. In addition, advances in aluminum can fabrication technology may result in development of aluminum food cans, and the aluminum alloy used in can manufacture contains an average of 3.5% magnesium.

Table 1.—Salient magnesium statistics

(Short tons unless otherwise specified)

	1982	1983	1984	1985	1986
United States:					
Production:					
Primary magnesium	102,197	115,431	159,207	149,614	138,493
Secondary magnesium	43,232	46,329	48,357	45,523	46,084
Exports	39,613	46,690	48,337	40,322	43,992
Imports for consumption	4,784	6,350	9,381	9,271	9,209
Consumption, primary	74,599	81,976	89,887	83,502	77,119
Price per pound	$1.34	$1.38	$1.43-$1.48	$1.48-$1.53	$1.53
World: Primary production	[r]279,899	[r]286,755	360,459	[p]362,372	[e]358,825

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

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 128 operations to which a survey request was sent, 94% responded, representing 84% of the primary magnesium consumption shown in tables 1 and 3. Consumption for the eight nonrespondents was estimated based on reported prior year consumption levels.

DOMESTIC PRODUCTION

Production of primary magnesium was about 75% of annual capacity. Primary magnesium was produced by three companies: 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 and Dow produced magnesium from natural brines by the electrolytic process, and Northwest Alloys produced magnesium from dolomite using the silicothermic process.

On June 8, a storm reportedly ruptured a 13-mile earthen dike protecting AMAX's solar evaporation ponds, which were adjacent to the Great Salt Lake in Utah. Resultant flooding of the ponds diluted the brine, making it unsuitable for magnesium chloride recovery. AMAX estimated that it would require 2 to 3 years to return the ponds to operation. AMAX reportedly continued to produce magnesium at a reduced level by using inventories and by purchasing brine from Kaiser Aluminum & Chemical Corp.'s Wendover, UT, brine facility. In September, AMAX announced that it would not rebuild the dike and no effort would be made to reclaim the ponds. In 2 years, the State was expected to complete construction of pumping stations that would create an evaporation pond in the west desert, and AMAX reportedly may receive brine from this pond. At yearend, the viability and continued operation of the facility was questionable.

Interstrat Resources Inc. reported that results of feasibility studies indicated that its Pine Flat Mountain property on the California-Oregon border had $2 billion worth of ore reserves. The feasibility study, completed by Davy McKee Corp., recommended an open pit mine with facility to process 2,500 tons per day of ore, containing recoverable quantities of cobalt, magnesium, and nickel. Capital costs to construct the facility were estimated to be $257.7 million, and yearly operating costs were estimated to be $98 million. Ore reserves were estimated to be 27.1 million tons, containing 8.2% magnesium, 1% nickel, and 0.13% cobalt. Annual yield for the plant was projected to be 36,000 tons of magnesium, 7,000 tons of nickel, and 1,000 tons of cobalt.

Table 2.—Magnesium recovered from scrap processed in the United States, by kind of scrap and form of recovery

(Short tons)

	1982	1983	1984	1985	1986
KIND OF SCRAP					
New scrap:					
Magnesium-base	2,455	2,873	3,192	1,664	1,092
Aluminum-base	17,346	18,718	18,402	17,915	19,645
Total	19,801	21,591	21,594	19,579	20,737
Old scrap:					
Magnesium-base	5,314	5,311	5,232	5,104	4,363
Aluminum-base	18,117	19,427	21,531	20,840	20,984
Total	23,431	24,738	26,763	25,944	25,347
Grand total	43,232	46,329	48,357	45,523	46,084
FORM OF RECOVERY					
Magnesium alloy ingot[1]	4,228	4,232	4,229	4,231	4,327
Magnesium alloy castings (gross weight)	746	952	980	483	508
Magnesium alloy shapes	--	--	--	--	34
Aluminum alloys	36,587	39,451	41,072	39,459	41,207
Zinc and other alloys	11	20	12	9	3
Chemical and other dissipative uses	3	4	9	3	W
Cathodic protection	1,657	1,670	2,055	1,338	W
Total	43,232	46,329	48,357	45,523	46,084

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

Consumption of primary magnesium in 1986 was about 8% less than that of 1985, principally owing to declines in demand for magnesium powder and titanium sponge production. Demand for magnesium for chemical uses also declined because of a decreased use of tetraethyllead in gasoline. Aluminum alloying remained the dominant use for magnesium, and aluminum alloys containing magnesium were used primarily in beverage cans and the automotive industry. Primary magnesium demand for iron and steel desulfurization was estimated to be 9,000 tons.

Brake and clutch pedal supports fabricated of magnesium reportedly will be used on General Motors Corp.'s (GM) W-body intermediate-size cars due out in 1988. The supports, weighing about 4 pounds each, will be manufactured by Webster Manufacturing Ltd. of Canada and will be integrally die cast with the magnesium steering column brackets that the company planned to manufacture. By 1990, GM expected to produce 1 million of the W-body cars, and the potential for magnesium consumption in the pedal-support applications would be 2,000 tons.[2]

GM's Pontiac Div. reportedly developed an experimental 4-cylinder engine equipped with a magnesium engine block. The 41-pound engine block, if testing proves successful, could replace a 108-pound cast iron engine block. GM reportedly used Dow's ZE41 alloy, which maintained dimensional stability up to 330° F to manufacture the engine block. GM planned to use the engine in racing cars first, then it may be used for passenger cars.

The Ford Motor Co. planned to use several magnesium transfer case components in its 1987 F-series and Bronco pickup trucks. The case and cover weighed about 8 pounds and 6 pounds, respectively. In addition, Ford planned to use a transfer case extension weighing between 2 and 3 pounds. Magnesium was substituted for aluminum components in these applications.

Engineers for the U.S. Army reportedly developed a portable, lightweight, fabric-covered shelter that could be used as a vehicle repair and maintenance facility. Magnesium extrusions were used to manufacture the frame. The shelter was a 20-foot-wide, 32-foot-long, 14-foot-high structure resembling a World War II Quonset hut. It weighed 3,276 pounds, was expandable in 8-foot increments, and required 20 worker-hours to assemble. The shelter reportedly could be transported by air and was adaptable for use in tropical or arctic climates. The primary extruded tubing components were manufactured from ZK40 and ZK60 magnesium alloys, and the remainder of the extruded shapes were made from AZ31B alloy.[3]

Table 3.—U.S. consumption of primary magnesium, by use

(Short tons)

Use	1982	1983	1984	1985	1986
For structural products:					
Castings:					
Die	1,600	1,937	595	2,457	4,019
Permanent mold	663	16	1,666	909	825
Sand	1,337	1,388	1,932	1,634	1,513
Wrought products:					
Extrusions	7,059	7,093	5,828	7,756	6,928
Other[1]	r3,069	r4,342	r4,418	r4,193	4,341
Total	13,728	14,776	14,439	16,949	17,626
For distributive or sacrificial purposes:					
Alloys:					
Aluminum	39,878	46,026	48,673	40,850	40,569
Other	r13	r7	r8	r8	6
Cathodic protection (anodes)	5,964	5,686	4,777	4,748	6,991
Chemicals	4,823	5,664	5,501	3,824	1,597
Nodular iron	2,541	2,200	2,408	1,698	1,788
Reducing agent for titanium, zirconium, hafnium, uranium, beryllium	5,901	4,711	6,689	8,126	5,771
Other[2]	1,751	2,906	7,392	7,299	2,771
Total	60,871	67,200	75,448	66,553	59,493
Grand total	74,599	81,976	89,887	83,502	77,119

rRevised.
[1]Includes sheet and plate and forgings.
[2]Includes scavenger, deoxidizer, and powder.

STOCKS

Consumer stocks of primary magnesium ingot declined from 6,168 tons at yearend 1985 to 5,473 tons at yearend 1986. Stocks of magnesium alloy ingot rose from 428 tons at yearend 1985 to 759 tons at yearend 1986. Primary producer stocks of magnesium increased slightly from 36,736 tons at yearend 1985 to 37,078 tons at yearend 1986.

Table 4.—Stocks and consumption of new and old magnesium scrap in the United States

(Short tons)

	Stocks, Jan. 1	Receipts	Consumption			Stocks, Dec. 31
			New scrap	Old scrap	Total	
1985:						
Cast scrap	1,224	5,078	15	5,104	5,119	1,183
Solid wrought scrap[1]	41	430	439	--	439	32
Total	1,265	5,508	454	5,104	5,558	1,215
1986:						
Cast scrap	1,183	4,264	14	4,363	4,377	1,070
Solid wrought scrap[1]	32	--	10	--	10	22
Total	1,215	4,264	24	4,363	4,387	1,092

[1]Includes borings, turnings, drosses, etc.

PRICES

AMAX increased its price quote for primary magnesium ingot from $1.48 per pound to $1.53 per pound, effective January 1, 1986, to match Dow's price increase, which took effect on December 9, 1985. The price quoted by both producers remained at this level throughout the year. AMAX also increased its quoted price for diecasting alloy from $1.26 per pound to $1.29 per pound, effective January 1, 1986, and Dow reduced its diecasting alloy price quote from $1.40 per pound to $1.33 per pound on January 20. Both producers maintained their respective quotes for diecasting alloy at those levels throughout the year.

FOREIGN TRADE

Magnesium exports increased 9% in quantity from those of 1985, but the average value declined slightly. Japan and the Netherlands were the principal destinations, accounting for 55% of U.S. exports. The United States remained a net exporter of magnesium.

Imports for consumption of magnesium were about the same in quantity as those of 1985, but the average value increased. Canada and Norway supplied 62% of U.S. magnesium imports.

Table 5.—U.S. exports and imports for consumption of magnesium

Year	EXPORTS					
	Waste and scrap		Metals and alloys in crude form		Semifabricated forms, n.e.c.	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1984	1,249	$3,362	44,880	$120,804	2,208	$12,495
1985	795	2,071	37,484	100,128	2,043	11,401
1986	852	1,990	41,012	106,896	2,128	13,492

Year	IMPORTS FOR CONSUMPTION							
	Waste and scrap		Metal		Alloys (magnesium content)		Powder, sheets, tubing, ribbons, wire, other forms (magnesium content)	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1984	2,160	$3,656	3,136	$8,604	3,596	$10,791	489	$2,620
1985	2,874	4,778	1,992	5,525	3,651	12,774	754	2,010
1986	2,099	3,895	3,092	8,112	1,808	7,008	2,210	5,556

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)
1985:						
Argentina	--	--	240	$634	8	$43
Australia	--	--	1,710	3,960	269	1,433
Austria	--	--	308	916	6	78
Belgium-Luxembourg	--	--	53	157	15	93
Brazil	--	--	131	326	2	19
Canada	377	$875	4,880	12,805	684	2,462
China	--	--	3,132	8,326	--	--
Colombia	--	--	24	63	37	98
Egypt	--	--	386	1,048	2	4
France	1	2	--	--	17	414
Germany, Federal Republic of	325	1,005	139	442	29	334
Ghana	--	--	134	338	--	--
Hong Kong	--	--	--	--	(1)	4
India	--	--	505	1,382	3	20
Israel	--	--	5	34	44	221
Italy	--	--	3	16	83	739
Japan	9	8	11,149	28,602	177	1,017
Korea, Republic of	--	--	354	1,054	91	396
Mexico	19	45	2,462	6,350	162	878
Netherlands	--	--	10,773	30,609	39	212
New Zealand	--	--	36	87	1	21
Norway	--	--	109	293	6	68
Saudi Arabia	--	--	7	30	23	59
Singapore	--	--	2	3	30	63
South Africa, Republic of	--	--	429	1,219	37	156
Spain	--	--	21	10	14	213
Sweden	--	--	6	15	12	172
Taiwan	--	--	225	664	19	43
United Kingdom	64	136	11	65	141	1,523
Venezuela	--	--	127	333	1	15
Other	--	--	r123	r347	91	r603
Total	795	2,071	37,484	100,128	2,043	11,401

See footnotes at end of table.

Table 6.—U.S. exports of magnesium, by country —Continued

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
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
Egypt	--	--	--	--	--	--
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
Israel	--	--	5	9	20	186
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
Saudi Arabia	--	--	6	13	7	12
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
United Kingdom	1	2	420	1,236	289	2,304
Venezuela	--	--	14	60	43	141
Other	2	7	162	440	145	794
Total	852	1,990	41,012	106,896	2,128	13,492

[r]Revised.
[1]Less than 1/2 unit.

Source: Bureau of the Census.

Table 7.—U.S. import duties for magnesium

Item	TSUS No.	Most favored nation (MFN)		Non-MFN
		Jan. 1, 1986	Jan. 1, 1987	Jan. 1, 1986
Unwrought metal	628.55	10% ad valorem	8% ad valorem	100% ad valorem.
Unwrought alloys	628.57	6.6% ad valorem	6.5% ad valorem	60.5% ad valorem.
Wrought metal	628.59	4.7 cents per pound on magnesium content plus 2.6% ad valorem.	4.5 cents per pound on magnesium content plus 2.5% ad valorem.	40 cents per pound on magnesium content plus 20% ad valorem.

WORLD REVIEW

Brazil.—In February, Brazileira do Magnesio S.A. (Brasmag) announced that it would increase capacity at its 4,400-ton-per-year primary magnesium plant by 34,100 tons by 1988, at a cost of $140 million. A capacity expansion of 2,200 tons was scheduled to be completed in April 1986, and an additional expansion of 4,400 tons was to be completed in October. Two further expansions were also scheduled: 11,000 tons to come on-stream in July 1987, and 15,600 tons to come on-stream in July 1988. Brasmag reportedly planned to market one-half of its output in Latin America. Before the expansion, Brasmag operated two electric vacuum reduction furnaces to produce magnesium by the silicothermic process, using dolomite and ferrosilicon as raw materials.

Canada.—Alcoa and MPLC Holdings S.A. reportedly formed a joint venture in April to construct a 55,000-ton-per-year primary magnesium facility in Aldersyde, Alberta.

The $270 million plant was scheduled to come on-stream in three phases: 11,000 tons per year in 1988, 22,000 tons per year in 1990, and 22,000 tons per year in 1992. In October 1986, Alcoa pulled out of the joint venture, citing that with the other new projects proposed in Brazil, Canada, and Norway, the additional production was in excess of what the market would need. At yearend, MPLC was actively seeking a new partner for the proposed plant.

The Chromasco Div. of Timminco Ltd. reportedly planned to double its annual primary magnesium capacity at Haley, Ontario, to 16,500 tons by 1990. The first phase of the program would mechanize the company's magnesium crown production, and the second through fourth phases would entail converting furnaces from electricity to natural gas, improving furnace energy efficiency, and developing a separate calcium production facility. By converting existing facilities from strontium and calcium production to magnesium production, Chromasco expected to increase magnesium production by 20% by yearend 1987. An anticipated increase in demand for high-purity magnesium alloys was cited as the reason for an increase in capacity.

In October, Norsk Hydro A/S reportedly formally approved construction plans for its 66,000-ton-per-year primary magnesium plant in Becancour, Quebec. Construction of the $228 million plant was scheduled to begin in the first half of 1987, and the completion date was set for the first quarter of 1989. Norsk Hydro also reported that it had completed a 25-year, low-cost, power supply arrangement with Hydro-Quebec.[4]

Japan.—Magnesium demand in Japan in 1986 was about 21,600 tons, about 9% less than demand in 1985. Primary magnesium production fell by 4% to about 9,000 tons, and imports of about 14,000 tons were 19% less than those of 1985. The United States supplied 68% of metal imports, and China was the destination for 85% of the 1,000 tons of magnesium exports. Rolled magnesium products accounted for 56% of Japan's magnesium demand.[5]

Norway.—In July, Elkem A/S announced plans to construct a 16,500-ton-per-year primary magnesium facility at Sauda at a cost of $75 million. Startup date for the plant was scheduled for early 1988. The plant would use the silicothermic process for magnesium production, using dolomite mined in northern Norway and byproducts from Elkem's primary ferrosilicon production as feed materials.

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

(Short tons)

Country	1982	1983	1984	1985^p	1986^e
Brazil	331	551	1,323	2,866	3,300
Canada^e	8,700	6,600	8,800	7,700	7,700
China^e	7,700	7,700	7,700	7,700	7,700
France	10,593	12,208	14,299	15,212	15,400
Italy	10,960	8,473	8,257	8,667	[2]13,687
Japan	6,123	6,643	7,830	9,312	[2]8,945
Norway	39,598	32,897	54,343	60,301	60,600
U.S.S.R.^e	89,000	91,000	94,000	96,000	98,000
United States	102,197	115,431	159,207	149,614	[2]138,493
Yugoslavia	4,697	5,252	^e4,700	^e5,000	5,000
Total	^r279,899	^r286,755	360,459	362,372	358,825

^eEstimated. ^pPreliminary. ^rRevised.
[1]Table includes data available through June 2, 1987.
[2]Reported figure.

Table 9.—Magnesium: World secondary production, by country[1]

(Short tons)

Country	1982	1983	1984	1985^p	1986^e
Japan	23,887	14,343	17,258	23,032	16,000
U.S.S.R.^e	9,000	9,000	9,000	9,000	9,000
United Kingdom	1,940	^e1,900	1,102	992	1,100
United States	43,232	46,329	48,357	45,523	[2]46,084
Total	78,059	71,572	75,717	78,547	72,184

^eEstimated. ^pPreliminary.
[1]Table includes data available through June 2, 1987.
[2]Reported figure.

TECHNOLOGY

Scientists at Allied-Signal Corp., Morristown, NJ, reportedly developed a number of magnesium alloys with novel compositions by RS processing. The key to Allied-Signal's RS process was a specialized technique, called Planar Flow Casting, to produce a wider strip of RS magnesium than was possible with conventional RS processing. After the magnesium alloy was induction melted in an inert atmosphere, a thin liquid metal stream was ejected through a rectangular orifice onto the external surface of a water-cooled rotating copper drum, where it formed a ribbon. The ribbon was then pulverized into a minus 60-mesh powder, and vacuum hot-pressed to produce a billet that was subsequently hot extruded or forged. As a result of these improvements in RS processing, properties in the resulting alloys such as corrosion resistance, yield strength, tensile strength, and elongation were reportedly improved compared with those of conventional magnesium alloys. The new RS alloys were expected to have future applications in the automotive and aerospace industries.[6]

Fansteel Inc., Chicago, IL, reportedly developed a high-purity AZ91E magnesium sand casting alloy with enhanced salt-fog corrosion resistance. Success of this alloy was dependent on a minimized iron-to-manganese ratio, use of pickling after grit blasting to remove surface contaminants, and proper temper selection. In a 10-day, 5%-salt-fog test, the standard casting alloy, AZ91C, exhibited a heavy buildup of corrosion products and significant surface damage, while the AZ91E alloy had no corrosion products and only minor surface damage. A joint program between Fansteel and Wellman Dynamics Corp. continued to optimize melting and surface cleaning techniques.

The development of an electrophoretic coating process that could be applied to aluminum cans of all sizes may permit aluminum food cans to be a viable alternative to three-piece steel cans. Until Alcoa developed the new coating technology, only shallow aluminum food cans could be produced. The aluminum alloy used for the food cans, AA5042, would have an average magnesium content of 3.5%. Alcoa estimated that the food can market had the potential to increase aluminum consumption by 500,000 tons per year, thus increasing annual magnesium consumption by 17,500 tons.

General Electric Co.'s Space Systems Div., King of Prussia, PA, reportedly constructed satellite equipment panels for the Defense Satellite Communications System (DSCS) III from a special magnesium alloy, HK31A. Because the DSCS III orbited at 23,230 miles above the Earth, it was constantly bombarded by tiny particles that could damage the electronic equipment. In addition, the DSCS III was exposed to a combination of extreme heat as one side faced the sun and subzero temperatures when the opposite side was in dark orbit. HK31A, developed by Dow, had a high strength-to-weight ratio and excellent thermal properties that helped protect the instrumentation in this environment. DSCS III was the largest and most sophisticated of a series of 30 satellites launched since 1958 to provide secure, instantaneous communications support for defense activities. The DSCS III, powered by solar cells, was designed to last 10 years.[7]

Materials Concepts Inc., Columbus, OH, reportedly produced a graphite fiber-reinforced magnesium casting weighing more than 10 pounds. By cross-plying and pultruding the graphite fibers, the new magnesium casting had better properties than castings previously produced by the company. Materials Concepts believed that a tubular product with a zero coefficient of expansion could be produced and that such products could have applications in space systems structures, where there was a need to match the coefficient of expansion of a ceramic with that of a metal.

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[1]Physical scientist, Division of Nonferrous Metals.

[2]Wrigley, A. Magnesium Brake and Clutch Pedal Supports Set for GM's W-Cars in '88. Am. Met. Mark., v. 94, No. 13, Jan. 20, 1986, p. 16.

[3]American Metal Market. Army Using Magnesium in Vehicle Repair Shelter. V. 94, No. 106, June 2, 1986, p. 26.

[4]Light Metal Age. Norsk Hydro's Canadian Magnesium Plant. V. 44, Nos. 11, 12, Dec. 1986, pp. 20-22.

[5]Japan Metal Journal. Home Demand for Primary Magnesium in '86 Drops Below 20,000 Tons. V. 17, No. 14, Apr. 6, 1987, pp. 6, 8.

[6]Das, S. K., C. F. Chang, and D. Raybould. High Performance Magnesium Alloys by Rapid Solidification Processing. Light Met. Age, v. 44, Nos. 11, 12, Dec. 1986, pp. 5-8.

[7]American Metal Market. GE Using Alloy To Protect Satellite. V. 94, No. 116, June 16, 1986, p. 26.

Magnesium Compounds

By Deborah A. Kramer[1]

Domestic caustic-calcined magnesia shipments declined for the fifth year in a row, and dead-burned magnesia shipments reached their lowest level in more than 40 years. Refractory products remained the dominant end use for magnesia and, although demand remained about the same as that of 1985, imports supplied a greater portion of demand in 1986. Changes in steel production technology over the past 5 years have resulted in increased use of magnesia-carbon refractories and magnesia refractories with higher wear resistance.

Seawater and well and lake brines were the primary source of domestically produced magnesium compounds. Only one magnesite mine operated during the year and, with the closure of an olivine mine in North Carolina, only one company produced olivine at yearend.

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 20 operations to which a survey request was sent, 80% responded, representing 73% of the total magnesium compounds shipped and used shown in table 3. Data for the four nonrespondents were estimated using prior year production levels and other factors.

Table 1.—Salient magnesium compound statistics

(Thousand short tons and thousand dollars)

	1982	1983	1984	1985	1986
United States:					
Caustic-calcined and specified magnesias:[1]					
Shipped by producers:[2]					
Quantity	148	143	142	100	95
Value	$56,363	$57,416	$42,257	$33,772	$33,969
Exports: Value[3]	$10,925	$8,426	$14,026	$9,773	$13,295
Imports for consumption: Value[3]	$2,055	$5,476	$9,594	$10,407	$11,493
Refractory magnesia:					
Shipped by producers:[2]					
Quantity	453	456	374	290	274
Value	$112,101	$98,473	$87,945	$81,149	$73,172
Exports: Value	$2,721	$1,955	$3,641	$5,529	$5,488
Imports for consumption: Value	$14,162	$11,495	$23,715	$29,767	$36,718
Dead-burned dolomite:					
Sold and used by producers:					
Quantity	337	418	487	376	[p]385
Value	$19,136	$24,454	$29,391	$24,454	[p]$25,025
World: Production (magnesite)	12,554	[r]12,252	13,167	[p]15,727	[e]13,615

[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

Shipments of caustic-calcined magnesia continued the decline begun in 1982, and refractory magnesia shipments also continued to decrease, reaching their lowest level in more than 40 years. Seawater and well and lake brines were the primary sources of domestically produced magnesium compounds, although some magnesium compounds were recovered from magnesite and dolomite.

Cortez International Ltd., a Canadian-based firm, reportedly planned to begin mining magnesite in Stevens County, WA, by the end of 1987. Magnesite reserves on the property were estimated to be 2.2 million short tons, containing more than 40% magnesia and less than 5% lime. This deposit was initially core drilled in 1943 by the State's Department of Conservation.

Tateho Chemical Industries Co. of Japan reportedly purchased the fused magnesia operations of Combustion Engineering Inc. at Greenville, TN, for an undisclosed purchase price. The magnesia plant had a rated annual capacity of 7,700 tons, and most of the product was used in electrical insulators. Tateho was the largest producer of fused magnesia in Japan, with a 19,800-ton-per-year plant in Hyogo-ken.

Olivine was mined from deposits in North Carolina and Washington by two companies. Shipments of olivine declined about 9% from those of 1985.

International Minerals & Chemical Corp. (IMC) reportedly sold its Industry Group to Applied Industrial Minerals Corp. (Aimcor) in December. IMC's Industry Group included its olivine mines in North Carolina and Washington and three custom blending plants for foundry sands.[2]

Spruce Pine Olivine Corp. reportedly ceased production at its mine in Spruce Pine, NC, in July. With the closure of this mine, Aimcor became the sole producer of olivine in the United States.

Table 2.—Magnesium compound producers, by raw material source, location, and production capacity in 1986

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 continued to be the dominant end use for domestically produced magnesium compounds. Magnesia and magnesia-based brick were used principally by the iron and steel industry for furnace linings. In 1986, 55% of domestically produced olivine was used by the foundry industry, 25% was used for slag control, and the remainder was used for refractories and abrasives.

Caustic-calcined and specified magnesias were used in diverse industries including agriculture, chemical processing, and construction. Animal feed remained the largest consuming industry, accounting for 24% of the total domestic shipments of caustic-calcined magnesia. Refractories, petroleum additives, chemicals, and rayon, in declining order, accounted for 44% of the total shipments. The following uses, in declining order, represented the remaining 32% of the total shipments: stack gas scrubbing, rubber, fertilizer, oxychloride and oxysulfate cements, ceramics, pulp and paper, insulation and wallboard, medicine and pharmaceuticals, sugar and candy, fluxes, water treatment, electrical heating rods, foundry, and uranium processing. Magnesium hydroxide was used mainly for refractories and pulp and paper processing; magnesium sulfate was used mostly for chemicals and medicine and pharmaceuticals; and precipitated magnesium carbonate was used for chemicals, insulation and wallboard, and medicine and pharmaceuticals.

Table 3.—U.S. magnesium compounds shipped and used

	1985		1986	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Caustic-calcined[1] and specified (USP and technical) magnesias	99,517	$33,772	95,366	$33,969
Magnesium hydroxide (100% $Mg(OH)_2$)[1]	r262,257	r64,075	228,917	56,305
Magnesium sulfate (anhydrous and hydrous)	55,863	14,813	51,295	15,388
Precipitated magnesium carbonate[1]	3,746	702	4,870	765
Refractory magnesia	290,271	81,149	274,429	73,172

rRevised.
[1]Excludes material produced as an intermediate step in the manufacture of other magnesium compounds.

PRICES

Prices for magnesium compounds at yearend, published in the Chemical Marketing Reporter, were as follows: magnesia, natural, technical, heavy, 85% and 90% (f.o.b. Nevada), $232 and $265 per short ton, respectively; magnesium chloride, hydrous, 99%, flake, $290 per ton; magnesium carbonate, light, technical (freight equalized), $0.73 to $0.83 per pound; magnesium hydroxide, National Formulary (NF), powder (freight equalized), $0.78 per pound; and magnesium sulfate, technical, $0.14 per pound. Except for the magnesium sulfate price, which increased $0.025 per pound, yearend prices for magnesium compounds did not change from those published at yearend 1985.

FOREIGN TRADE

Total exports of caustic-calcined and dead-burned magnesias in 1986 were about the same as those of 1985, but the average value increased. Canada remained the primary destination, accounting for over 67% of U.S. exports.

Imports of magnesia continued to increase in quantity as they have each year for the past 5 years. Canada was the source for 56% of U.S. imports of caustic-calcined magnesia, and China, Greece, and Ireland accounted for 72% of domestic imports of dead-burned magnesia. In addition, other magnesium compounds with a value of more than $11 million were imported into the United States.

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			
	1985		1986		1985		1986	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Argentina	--	--	--	--	54	$48	13	$18
Australia	--	--	--	--	469	260	1,250	410
Austria	--	--	3,308	$897	--	--	--	--
Belgium-Luxembourg	--	--	--	--	414	310	339	376
Brazil	--	--	7	6	58	165	175	400
Canada	16,391	$3,704	16,593	3,747	8,277	3,191	14,788	7,744
Chile	188	43	--	--	2	4	677	225
Colombia	1,511	216	822	118	72	101	91	138
France	--	--	--	--	5,761	1,800	113	99
Germany, Federal Republic of	--	--	--	--	447	351	725	578
Israel	--	--	--	--	973	505	10	12
Italy	--	--	--	--	137	124	306	202
Korea, Republic of	--	--	--	--	249	182	98	58
Mexico	6	1	620	145	804	545	1,587	1,026
Netherlands	--	--	--	--	557	472	605	417
New Zealand	172	82	150	67	30	45	44	74
Peru	--	--	1,102	294	9	13	9	15
Saudi Arabia	2,872	525	824	152	--	--	--	--
Spain	--	--	--	--	107	68	175	109
Sweden	--	--	--	--	270	188	297	228
Taiwan	38	5	78	11	172	104	206	84
U.S.S.R	--	--	--	--	--	--	14	9
United Kingdom	--	--	--	--	125	193	226	369
Venezuela	3,306	893	19	2	2,444	895	853	387
Other	r321	r60	223	49	r136	r209	200	317
Total	24,805	5,529	23,746	5,488	21,567	9,773	22,801	13,295

rRevised.

Source: Bureau of the Census.

Table 5.—U.S. import duties for magnesium compounds

Item	TSUS No.	Most favored nation (MFN)		Non-MFN
		Jan. 1, 1986	Jan. 1, 1987	Jan. 1, 1986
Crude magnesite	522.61	33 cents per ton	Free	$10.50 per ton.
Caustic-calcined magnesite	522.64	$2.10 per ton	$2.10 per ton	$21.00 per ton.
Refractory magnesia (containing not over 4% lime).	531.01	0.16 cent per pound.	0.16 cent per pound.	0.75 cent per pound.
Refractory magnesia (containing over 4% lime).	531.04	6% ad valorem	6% ad valorem	30% ad valorem.

Table 6.—U.S. imports for consumption of crude and processed magnesite, by country

Country	1985		1986	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Lump or ground caustic-calcined magnesia:[1]				
Australia	296	$52	--	--
Canada	40,937	7,482	44,230	$7,990
China	5,871	415	796	84
Czechoslovakia	2,755	175	8,105	574
Greece	4,831	756	13,710	1,364
Mexico	2,111	274	1,037	154
Spain	7,441	905	7,431	836
Turkey	1,323	300	3,366	468
Other	144	48	67	23
Total	65,709	10,407	78,742	11,493

See footnotes at end of table.

Table 6.—U.S. imports for consumption of crude and processed magnesite, by country —Continued

Country	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)
Dead-burned and grain magnesia and periclase:				
Not containing lime or not over 4% lime:				
Brazil	3,161	$444	1,654	$225
Canada	217	102	1,481	566
China	44,478	5,274	42,708	5,141
Czechoslovakia	--	--	3,858	262
Greece	37,793	5,874	84,317	11,933
Ireland	24,729	6,822	24,088	6,959
Japan	15,049	3,964	9,255	3,878
Mexico	6,684	1,772	11,395	2,980
Netherlands	4,947	1,347	10,575	3,149
South Africa, Republic of	122	601	--	--
Turkey	--	--	1,689	243
United Kingdom	25,870	3,345	3,511	1,314
Other	r500	r222	83	68
Total	163,550	29,767	194,614	36,718
Containing over 4% lime:				
Austria	2,981	733	863	302
Belgium-Luxembourg	115	37	--	--
Canada	11,239	1,267	15,025	1,565
Germany, Federal Republic of	533	160	132	49
Greece	--	--	1,372	188
Mexico	736	94	1,109	80
United Kingdom	20	4	20	4
Other	33	13	--	--
Total	15,657	2,308	18,521	2,188
Total dead-burned and grain magnesia and periclase	179,207	32,075	213,135	38,906

rRevised.

[1]In addition, crude magnesite was imported as follows, in short tons and thousand dollars: 1985—Austria, 20 ($6); Canada, 49 ($12); the Federal Republic of Germany, 22 ($6); Italy, 1,234 ($300); Japan, 19 ($7); and the United Kingdom, 6 ($1). 1986—Canada, 37 ($15).

Source: Bureau of the Census.

Table 7.—U.S. imports for consumption of magnesium compounds

Year	Oxide or calcined magnesia: Quantity (short tons)	Oxide or calcined magnesia: Value (thousands)	Magnesium carbonate[1] (precipitated): Quantity (short tons)	Magnesium carbonate[1] (precipitated): Value (thousands)	Magnesium chloride (anhydrous): Quantity (short tons)	Magnesium chloride (anhydrous): Value (thousands)	Magnesium chloride (other): Quantity (short tons)	Magnesium chloride (other): Value (thousands)	Magnesium sulfate (epsom salts and kieserite): Quantity (short tons)	Magnesium sulfate (epsom salts and kieserite): Value (thousands)	Magnesium salts and compounds, n.s.p.f.[2]: Quantity (short tons)	Magnesium salts and compounds, n.s.p.f.[2]: Value (thousands)
1984	6,121	$4,918	284	$395	63	$17	2,987	$347	34,255	$2,621	2,443	$1,738
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

[1]In addition, magnesium carbonate, not precipitated, was imported as follows, in short tons and thousand dollars: 1984—33 ($63); 1985—110 ($125); and 1986—23 ($48).

[2]Includes magnesium silicofluoride or fluosilicate and calcined magnesia.

Source: Bureau of the Census.

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Australia.—A prefeasibility study of Queensland Metal Corp. NL's magnesite deposit in central Queensland reportedly was completed. Initial tests indicated that a concentrate with a magnesia content of greater than 95% could be produced solely by beneficiation. Seven options were studied for construction of a 110,000-ton-per-year, dead-burned-magnesia plant. Capital costs were estimated to range from $14 to $22 million, and production costs for the dead-burned magnesia were estimated to range from $93 to $128 per ton. Magnesium metal production utilizing ore from this deposit would involve a capital cost estimated at $60 to $140 million, with operating costs ranging from $1,600 to $2,000 per ton for a 22,000-ton-per-year plant.[3]

Savage Resources Ltd. announced the discovery of magnesite near Savage River Township in northwest Tasmania. The company estimated total resources to be 220 million tons of magnesite-bearing rock, of which 16.5 to 22 million tons contains 65% magnesite. Savage reportedly intended to manufacture high-grade magnesia for use in the refractory industry.[4]

Devex Ltd. reportedly purchased the Fifield, New South Wales, magnesite mine from Heat Containment Industries Ltd. (HCI). The mine was expected to be operated by Devex subsidiaries Causmag Ore Co. Pty. Ltd. and Young Mining Co. Pty. Ltd. This mine reportedly will continue to supply HCI's basic refractories plant in Unanderra.

Italy.—In a review of Italy's industrial minerals producers, two seawater magnesia plants were discussed. Sardamag S.p.A. produced three grades of dead-burned magnesia from its 77,000-ton-per-year plant in Sardinia. Sardamag reportedly intended to invest in plant improvements to save energy, develop new products, and possibly increase capacity. Cia. Generale del Magnesio Cives S.p.A. (COGEMA) operated a calcining plant in Sicily, with an annual capacity of 72,000 tons per year. COGEMA, which was owned principally by Sardamag, produced high-purity, caustic-calcined, and dead-burned magnesias.[5]

Turkey.—A review of magnesite producers in Turkey was published. Most of the magnesite produced was controlled by the public sector mining companies of Etibank, through partial ownership of Kümaş-Kutahya Magnesite Works Corp. and Sumerbank, which had a partial ownership of Konya Krom Magnezit Tugla Sanayii Müessesesi. But through a reorganization, control of the magnesite operations of both of these companies was transferred to Çitosan, another publicly owned company. Kümaş reported annual capacity at its Kutahya calcining operation was 159,000 tons of dead-burned magnesia. Konya produced crude magnesite from its two mines and plants in the Konya District. Total annual capacity was estimated to be 99,000 tons of concentrate, which was used for refractory production.

The private sector produced caustic-calcined and dead-burned magnesites primarily for export to Europe and the United States. Comag Continental Madencilik Sanayive Ticaret AS produced caustic-calcined magnesite from two plants with a total annual capacity of about 40,000 tons; Manyezit AS, a subsidiary of Veitscher Magnesitwerke AG of Austria, produced dead-burned magnesia from one plant with an annual capacity of 66,000 tons; and Dedeman Madencilik produced crude magnesite from a mine with an annual capacity of 20,000 tons, primarily for export to Greece and Yugoslavia.[6]

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

(Short tons)

Country	1982	1983	1984	1985[p]	1986[e]
Australia	32,707	[r]22,640	73,900	[r e]77,000	77,000
Austria	1,136,927	1,108,668	1,304,484	1,383,446	1,400,000
Brazil[2]	248,607	254,634	259,043	[e]259,000	280,000
Canada[e 3]	75,000	74,000	76,000	[r]150,000	160,000
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	1,800	1,800
Czechoslovakia	740,752	729,729	728,000	[e]739,000	740,000
Greece	1,066,051	981,618	1,173,111	932,431	1,000,000
India	448,718	478,482	456,388	460,117	460,000
Iran[e 4]	5,500	5,500	5,500	5,500	5,500

See footnotes at end of table.

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

(Short tons)

Country	1982	1983	1984	1985[p]	1986[e]
Kenya	--	NA	343,098	[e]330,000	330,000
Korea, North[e]	2,095,000	2,095,000	2,095,000	2,095,000	2,095,000
Mexico	24,793	25,559	33,537	21,273	22,000
Nepal	[e]22,000	16,552	16,097	21,882	22,000
Pakistan	1,276	2,202	4,105	2,329	4,600
Poland	18,739	17,747	[e]18,000	[e]18,000	18,000
South Africa, Republic of	35,193	24,868	36,441	31,855	68,000
Spain	588,187	658,230	762,294	763,015	770,000
Turkey	1,013,653	792,698	797,261	3,353,871	1,100,000
U.S.S.R.[e]	2,370,000	2,400,000	2,400,000	2,400,000	2,400,000
United States	W	W	W	W	W
Yugoslavia	362,060	335,064	359,353	459,663	440,000
Zimbabwe	66,866	26,534	23,856	21,368	21,000
Total	12,553,829	[r]12,251,525	13,167,268	15,726,550	13,614,900

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available. 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 5, 1987.

[2]Series reflects output of marketable concentrates. Production of crude ore was as follows, in short tons: 1982—556,667; 1983—486,374 (revised); 1984—724,280; 1985—638,325; and 1986—650,000 (estimated).

[3]Magnesitic dolomite and brucite. Figures are estimated on the basis of reported tonnage dollar value.

[4]Year beginning Mar. 21 of that stated.

TECHNOLOGY

The Bureau of Mines reported that filtration of synthetic mine water through a magnesium oxide bed can remove more than 95% of dissolved heavy metals, such as cadmium, copper, manganese, nickel, and zinc. Conventional practice of treating water contaminated with heavy metals was lime precipitation, which generally produced a voluminous sludge and did not produce sufficiently pure water. Analogous treatment of the contaminated water with magnesia produced a sludge that was up to four times more compact than that produced by liming.[7]

Standard Oil Co. announced the development of high-purity magnesia-alumina spinel refractory products that were useful as linings in aluminum remelters when alloying 5000 and 7000 series aluminum alloys. The company claimed that the new refractories were less reactive to alloying metal oxides than alumina-based refractories. These products also may be useful at high temperatures or under special atmospheric conditions.

Changes in steel production technology over the past 5 years have created the need for improved refractories as most open-hearth furnaces have been replaced by electric arc furnaces. Consequently, water-cooled sidewalls and magnesia-carbon brick in slaglines have replaced most of the magnesia-chrome refractories previously used in these applications. Improved furnace lining performance has resulted because of the increased corrosion resistance of the magnesia-carbon brick. In addition, the increased use of ladle processing and continuous casting of molten metal, which require high temperatures and basic slags, has led to the substitution of magnesia-based brick for high-alumina refractories. Higher wear resistance in magnesia refractories has resulted from improvements in several physical characteristics: bulk density, increased lime-to-silica ratio, higher purity, and increased particle size.[8]

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[1]Physical scientist, Division of Nonferrous Metals.

[2]Industrial Minerals (London). IMC Sells Industry Group. No. 231, Dec. 1986, pp. 13-14.

[3]———. Kunwarara Magnesite—450m. Tonne Reserve. No. 224, May 1986, p. 8.

[4]———. Savage Finds Tasmanian Magnesite. No. 223, Apr. 1986, p. 9.

[5]Robbins, J. Italy's Industrial Minerals. Ind. Miner. (London), No. 231, Dec. 1986, pp. 19-50.

[6]Dickson, T. Turkey's Minerals. Potential Still There. Ind. Miner. (London), No. 227, Aug. 1986, pp. 18-33.

[7]Tallman, D. N., J. E. Pahlman, and S. E. Khalafalla. Reclaiming Heavy Metals From Wastewater Using Magnesium Oxide. BuMines RI 9023, 1986, 13 pp.

[8]Martinek, C. A. Basic Refractories—A Changing Market. Ind. Miner. Refract. Suppl. (London), No. 224, May 1986, pp. 9-16.

Mörtl, G. A User View of Challenges for the Magnesite Industry. Ind. Miner. (London), No. 226, July 1986, pp. 29-39.

Manganese

By Thomas S. Jones[1]

World production of manganese ore decreased from that in 1985 by only a nominal amount, according to preliminary data. Production by Gabon advanced to another record high. U.S. production again consisted only of a small quantity of manganiferous material for brick coloring.

Supplies of ore, ferroalloys, and other main manganese materials were still more than adequate to meet demand. The price of metallurgical ore decreased on international markets. The price of ore delivered to U.S. customers declined over 6% to the lowest current dollar amount since 1974. Prices averaged over the year for imported high-carbon ferromanganese and silicomanganese were little changed in the United States from prior year averages.

Among U.S. imports, those of ore were the largest since 1981. Silicomanganese imports were up 20% to set a record-high total for the second straight year. U.S. imports of manganese dioxide decreased, however, for the first time since data became available in 1978.

U.S. reported consumption of ferromanganese fell below 400,000 tons,[2] the lowest since before World War II. This was at least partly the result of a labor dispute that shut down the Nation's largest steelmaker for the last 5 months of the year. The Government's program of upgrading ore in the National Defense Stockpile (NDS) into high-carbon ferromanganese was extended by Congress through fiscal year 1993. Legislation was passed that would add 472,000 tons of domestically produced high-carbon ferromanganese to the stockpile during the 1987-93 fiscal years. Only one ferromanganese producer remained to fulfill this objective.

In Brazil, developments in the Carajás region included increased ore production and further planning for ferroalloy production from ore produced there. Statistics on world production of manganese ferroalloys are presented in the "Ferroalloys" chapter.

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.

Table 1.—Salient manganese statistics

(Thousand short tons)

	1982	1983	1984	1985	1986
United States:					
Manganese ore (35% or more Mn):					
Imports for consumption	238	368	338	387	463
Consumption	609	531	615	e545	e500
Manganiferous ore (5% to 35% Mn):					
Production (shipments)	32	34	88	20	14
Ferromanganese:					
Production	119	86	W	W	W
Exports	10	8	7	7	4
Imports for consumption	493	342	409	367	396
Consumption	439	446	492	466	376
World: Production of manganese ore	26,701	r24,147	26,106	p26,912	e26,716

eEstimated. pPreliminary. rRevised. W Withheld to avoid disclosing company proprietary data.

Legislation and Government Programs.—Conversion of stockpiled metallurgical manganese ore into high-carbon ferromanganese by Elkem Metals Co. continued under the stockpile-upgrading program being administered by the General Services Administration (GSA). During the summer, the National Security Council approved continuance of the ore-to-ferroalloy upgrading program for the three additional fiscal years of 1987-89. This action was superseded by congressional passage of the National Defense Authorization Act for fiscal year 1987 and its signing into law as Public Law 99-661 on November 14. This act stipulated that the Government should contract with domestic producers for converting stockpiled manganese and chromium ores into high-carbon ferromanganese and high-carbon ferrochromium, respectively, throughout the next 7 fiscal years, 1987-93. For manganese, the act called for adding to the stockpile a minimum of 67,500 tons of high-carbon ferromanganese in each of fiscal years 1987 through 1993, for a total addition over that period of 472,000 tons.

GSA did not contract further in 1986 for manganese upgrading. In February and December, GSA accepted into inventory 46,582 and 34,060 tons, respectively, of high-carbon ferromanganese produced under the upgrading program, to bring the stockpile yearend inventory of high-carbon ferromanganese to 704,952 tons. This and other changes in stockpile inventories of manganese materials in 1986 are shown below. The only excess stockpile manganese material sold in 1986 was nonstockpile-grade metallurgical ore, from an inventory not subject to the October 1, 1985, restriction relating sales to the balance in the NDS Transaction Fund.

Material	Sales (short tons)		Change in yearend inventory (short tons)
	Stockpile grade	Nonstockpile grade	
Natural battery ore	--	--	-1,601
Chemical ore	--	--	-1,084
Metallurgical ore	--	11,200	-147,425
High-carbon ferromanganese	--	--	+80,642

Table 2.—U.S. Government stockpile goals and yearend inventories for manganese materials in 1986

(Short tons)

Material	Stockpile goals	Physical inventory, Dec. 31				
		Uncommitted			Sold, pending shipment	Grand total
		Stockpile grade	Nonstockpile grade	Total		
Natural battery ore	62,000	171,960	33,561	205,521	4,681	210,202
Synthetic manganese dioxide	25,000	3,011	--	3,011	--	3,011
Chemical ore	170,000	171,717	89	171,806	649	172,455
Metallurgical ore	2,700,000	2,221,811	931,479	3,153,290	89,432	3,242,722
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

The Logistics Management Institute of Bethesda, MD, issued a report in June prepared for the U.S. Department of Defense on the effect of a complete loss of domestic ferroalloy capacity. Such a study had been required when Congress legislated defense authorizations for fiscal year 1986. According to this study, foreign sources could readily compensate for a peacetime lack of U.S. capacity for manganese and other ferroalloys. The study found that ferromanganese supplies would also be sufficient even under mobilization conditions, although domestic processing of ore in blast furnaces and drawdown of the stockpile might be necessary.

U.S. imports of spiegeleisen from the Republic of South Africa were prohibited late in the year. This development had only technical significance, as there have been no such imports in recent years. The prohibition stemmed from a determination by the U.S. Department of the Treasury in November as to the meaning of iron and steel for purposes of the Comprehensive Anti-Apartheid Act of 1986, which became Public Law 99-440 on October 2.

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 material consisted of manganiferous schist, clay, or other earthy material associated with the manganiferous member of the Battleground Schist of the Kings Mountain area. This material has a natural manganese content ranging from 5% to 15%, averaging less than 10%, and is classified as manganiferous iron ore. Shipments of this material in 1986 amounted to 14,320 tons with a manganese content of 1,384 tons, as compared with shipments in 1985 of 19,882 tons with a manganese content of 1,882 tons.

Ferroalloys and Metal.—Publication of statistics continued to be precluded to avoid disclosing proprietary data of the few producers. Production of manganese ferroalloys was limited to the Marietta, OH, plant of Elkem Metals and the Calvert City, KY, plant of SKW Alloys Inc. At the latter plant, a strike that began in September 1983 finally ended on January 13, 1986.

In the latter part of the year, Chemetals Inc. ended all operations at its Kingwood, WV, plant, which had produced low- and medium-carbon ferromanganese by a fused-salt electrolytic process. Chemetals entered into a 5-year agreement to market throughout North America a similar manganese product manufactured in France by Pechiney Électrométallurgie. Chemetals' Kingwood plant, established in 1962, was disabled by a flood in November 1985. Chemetals continued to manufacture nitrogen-bearing manganese, weld-grade powders, and manganese-aluminum briquets at its other plant in Baltimore, MD.

Table 3.—Domestic producers of manganese products in 1986

Company	Plant location	Products[1] FeMn	SiMn	Mn	MnO_2	Type of process
Chemetals Inc	Baltimore, MD	--	--	--	X	Chemical.
Elkem Metals Co	Marietta, OH	X	X	X	--	Electric furnace and electrolytic.
Foote Mineral Co	New Johnsonville, TN.	--	--	--	X	Electrolytic.
Kerr-McGee Chemical Corp	Hamilton, MS	--	--	X	--	Do.
Do	Henderson, NV	--	--	--	X	Do.
Ralston Purina Co.: Eveready Battery Co.	Marietta, OH	--	--	--	X	Do.
RAYOVAC Corp.: ESB Materials Co.	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 decreased to 0.8 pound per ton of raw steel. This rate was calculated from an estimated consumption of 74,000 tons of manganese ore containing more than 35% manganese, all of foreign origin, in iron blast furnaces and production of 81.6 million tons of raw steel ingots, continuous- or pressure-cast blooms, billets, slabs, etc. The quantity of domestic manganiferous iron ore containing 5% to 10% manganese also consumed in iron blast furnaces was not publishable for proprietary reasons. The quantity of manganese ore containing 35% or more manganese used directly in steelmaking was reportedly negligible.

The trend in recent years toward decreased unit consumption in steelmaking of manganese as ferroalloys and metal was accentuated in 1986 by a labor dispute that shut down the steelmaking operations of USX Corp. after July 31. For reported consumption in the production of 82.5 million tons of raw steel and steel castings in 1986, the pounds of manganese consumed per ton of raw steel was 6.9 as ferromanganese, 1.6 as silicomanganese, and 0.1 as metal, for a total of 8.6. In 1985, the corresponding unit consumption in production of 89.1 million tons of raw steel and steel castings totaled 9.3, of which ferromanganese accounted for 7.7; silicomanganese, 1.5; and metal, 0.1. The chief difference between 1986 and 1985 was a decrease in the usage rate of high-carbon ferromanganese. The manner in which combined blowing could lower the manganese requirement per heat of steel by 25% was discussed in a review of the effects of steelmaking developments on ferroalloy usage.[3]

Battery and Miscellaneous Industries.—Corporate initiatives significantly affected control of dry cell battery manufacture. As of June 30, the worldwide battery products business of Union Carbide Corp., exclusive of operations in India and Japan, was acquired by Ralston Purina Co. for $1.4 billion. The U.S. portion of this business was organized as Eveready Battery Co. Inc., a wholly owned subsidiary of Ralston Purina. Union Carbide's activities in the United States had included manufacture of carbon-zinc dry cells, alkaline batteries, and electrolytic manganese dioxide. Effective November 21, Kraft Inc., after 6 years as part of Dart & Kraft Inc., was reestablished as a separate company that included Duracell Inc., a manufacturer of alkaline batteries. Eastman Kodak Co. entered the consumer battery business by marketing alkaline batteries imported from Japan. This step was followed late in 1986 by domestic manufacture of a lithium-manganese dioxide battery by a newly formed battery subsidiary, Ultra Technologies Inc.

Tennessee Eastman Co. sold its soluble manganese sulfate business in June to Mexalloy International Inc. of Theodore, AL. For a number of years, Tennessee Eastman had been obtaining manganese sulfate as a coproduct with hydroquinone at its Kingsport, TN, plant. However, the company decided to switch its hydroquinone production to another process not based on use of manganese ore. Agromex Inc., an affiliate of Mexalloy, was to market manganese sulfate in Canada and the United States, initially using stocks remaining from Tennessee Eastman and then obtaining sulfate from a new Mexican source described under "Mexico" in the "World Review" section of this chapter.

The domestic portion of Cabot Corp.'s aluminum master alloys business was sold in the latter part of the year to Harbour Group Investments Inc., a multi-interest private company headquartered in St. Louis, MO. The two plants involved in the transaction were in Henderson County, KY, and at Wenatchee, WA; both had been producing aluminum-manganese master alloys.

Table 4.—U.S. consumption and industry stocks of manganese ore,[1] by use

(Short tons)

Use	Consumption 1985	Consumption 1986	Stocks, Dec. 31 1985	Stocks, Dec. 31 1986
Manganese alloys and metal	W	W	262,664	197,639
Pig iron and steel[e]	90,000	74,000	78,940	64,300
Dry cells, chemicals, miscellaneous[2]	W	W	247,008	193,544
Total[e]	545,000	500,000	588,612	455,483

[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 1986

(Short tons, gross weight)

End use	Ferromanganese: High carbon	Ferromanganese: Medium and low carbon	Ferromanganese: Total	Silicomanganese	Manganese metal
Steel:					
Carbon	216,863	69,256	286,119	69,614	2,498
Stainless and heat-resisting	13,259	(1)	13,259	3,136	1,371
Full alloy	23,169	8,315	31,484	18,989	876
High-strength, low-alloy	24,065	5,534	29,599	5,217	397
Electric	(1)	(1)	(1)	(1)	(1)
Tool	314	(1)	314	(1)	79
Unspecified	226	542	768	402	88
Total steel[2]	277,896	83,647	361,543	97,358	5,309
Cast irons	8,628	779	9,407	2,563	W
Superalloys	W	W	W	W	152
Alloys (excluding alloy steels and superalloys)	1,355	95	1,450	W	[3]18,158
Miscellaneous and unspecified	3,447	4	3,451	2,849	521
Total consumption	291,326	84,525	375,851	[4]102,770	24,140
Total manganese content[5]	227,000	68,000	295,000	68,000	24,100
Stocks, Dec. 31	76,664	16,139	92,803	13,028	3,201

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]Partly based on data of the Aluminum Association Inc.; not directly comparable with data prior to 1984.
[4]Internal evaluation indicates that silicomanganese consumption is considerably understated.
[5]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.

Downward pressure on the price of metallurgical ore was evident in 1986. Compared to recent years, early settlement was achieved between Japanese ferroalloy producers and their ore suppliers in Australia and the Republic of South Africa, resulting in contracts for a reduced volume of ore at a price 5.5% below that in 1985. Metal Bulletin of London reported no change in the price of ore delivered to West European ports. The price of ore delivered to U.S. customers decreased over 6% to the lowest level since 1974. The average price, c.i.f. U.S. ports, for metallurgical ore containing 48% manganese was $1.34 per long ton unit, compared with $1.43 in 1985; per metric ton unit, these prices were $1.31 and $1.41, respectively. These prices convert to 6.0 and 6.4 cents per pound of manganese in ore, respectively.

Manganese Ferroalloys.—Current list prices of domestic producers for the most widely used manganese ferroalloys were not available in trade publications. The price of imported high-carbon ferromanganese containing 78% manganese averaged about 3% less than in 1985. The price ranged from $320 to $330 per long ton of alloy, f.o.b. Pittsburgh or Chicago warehouse, during the first half of 1986, the same as for yearend 1985. Two subsequent declines, the last in mid-September, brought the final price for 1986 to $305 to $320. The price of imported silicomanganese containing 2% carbon averaged only a nominal amount higher than in 1985. For this material, the price per pound of alloy, f.o.b. Pittsburgh or Chicago warehouse, continued into 1986 at the same level as at yearend 1985, 15.5 to 16.5 cents, rose to a peak of 18.25 to 19 cents in mid-May, and then tapered off in several steps to a final price of 17 to 18.25 cents. This price trend in imported silicomanganese generally followed that in imported ferrosilicon.

Manganese Metal.—The only information provided by trade publications as to current prices of domestic suppliers was that one such supplier raised its price from 76 to 80 cents per pound for bulk shipments, f.o.b. shipping point. Otherwise, trade publications continued to quote the November 1984 price of 80 cents.

FOREIGN TRADE

Reported ore exports and reexports were presumed to have been mostly metallurgical ore and to have been obtained from excess Government stocks except for 3,817 tons of reexports, all shipped to Canada. About 2,600 tons of ore exported to Canada plus about one-fifth of that shipped to destinations other than Canada and Mexico apparently was imported manganese dioxide ore, possibly ground, blended, or otherwise classified in the United States. Compared with those in 1985, the relatively insignificant exports of ferromanganese and silicomanganese were each somewhat more than one-third less, while exports of manganese metal were nearly unchanged.

The quantity of ore imported was the largest since 1981, with over one-half the total coming from Gabon. Both the average grade of imported ore, 48.7%, and the ratio of manganese imported as ore and dioxide to that imported as ferroalloys and metal, about 50%, remained nearly the same as in 1985. No imports of manganiferous ore were reported.

Imports of ferromanganese, silicomanganese, and manganese metal all were greater than in 1985. Silicomanganese imports rose again by one-fifth to another record high; nearly one-half were from the Republic of South Africa. Imports of low-carbon ferromanganese easily surpassed the total of any previous year at least as far back as 1970. The average manganese content of all ferromanganese imports increased slightly to 78.6%.

Reported imports for consumption of spiegeleisen were 177 tons, consisting of 114 tons of material of relatively high unit value, of which 95 tons was from the Federal Republic of Germany and 19 tons was from Belgium-Luxembourg, and 63 tons was from Canada.

Imports of manganese dioxide decreased for the first time since specific data on dioxide imports became available beginning in 1978. The decrease was about 25% overall. Imports from Japan fell almost 50%, whereas those from the Republic of South Africa grew over 70% to make that country the second largest source. All but 54 tons were apparently synthetic dioxide for battery or chemical applications.

Tariffs.—Effective July 1, imports of medium-carbon ferromanganese from Mexico no longer received duty-free treatment. This change in the U.S. Generalized System of Preferences (GSP) was made because such imports exceeded 50% of the value of total U.S. imports of medium-carbon ferromanganese in 1985. This was one of the changes in the GSP program implemented by a Presidential proclamation signed April 1.

A new user fee of 0.22% ad valorem applicable to most imports became effective December 1. This fee was provided for by the Omnibus Budget Reconciliation Act of 1986 (Public Law 99-509). The fee was to be paid into the Customs User Fee Account by the importer of record for the processing of each formal entry of merchandise for consumption. After the end of fiscal year 1987 on September 30, 1987, the fee was to decrease to 0.17% ad valorem or less as adjusted by the Secretary of the Treasury on the basis of U.S. Customs commercial operating costs. This new fee did not apply to imports that were products from least developed developing countries or beneficiary countries under the Caribbean Basin Economic Recovery Act.

Table 6.—U.S. exports of manganese ore, ferroalloys, and metal, by country

(Gross weight)

Country	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)
Ore and concentrates containing 5% or more manganese:				
Canada	23,977	$1,530	7,669	$613
Colombia	--	--	3,616	295
Mexico	30,020	2,379	29,307	2,085
Other	2,043	377	1,374	285
Total	56,040	4,286	41,966	3,278
Ferromanganese:				
Canada	6,165	4,158	2,433	1,676
Germany, Federal Republic of	22	17	1,274	554
Mexico	288	241	141	116
Other	r452	r346	475	304
Total	6,927	4,762	4,323	2,650
Silicomanganese:				
Canada	2,149	904	277	190
Germany, Federal Republic of	--	--	1,169	199
Trinidad and Tobago	881	373	496	214
Other	r59	[2]81	62	84
Total[1]	3,089	1,359	2,004	687
Metal including alloys and waste and scrap:				
Belgium-Luxembourg	932	1,304	702	1,061
Canada	429	766	580	1,055
Germany, Federal Republic of	400	563	295	439
Japan	1,873	2,322	1,705	2,330
Netherlands	888	1,215	371	519
Sweden	8	18	109	173
Other	632	1,054	1,385	2,317
Total[1]	5,162	7,242	5,146	7,892

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

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	1985 Gross weight (short tons)	1985 Manganese content (short tons)	1985 Value (thousands)	1986 Gross weight (short tons)	1986 Manganese content (short tons)	1986 Value (thousands)
ORE AND CONCENTRATES						
35% or more manganese:						
Australia	82,948	43,104	$4,490	68,131	35,539	$3,305
Belgium-Luxembourg[1]	--	--	--	252	[2]151	27
Brazil	122,726	59,816	5,423	82,702	38,728	3,221
Gabon	129,360	64,093	8,240	239,132	119,068	11,435
Germany, Federal Republic of[1]	--	--	--	5	[2]2	1
Mexico	51,708	[2]21,761	4,379	34,717	[2]14,771	3,603
Morocco	118	65	29	316	[2]186	36
Panama	--	--	--	6,612	3,174	275
South Africa, Republic of	--	--	--	31,376	13,988	1,219
Total[3]	386,859	188,840	22,561	463,242	225,608	23,122
Of which, more than 35% but less than 47% manganese:						
Brazil	--	--	--	17,492	7,532	541
Mexico	43,698	16,842	2,422	33,443	[2]14,156	3,391
South Africa, Republic of	--	--	--	12,044	4,577	430
Total	43,698	16,842	2,422	62,979	26,265	4,362

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	1985 Gross weight (short tons)	1985 Manganese content (short tons)	1985 Value (thousands)	1986 Gross weight (short tons)	1986 Manganese content (short tons)	1986 Value (thousands)
FERROMANGANESE						
All grades:						
Australia	11,133	8,729	$2,908	13,423	10,401	$2,816
Belgium-Luxembourg	--	--	--	4,952	4,465	4,864
Brazil	11,538	8,854	2,814	20,392	15,418	4,945
Canada	36,562	28,275	9,270	52,049	39,907	12,733
France	117,708	91,905	33,196	86,728	68,573	27,546
Germany, Federal Republic of	10,158	8,157	3,842	25,775	21,043	11,181
Japan	212	192	213	2,803	2,277	1,334
Mexico	38,071	30,401	12,548	28,152	22,540	10,836
Norway	2,894	2,512	2,616	6,663	5,603	4,439
Portugal	5,842	4,483	1,258	--	--	--
South Africa, Republic of	127,591	99,121	34,013	145,549	113,043	35,944
Spain	2,243	1,892	974	9,164	7,775	3,845
Yugoslavia	2,921	2,225	738	--	--	--
Total[3]	366,874	286,744	104,389	395,650	311,045	120,482
Of which, 1% or less carbon:						
Belgium-Luxembourg	--	--	--	4,952	4,465	4,864
Canada	40	27	5	--	--	--
France	2,389	2,113	2,239	8,950	8,034	8,180
Germany, Federal Republic of	--	--	--	8	6	8
Japan	212	192	213	37	34	34
Norway	2,895	2,512	2,616	4,128	3,588	3,633
South Africa, Republic of	--	--	--	54	51	64
Spain	40	34	26	--	--	--
Total[3]	5,575	4,877	5,098	18,129	16,178	16,782
More than 1% to 4% or less carbon:						
Canada	171	124	32	410	315	76
France	--	--	--	2,800	2,226	1,363
Germany, Federal Republic of	5,204	4,269	2,310	25,767	21,037	11,173
Japan	--	--	--	2,766	2,243	1,300
Mexico	20,592	16,652	8,667	20,477	16,572	8,689
Norway	--	--	--	882	709	404
South Africa, Republic of	2,214	1,787	966	3,960	3,191	1,633
Spain	2,203	1,858	948	9,164	7,775	3,845
Total[3]	30,383	24,689	12,923	66,225	54,068	28,483
SILICOMANGANESE						
Australia	14,762	9,774	4,420	17,363	11,525	5,310
Brazil	20,315	13,471	6,204	19,563	12,850	5,675
Canada	2,249	1,388	315	1,822	1,067	320
Chile	--	--	--	176	117	47
Italy	551	340	352	766	473	469
Mexico	9,656	6,358	2,855	19,339	12,930	5,649
Norway	13,635	8,948	5,075	16,602	10,917	5,596
Portugal	2,425	1,642	770	9,125	5,925	2,755
South Africa, Republic of	71,736	48,133	21,365	88,642	59,114	24,931
Spain	1,475	958	916	2,694	1,730	1,595
Sweden	1	1	1	--	--	--
Thailand[1]	1,320	858	600	--	--	--
United Kingdom	41	23	5	--	--	--
Yugoslavia	27,356	17,827	8,545	22,553	14,777	6,491
Total[3]	165,523	109,719	51,423	198,645	131,425	58,839
METAL						
Unwrought:						
South Africa, Republic of	8,402	XX	8,890	9,641	XX	9,760
Other	164	XX	162	27	XX	40
Total	8,566	XX	9,052	9,668	XX	9,800
Waste and scrap:						
Canada	--	XX	--	6	XX	3
Japan	4	XX	2	--	XX	--

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	1985 Gross weight (short tons)	1985 Manganese content (short tons)	1985 Value (thousands)	1986 Gross weight (short tons)	1986 Manganese content (short tons)	1986 Value (thousands)
MANGANESE DIOXIDE						
Belgium-Luxembourg	439	XX	$401	1,375	XX	$1,329
Brazil	505	XX	612	734	XX	845
Greece	2,386	XX	2,625	575	XX	645
Ireland	933	XX	1,190	2,778	XX	3,133
Japan	19,429	XX	23,805	10,335	XX	12,440
South Africa, Republic of	1,888	XX	1,490	3,230	XX	3,243
Other	90	XX	31	347	XX	390
Total[3]	25,671	XX	30,154	19,374	XX	22,025
MANGANESE SULFATE						
Australia	--	XX	--	529	XX	123
Belgium-Luxembourg	114	XX	29	--	XX	--
Germany, Federal Republic of	19	XX	48	68	XX	113
Japan	29	XX	95	46	XX	105
Other	4	XX	2	16	XX	34
Total	166	XX	174	659	XX	375
POTASSIUM PERMANGANATE						
China	207	XX	209	318	XX	312
German Democratic Republic	191	XX	218	259	XX	290
Spain	1,091	XX	1,700	1,283	XX	2,153
Other	10	XX	73	10	XX	124
Total	1,499	XX	2,200	1,870	XX	2,879

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.	Most favored nation (MFN) Jan. 1, 1986	Most favored nation (MFN) Jan. 1, 1987	Non-MFN Jan. 1, 1986
Manganese dioxide	419.4420	5% ad valorem[2 3]	4.7% ad valorem	25% ad valorem.
Ore and concentrate	601.27	Free	Free	1 cent per pound Mn.
Ferromanganese:				
Low-carbon	606.26	2.4% ad valorem[2 3]	2.3% ad valorem	22% ad valorem.
Medium-carbon	606.28	1.4% ad valorem[2 4]	1.4% ad valorem	6.5% ad valorem.
High-carbon	606.30	1.5% ad valorem[5 6]	1.5% ad valorem	10.5% ad valorem.
Silicomanganese	606.44	4.2% ad valorem[2 3 7]	3.9% ad valorem	23% ad valorem.
Metal	632.30	14% ad valorem[6]	14% ad valorem[8]	20% ad valorem.

[1]All subject to 0.22% ad valorem user fee as of Dec. 1, 1986, except for products from least developed developing countries (LDDC) and beneficiary countries under the Caribbean Basin Economic Recovery Act (CBERA).
[2]Free from certain countries under Generalized System of Preferences, including Israel.
[3]Dutiable at Jan. 1, 1987, rate if from LDDC.
[4]Not duty-free for Mexico as of July 1, 1986.
[5]Free for products of Israel.
[6]Free from beneficiary countries under the CBERA.
[7]Not duty-free for Brazil.
[8]5.6% ad valorem for products of Israel.

WORLD REVIEW

Australia.—Manganese ore production and exports both decreased about one-sixth for Groote Eylandt Mining Co. Pty. Ltd. (GEMCO), Australia's only producer, according to preliminary data of the Australian Bureau of Mineral Resources. Total shipments decreased 6% to about 1,790,000 tons, consisting of about 1,260,000 tons for exports and about 525,000 tons for domestic shipments.[4] GEMCO was upgrading its ore concentration plant to a capacity of 2,650,000 tons per year. GEMCO offered high-manganese ore sinters to Japanese steelmakers engaged in pretreatment of hot metal. Two grades of sinter were being produced in Tasmania for this purpose at the ferroalloy plant of Tasmanian Electro Metallurgical Co. Pty. Ltd., which, like GEMCO, is a subsidiary of The Broken Hill Pty. Co. Ltd. (BHP). Minimum manganese contents were 59% for a higher grade sinter and 53% for a lower grade sinter.[5]

Belgium.—Société Européenne des Dérives du Manganèse SA (Sedema) announced the second increase of production capacity for manganese sulfate solution and manganese sulfate monohydrate ($MnSO_4 \cdot H_2O$) powder at its Tertre plant in little more than 1 year. The second increase resulted from a major sulfur dioxide abatement program at an affiliated molybdenum ore roasting plant at Ghent, which will yield manganese sulfate as a byproduct. The expansion was to be completed by early 1987 and would raise Sedema's capacity for sulfate solution and monohydrate powder to 107,000 and 26,500 tons per year, respectively, both expressed as $MnSO_4 \cdot H_2O$ equivalent. This represented a 10,000-ton-per-year increase in capacity for monohydrate powder, additional production of which was to be marketed throughout North America by Chemetals, Sedema's U.S. subsidiary.

Brazil.—Overall shipments of manganese ore from the Serra do Navio, Amapá Territory, operations of Indústria e Comércio de Minérios S.A. (ICOMI) decreased over one-fifth to 789,000 tons, all via Porto de Santana on the Amazon River. Compared with shipments in recent years, the biggest change was in shipments to Europe. Total exports declined one-third to 547,000 tons; the destinations were Europe, 308,000 tons, a drop of over 40%; North America, 155,000 tons; South America, 56,000 tons; and Asia, 28,000 tons. Shipments in coastal vessels to Brazilian consumers rose to 243,000 tons.[6] ICOMI's mining concession that includes the Serra do Navio Mine runs to the year 2003. Speculation about output levels until the concession expires included one report that prevailing production levels could be sustained for 8 to 9 years rather than the 6 to 7 years of an earlier estimate.[7]

Open pit mining of manganese ore from the Igarapé Azul deposit in the Carajás region by the state-controlled Cia. Vale do Rio Doce (CVRD) progressed toward the current goal of about 700,000 tons per year of output. For the first full year, crude ore was processed in a beneficiation plant that became operational as of December 1985 with a capacity of 1,100,000 tons per year. Shipments of metallurgical ore rose to almost 275,000 tons. Exports totaling 111,300 tons were shipped to Portugal, 51,000 tons; the United Kingdom, 38,600 tons; Japan, 18,300 tons; and Spain, 3,400 tons. Shipments in coastal vessels to Brazilian consumers were 163,300 tons. Exports via the large Ponta da Madeira iron ore terminal slightly exceeded those through the commercial dock at Itaqui.[8] Both shipping points are near São Luís at the terminus of the railroad to the Carajás mineral province.

A controversy developed over proposals to install plants in the Carajás region for converting ore from the Azul deposit into manganese ferroalloys. CVRD started making formal arrangements with the Soviet Union beginning late in 1985 for a manganese ferroalloy plant that would be partly financed by the Soviets in exchange for output from the plant. The proposed plant was to have a capacity of 150,000 tons per year, roughly twice the combined capacities of similar plants already proposed by Cia. Paulista de Ferro-Ligas and Prometal Produtos Metalúrgicos S.A. The CVRD-Soviet plans generated considerable opposition from the private sector ferroalloy industry and caused Paulista to put off its project indefinitely. The year ended with negotiations continuing toward resolving these conflicting interests.

Production of manganese ferroalloys set a record at about 375,000 tons, according to preliminary data. Increased production of high-carbon ferromanganese more than offset decreased production of silicomanganese.

Paulista, a leading producer of manganese ferroalloys and especially of silicomanganese, was expanding into production of electrolytic manganese metal. A plant for metal was to be set up in Minas Gerais State near its ore source, the Conselheiro

Lafaiete manganese mine operated by Paulista. Capacity of the plant was projected at about 2,000 tons per year, with production, aimed at Brazilian customers, to begin in late 1987.

Prometal, also a producer of manganese ferroalloys, invested in its future manganese ore supply by purchasing the Mineração Buritirama subsidiary of Utah International Inc., a subsidiary of Australia's BHP. Prometal thus acquired the second largest manganese deposit in the Carajás region, with an ore reserve reportedly near 20 million tons. Through a subsidiary, Mineração Morro do Guerreiro Ltda., Prometal made preparations to mine a low-grade manganese deposit at Jacutinga in Minas Gerais State.

China.—The ferrosilicon and silicomanganese capacities of the Zunyi ferroalloy plant in the southeastern Province of Guizhou were to be enlarged with submerged arc furnaces ordered from the Federal Republic of Germany. The expansion was planned for completion by 1989 and would double existing plant capacity to about 175,000 tons per year.

France.—Blast furnace production of high-carbon ferromanganese plus a small amount of spiegeleisen decreased to 330,000 tons, according to preliminary data. The drop reflected curtailed operations at the Boulogne plant of Société du Ferromanganèse de Paris-Outreau and the idling, at least temporarily, of Sté. Nouvelle des Aciéries de Pompey's furnace at Pompey in the first part of the year.

Gabon.—Production of manganese ore at the Moanda Mine of Compagnie Minière de l'Ogooué S.A. (Comilog) rose 7% to reach a record high for the second consecutive year. Comilog's exports also increased, to about 2,740,000 tons, or only slightly less than production. A milestone on the path toward even greater manganese output was reached on December 30 when the second and last portion of the Trans-Gabon Railroad was inaugurated. Actual service was estimated to begin in the latter part of 1987. This would provide a wholly Gabonese export route, once the final task of constructing a mineral port at Owendo has been completed. Coupling of this intranational route with the existing international route that terminates at Pointe-Noire, Congo, would permit Comilog's manganese shipments to be increased significantly.

Ghana.—Shipments from the Nsuta Mine of Ghana National Manganese Corp. decreased slightly to 284,000 tons. Shipments through the Port of Takoradi reportedly went to seven European countries, Japan, and the Ivory Coast.[9] Upgrading of both the mine and its rail link with the port continued.

Japan.—Ore was produced during only the first 5 months of 1986, and the quantity was small.

Production of manganese ferroalloys fell by almost 25%, with the decline in silicomanganese production being sharper than that for ferromanganese. Quantities produced were 396,000 tons of ferromanganese and 164,000 tons of silicomanganese. Production was cut back indefinitely at a number of the leading manganese ferroalloy producers, and efforts were made by at least one producer to reduce labor costs. Mizushima Ferroalloy Co. Ltd. reported that a shaft furnace for high-carbon ferromanganese had operated satisfactorily since its startup on June 24, 1985. Exports of both ferromanganese and silicomanganese were again comparatively small, 7,600 tons for ferromanganese and only 18 tons for silicomanganese. Imports of ferromanganese also remained small at 7,900 tons, but those of silicomanganese rose almost 50% to nearly 195,000 tons, setting a record for the second consecutive year.

The continuing success of Japan's integrated steelmakers with hot-metal pretreatment practices contributed to the problems of domestic manganese ferroalloy producers. With these practices, manganese units required in steels produced were being obtained directly from ore rather than from ferroalloy, with a resultant cost savings to the steelmaker. For Nippon Steel Corp., it was estimated that ferromanganese requirements could be reduced within a few years to one-third the level of recent years.[10] Use of various Australian and South African manganese ore products was being optimized, including new sinters from Australia and traditional items such as ferruginous manganese ore.

Production of synthetic manganese dioxide reached another record high at 63,000 tons, but a similar trend in dioxide exports was broken, as exports fell 20% to 38,700 tons.

Mexico.—Industrias Sulfamex S.A. de C.V. was building a plant at Tamos, Veracruz State, near the gulf coast Port of Tampico for production of manganese sulfate, to begin in the latter part of 1987. The plant was to be fed with waste sulfuric acid from the electrolytic zinc refinery in San Luis Potosí and flue dust from the manganese carbonate nodulizing kiln at the Molango mines of Cía. Minera Autlán S.A. de

C.V., with which Sulfamex is affiliated. Initial annual capacity of the Sulfamex plant was projected as 22,000 tons. Sales of Sulfamex' sulfate in North America were to be handled through the U.S. headquarters in Mobile, AL, of Agromex Inc., an affiliate of Mexalloy.

At Autlán's operations in the Molango District, Hidalgo State, production of carbonate ore and oxide nodules increased in 1986 after having decreased in 1985. Respective 1986 and 1985 production quantities were 708,000 tons and 670,000 tons for carbonate ore and 435,000 tons and 372,000 tons for oxide nodules. Production of battery ore at the Nonoalco Mine advanced slightly in 1986 to 34,400 tons after having recovered in 1985 to 33,400 tons. A 1985 development in briquetting at Autlán's manganese ferroalloy operations reduced the company's need for imported manganese and improved utilization of its own resources.

Portugal.—Eurominas Electro Metalurgia S.A.R.L. suspended production at its coastal plant in Setúbal beginning in August. Ferromanganese oversupply and power contract negotiations were cited as factors in the shutdown. This idled for the rest of the year a capacity for over 150,000 tons per year of high-carbon ferromanganese and/or silicomanganese.

South Africa, Republic of.—Ore production increased for the third consecutive year, advancing to slightly over 4 million tons. Compared with that of 1985, the changes in ore production were modest. Overall production and production of metallurgical ore increased, whereas production of chemical ore decreased. Production of the various categories of ore was as follows:

	Quantity (thousand short tons)
METALLURGICAL ORE	
30% to 40% Mn	1,411
Over 40% to 45% Mn	1,093
Over 45% to 48% Mn	372
Over 48% Mn	1,052
Total	3,928
CHEMICAL ORE	
35% MnO_2 and less	18
Over 35% to 65% MnO_2	148
Over 65% to 75% MnO_2	5
Total	171

Ore shipments by The Associated Manganese Mines of South Africa Ltd. rose 10% to about 1,370,000 tons compared with 1,240,000 tons in 1985.

Samancor Ltd. announced that it would install a plant for sintering manganese ore at its Mamatwan Mine. The sintering plant was projected to have a capacity of 550,000 tons per year and was to be completed in 1988. Ore sintering was expected to improve the overall cost effectiveness of Samancor's production of manganese ferroalloys.

Delta EMD (Pty.) Ltd. raised its production rate for electrolytic manganese dioxide to 8,800 tons from 6,600 tons per year. Delta began production of dioxide in 1982 at a plant having a design capacity of 22,000 tons per year. Delta's plant is in Nelspruit, Transvaal Province, where the largest of the two electrolytic manganese metal plants of Manganese Metal Co. (Pty.) Ltd. is also situated.

U.S.S.R.—Production of high-grade ore suitable for making ferroalloys was adversely affected by a 20% decrease in mine production to 2.4 million tons for the Chiatura Basin in Georgia. Even so, this amount of production slightly exceeded the objective, indicating reduced expectations in line with declining reserves at Chiatura. To increase overall manganese recovery, low-grade ore from dumps at Chiatura was being sent to the nearby Zestafoni ferroalloy works for processing.

Looking to the future, the 1986-90 5-year plan outlined development of the Tavricheskiy mining and concentrating complex, which is based on the Bol'shoy Tokmak deposit south of Zaporozh'ye. The Tavricheskiy complex centers around the train station of that name at Vasil'yevka and would extend present manganese operations in the Ukraine's Nikopol' Basin to the east. Plans for the complex included five underground mines that would eventually have a capacity of about 10 million tons of crude ore from which nearly 6 million tons of concentrate would be obtained.[11] This new complex reportedly produced its first manganese ore in 1986.

The quantity of ore exported in 1985, 1,241,000 tons, was marginally greater than that in 1984. Principal destinations, accounting for nearly 90% of the total, were, in tons, Poland, 578,000; Czechoslovakia, 356,000; Bulgaria, 86,000; and the German Democratic Republic, 75,000.

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				
		1982	1983	1984	1985[p]	1986[e]	1982	1983	1984	1985[p]	1986[e]
Australia[4]	37-53	1,238	1,510	2,038	2,208	[5]1,818	594	754	969	[e]1,070	882
Brazil[6 7]	38-50	[8]2,580	2,306	[8]2,969	[e]2,976	2,976	1,032	922	1,187	1,190	1,190
Bulgaria	29	50	50	50	42	44	15	14	14	12	13
China[e 9]	30	1,760	1,760	1,760	1,760	1,760	530	530	530	530	530
Gabon[6 10]	50-53	1,667	2,047	2,336	2,579	[5]2,767	769	945	1,078	1,191	1,277
Ghana[6]	30-50	176	191	296	[r e]320	309	71	76	118	128	123
Hungary[6 11]	30-33	91	65	74	[r e]69	66	27	20	22	21	20
India[6 10 12]	10-54	1,642	[r]1,412	1,246	1,367	1,433	603	530	464	509	534
Japan	25-27	86	83	68	23	[5]7	22	22	18	6	[5]2
Mexico	27-50	[e]561	[e]386	[e]525	[r e]437	506	202	147	199	166	[5]192
Morocco[6]	50-53	106	81	65	48	[5]40	56	43	35	26	21
Romania[6 11]	30	61	86	73	73	72	18	26	22	22	21
South Africa, Republic of[6 10]	30-48+	5,750	3,181	3,361	3,969	[5]4,100	2,220	1,225	1,341	1,587	1,663
Thailand[6]	46-50	9	7	10	5	4	4	4	5	2	2
Turkey[6]	27-46	8	4	47	15	17	3	1	17	5	6
U.S.S.R	29-30	10,830	10,890	11,100	10,900	10,700	3,260	3,280	3,300	3,200	3,100
Yugoslavia	25-45	30	35	[e]30	[e]28	28	11	12	[e]11	[e]10	10
Other[e 13]	XX	56	54	60	[r]92	71	22	20	23	[r]37	28
Total[14]	XX	26,701	[r]24,147	26,106	26,912	26,716	[r]9,459	[r]8,571	9,354	9,713	9,615

[e]Estimated. [p]Preliminary. [r]Revised. XX Not applicable.
[1]Table includes data available through June 9, 1987.
[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), 1982—4; 1983—8; 1984—9; 1985—8 (estimated); and 1986—9 (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]Only about two-thirds of this quantity was marketed.
[9]Includes manganiferous ore.
[10]Calculated metal content includes allowance for assumed moisture content.
[11]Concentrate.
[12]Much of India's production grades below 35% Mn; average content was reported as 37.5% Mn in 1982 and 38.3% Mn in 1983.
[13]Category represents the combined totals of Bolivia (exports), Chile, Greece, Indonesia, Italy (from wastes), the Republic of Korea, Pakistan, the Philippines, and Sudan.
[14]Data may not add to totals shown because of independent rounding.

TECHNOLOGY

The Bureau of Mines made a further contribution to the understanding of marine manganese nodules by presenting data on the elemental composition of nodules found in various seabeds of the Pacific Ocean. Such data were given for 74 elements and were related to the ocean region for the major and some minor constituents. The study was performed under an interagency agreement with the National Oceanic and Atmospheric Administration.[12]

Sensitivity of the economics of mining and processing ocean manganese nodules to changes in major cost and revenue factors was examined. The study assumed four-metal recovery of cobalt, copper, manganese, and nickel from the deep seabed of the Clarion-Clipperton Zone of the Pacific Ocean. Processing costs were found to be much more important than mining costs to overall project economics. Also investigated were the comparative advantages of different countries as processing sites and whether the economic potential is greater for crusts than for seabed deposits.[13]

The U.S. Geological Survey briefly described the characteristic features and geological environment of replacement, volcanogenic, epithermal, and sedimentary categories of manganese deposits, and provided a grade and tonnage model for each.[14]

Geology of the Imini manganese deposit in Morocco was investigated by means of field work and mineralogical studies. It was established that the manganese zones of the deposit have a secondary origin. Mineralogical features were explained by assuming a mixing of fresh and saline ground waters that passed through a coastal plain deposit as the sea level fell.[15]

Flotation behavior was summarized for oxide manganese minerals, as observed in studies performed mostly in the 1950's through the 1970's. Results were presented for flotation with fatty acids, amines, sulfates, sulfonates, and hydroxamates.[16]

A preliminary laboratory investigation showed that an acidic slurry of coal or lignite could be used to leach manganese from manganese dioxide. This procedure was investigated because of its possible application to hydrometallurgical extraction of manganese from low-grade ores and marine nodules. Reaction rates were several times greater when hydrochloric rather than sulfuric acid was used. With hydrochloric acid, use of coal eliminated chlorine generation and excess acid consumption. Several natural forms of manganese dioxide and a sample of chemical-grade dioxide were used in the tests.[17]

In another laboratory investigation, the rate of dissolution of manganese oxides into hydrohalogen acid solutions was found to increase in the sequence chloride-bromide-iodide and to increase inversely with the degree of oxidation of manganese in the mineral lattice. Use of iodide solutions accelerated dissolution to a rate as much as five orders of magnitude greater than that observed in chloride solutions. The same acceleration of dissolution rate could be achieved by adding anions as neutral salts to acid solutions or by using the hydrohalogen acid directly. Tests were conducted on powder samples of MnO_2, Mn_3O_4, Mn_2O_3, and MnO. The least acceleration was observed for dissolution of MnO, for which differences in dissolution rate were related to the nature of the surface attack.[18]

Also in the laboratory, iron was selectively precipitated from manganese sulfate leach solutions in filterable form as ammonium jarosite, $NH_4Fe_3(SO_4)_2(OH)_6$. The optimum combination of solution acidity, temperature, ammonium sulfate concentration, and amount of jarosite seed addition for rapid precipitation was determined using a factorially designed study of the kinetics of the precipitation reaction. Possible applications of the work include processing of manganese ores having high contents of soluble iron and direct reductive leaching of manganese ores with sulfuric acid solutions containing ferrous sulfate. The latter would be an alternative to processing of ores by the conventional beginning step of pyrometallurgical reduction when manganese is present in quadrivalent form, commonly as MnO_2.[19]

Operating results were described for production of high-carbon ferromanganese using ores from different sources at the Beauharnois, Quebec, Canada, plant of Elkem Metals Canada Inc. Of four practices employed in recent years, the preferred practice in 1986 was a high-alumina practice in which all manganese units were obtained from ore or ore fines from Gabon and for which the energy consumption per ton of product was lowest. Slag from the high-alumina practice was relatively high in manganese with an MnO content of 45% and was used subsequently in making silicomanganese.[20]

Owing to modern developments in steel refining, previously unattainable purity levels are now possible in production heats of steel, thereby impacting manganese needs in steelmaking. This was exemplified in Austria with pilot production of a 37-ton ingot of nickel-chromium-molybdenum-vanadium steel, which was forged into a steam-turbine-type model rotor. Ladle refining and vacuum treatment were used to achieve silicon and sulfur contents of only 0.03% and 0.001%, respectively, in the steel. This sulfur content allowed the manganese content to be lowered to 0.02%. The low silicon and manganese contents greatly improved resistance to temper embrittlement, which could be advantageous to the design and operation of future powerplants. The Electric Power Research Institute provided financial assistance for this program on rotor steel.[21]

An electroplated coating of zinc-manganese alloy for improving corrosion resistance of automotive sheet steel was under development by Japan's Nippon Kokan K.K. A manganese content of 30% to 50% in the coatings produced an optimum combination of properties. The coating was deposited from a citrate bath containing zinc and manganese sulfates. A favorable characteristic of the coating was that, even without painting, corrosion resistance was far superior to that of electrogalvanized steel.[22]

Several methods of alloying molten aluminum with manganese were investigated at Norway's Lista Aluminiumverk. Manganese powder injection using nitrogen carrier gas was accepted as the preferred method. This has lowered material costs and handling requirements, shortened dissolution time, and raised manganese recovery to as high as 98% to 100%. Powder injection has displaced more conventional use of manganese-aluminum briquets or master alloys.[23]

Manganese pigment, in the form of the oxide Mn_3O_4, compared favorably with conventional prime color pigments in laboratory tests of acrylic latex coatings for anticorrosive service, such as bridges. This oxide, a relatively new pigment material, previously tested well against conventional pigments in alkyd systems.[24]

The Roskill organization issued another comprehensive report on the manganese industry worldwide. The report discussed production and processing of manganese ore and the various uses for mineral-related forms of manganese.[25]

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[2]Unless otherwise stated, the unit of weight in this chapter is the short ton of 2,000 pounds.

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Mercury

By Linda C. Carrico[1]

Domestic mine production of mercury decreased for the sixth consecutive year, with Nevada continuing to be the major producing State. Mercury produced as a byproduct from gold mining operations accounted for 5% of the total reported production. Total secondary production increased 59% owing to the availability of larger quantities of imported waste and scrap material, especially from dismantled mercury-cell chlor-alkali plants worldwide and sales of secondary mercury by the General Services Administration (GSA). Imports for consumption (metal and waste and scrap) increased 7% owing to increased demand for lower cost foreign material. Reported consumption declined 8% in 1986, with the majority of consumers east of the Mississippi River.

The New York and London prices declined substantially in 1986, to the lowest levels since December 1978 and September 1977, respectively. Falling prices were attributed to large quantities of material from the U.S.S.R. entering the mercury market at below market value.

Spanish and Algerian producers met intermittently during the year to review the weak market conditions. In response to weak prices and an oversupply of mercury in the European community, they agreed to suspend spot sales in an attempt to bolster prices.

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 348 firms to which this survey report was sent, 96% responded, representing an estimated 99.6% of the reported U.S. consumption shown in tables 1 and 4. Consumption for the nonrespondents was estimated, using prior years' consumption levels.

Table 1.—Salient mercury statistics

	1982	1983	1984	1985	1986
United States:					
Producing mines	3	3	3	4	6
Mine production flasks	25,760	25,070	19,048	16,530	W
Value thousands	W	W	W	W	W
Secondary production:					
Industrial flasks	4,473	13,751	5,673	5,358	6,362
Government[1] do	--	--	--	585	3,078
Industry stocks, yearend[2] do	28,827	31,018	27,255	27,985	W
Shipments from the National Defense Stockpile[3] do	7,076	6,000	4,092	4,534	463
Imports for consumption do	8,916	12,786	25,327	18,890	20,187
Exports do	NA	NA	NA	NA	NA
Consumption do	48,943	49,138	54,669	r49,846	45,946
Price: New York, average per flask	$370.93	$322.44	$314.38	$310.96	$232.79
Employment, mine and mill, average	45	45	41	35	22
World:					
Mine production flasks	197,901	r180,835	195,331	p195,823	e175,820
Price: London, average per flask	$376.96	$313.33	$306.40	$288.56	$193.80

eEstimated. pPreliminary. rRevised. NA Not available. 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.

Legislation and Government Programs.—Although GSA was not authorized to dispose of primary mercury from the National Defense Stockpile (NDS) in fiscal year 1986, a total of 1,313 flasks[2] of previously sold mercury was shipped during the fiscal year, including 463 flasks shipped during the calendar year. Total inventory at the end of September was 169,226 flasks, and the goal remained at 10,500 flasks. On November 14, 1986, the President signed Public Law 99-661, the Department of Defense Authorization Act, 1987, authorizing GSA to dispose of 3,700 flasks of primary mercury from the NDS. GSA planned to auction a maximum of 750 flasks of primary mercury per month, commencing January 1987; the mercury was to be offered instead of cash to pay contractors for services performed on the ferroalloy upgrading program.

In June 1986, GSA shipped the remaining mercuric oxide, 80 pounds, from the NDS.

GSA continued its monthly auctions of surplus secondary mercury managed by the U.S. Department of Energy (DOE) in Oak Ridge, TN. On the third Tuesday of each month, the agency offered a maximum of 1,500 flasks on an "as-is" basis. It sold 3,662 flasks and shipped 3,663 flasks during fiscal year 1986, leaving 31,642 flasks available for disposal at the end of the fiscal year. During the calendar year, sales and shipments were 3,077 and 3,078 flasks, respectively, with a yearend inventory of 31,642 flasks. Starting in January 1987, GSA planned to auction to the general public a maximum of 750 flasks of secondary mercury per month on an as-is basis.

Under the Resource Conservation and Recovery Act (RCRA), the Environmental Protection Agency (EPA) issued final regulations on March 24, 1986,[3] for small quantity generators that generate between 220 and 2,200 pounds of hazardous waste per calendar month. The mercury and mercury-containing compounds classified as a "hazardous waste" were as follows: mercury in metal form, 2-methoxy mercuric chloride, and phenylmercuric acetate. Most of the new rules became effective September 22, 1986, except that small quantity generators that decide to (1) store hazardous waste for longer than 6 months, (2) perform certain kinds of waste treatment, or (3) dispose of hazardous waste on their property must apply for an RCRA permit and comply with additional rules starting March 24, 1987. Further information was provided in an EPA handbook.[4]

Public Law 99-499, Superfund Amendments and Reauthorization Act of 1986, was signed by the President October 17, 1986. This law extended and amended the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, commonly referred to as the Superfund Act. As provided by Public Law 99-499, mercury sold by the manufacturer, producer, or importer during the 1987-91 period will be taxed 17 cents per flask. A major provision of the law was the establishment of a fund to clean up hazardous materials disposal sites and spills.

The Safe Drinking Water Act Amendments of 1986, Public Law 99-339, was signed by the President June 19, 1986. This law requires EPA to review and promulgate within 3 years of its enactment the maximum permissible levels for 83 contaminants, 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 has been the major mercury producing State since 1975 and the sole source of domestic primary mercury since 1982. The figure for 1986 domestic mine production, reported by six mines, all in Nevada, and including byproduct mercury from gold operations, was withheld by the Bureau of Mines to avoid disclosing company proprietary data. Mine production over the past 6 years has decreased, owing to the availability of low-cost foreign material and sales of mercury from Government stockpiles. The McDermitt Mine, operated by Placer U.S. Inc., remained the principal domestic mercury producing mine in 1986.

Mercury produced as a byproduct from five gold mining operations in 1986 accounted for 5% of the total reported production. The mines and operators were as follows: Borealis project, CanAm Minerals Co.; Carlin, Newmont Gold Co. (formerly Carlin Gold Mining Co.); Enfield Bell (Jerritt Canyon), Freeport-McMoRan Inc.; Paradise Peak, FMC Corp.; and Pinson, Pinson Mining Co.

In April, the Paradise Peak surface gold mine near Gabbs, NV, came on-line. In the first 9 months of operation, a significant amount of byproduct mercury was produced. FMC's geologist predicted the mine could yield between 800 and 2,600 flasks of mercury per year as a byproduct from gold mining.

Table 2.—Mercury ore treated and mercury produced in the United States[1]

Year	Ore treated (short tons)	Mercury produced	
		Flasks	Pounds per ton of ore
1982	300,978	25,704	6.5
1983	335,389	25,033	5.7
1984	216,212	19,014	6.7
1985	182,385	16,337	6.8
1986	W	W	W

W Withheld to avoid disclosing company proprietary data.
[1]Excludes mercury produced from old surface ores, dumps, and placers, and as a byproduct.

Table 3.—Production of secondary mercury in the United States

(Flasks)

Year	Industrial production	GSA releases	Total
1982	4,473	--	4,473
1983	13,751	--	13,751
1984	5,673	--	5,673
1985	5,358	585	5,943
1986	6,362	3,078	9,440

According to the Alaska Division of Geological and Geophysical Surveys,[5] the Mountain Top mercury mine produced about 27 flasks of mercury in 1985 (latest available statistics), and was active in 1986. The mine and small retort are in a remote area southwest of Sleetmute, AK.

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 21% of the reported mercury consumption. Secondary mercury was salvaged from wornout or obsolete items and waste products, such as amalgams, batteries, and industrial and control instruments. It was also retrieved from both closed and operating chlorine and caustic soda plants, and from DOE stocks of mercury.

CONSUMPTION AND USES

Consumption of mercury was reported by about 250 plants, of which more than one-half were east of the Mississippi River. Prime virgin mercury accounted for 69% of the total reported consumption, followed by secondary mercury, 16%, and redistilled mercury,[6] 15%.

Total reported domestic mercury consumption decreased slightly compared with the revised 1985 data. The battery industry reported a 21% decline in mercury consumption but continued to be the dominant consumer, followed by industries producing chlorine and caustic soda, paints, wiring devices and switches, and measuring and control instruments.

Mercury consumed by the battery industry decreased dramatically in 1986 owing to improved technology that allowed a reduction in the amount of mercury used in each dry cell. On July 1, Ralston Purina Co. acquired Union Carbide Corp.'s U.S. battery products division, known as Eveready Battery Co. Inc.

Consumption of mercury by the chlorine and caustic soda manufacturing industry, which operated 20 mercury-cell plants, increased in 1986 owing to higher demand for chlorine. Occidental Petroleum Corp. announced in late September its acquisition of Diamond Shamrock Chemicals Co., a subsidiary of Diamond Shamrock Corp. Diamond Shamrock Chemicals operated four mercury-cell chlor-alkali plants in the United States, with two in Alabama and one each in Delaware and Texas. Prior to the acquisition, Occidental owned one mercury-cell chlor-alkali plant in Niagara Falls, NY, which was idle throughout 1986. Reportedly,[7] with this acquisition, Occidental became the second largest domestic producer of chlorine and caustic soda.

The Chlorine Institute Inc., an association of manufacturers of chlorine and caustic soda, moved its headquarters from New York City to Washington, DC.

Ciba-Geigy Corp., a mercury pigment producer in Glens Falls, NY, announced the phasing out of its plant over the next 2 years.

Table 4.—Mercury consumed in the United States, by use

(Flasks)

SIC code	Use	1982	1983	1984	1985[r]	1986
28	Chemical and allied products:					
2812	Chlorine and caustic soda manufacture	6,243	8,054	7,347	6,804	7,548
2816	Pigments	W	W	W	W	W
2819	Catalysts, miscellaneous	499	484	359	488	536
2821	Catalysts for plastics	W	W	W	W	W
2819	Laboratory uses	281	280	269	413	568
2851	Paints	6,794	6,047	4,651	4,892	5,006
2879	Agricultural chemicals	36	--	--	--	--
--	Other chemicals and allied products	W	W	W	478	W
36	Electrical and electronic uses:					
3641	Electric lighting	826	1,273	1,487	1,147	1,197
3643	Wiring devices and switches	2,004	2,316	2,730	2,762	2,981
3692	Batteries	24,880	23,350	29,700	27,622	21,764
--	Other electrical and electronic uses	W	W	W	W	213
38	Instruments and related products:					
382	Measuring and control instruments	3,064	2,465	2,856	2,300	1,814
3843	Dental equipment and supplies	1,019	1,597	1,432	1,444	1,507
--	Other instruments and related products	194	W	W	W	W
--	Other	984	1,356	1,404	267	309
	Total	48,943	49,138	54,669	49,846	45,946

[r]Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."

STOCKS

The NDS, as of December 31, 1986, contained 169,226 flasks of mercury. DOE held 31,642 flasks of secondary mercury in Oak Ridge, TN. Reported stocks of mercury held by mine producers were withheld to avoid disclosing company proprietary data. Consumer and dealer-broker stocks increased during the second quarter of 1986, then rapidly declined, ending the year at 7,189 flasks, from 8,587 flasks at the end of 1985.

Table 5.—Stocks of mercury in the United States, December 31

(Flasks)

Year	Producer (mine)	Consumer and dealer	Total
1982	13,598	15,229	28,827
1983	18,323	12,695	31,018
1984	19,964	7,291	27,255
1985	19,398	8,587	27,985
1986	W	7,189	W

W Withheld to avoid disclosing company proprietary data.

PRICES

The price of mercury fell dramatically during the summer months owing to aggressive selling coupled with static demand. According to Metals Week, the New York dealers' price for primary mercury reached the high for the year on January 1 at a range of $273 to $280 per flask. The lowest price range reported for the year was $170 to $185 per flask on September 18, the lowest range since December 1978. Thereafter, the price gradually increased throughout the remainder of the year and on December 31 was $220 to $230 per flask.

The London price range of mercury (minimum 99.99% pure), quoted by Metal Bulletin (London), reached a high of $249 to $259 per flask on January 3, and then gradually fell. On July 25, the price fell below the $200-per-flask level to $170 to $195 per flask. The yearly low was reported on September 30 at $115 to $130 per flask, the lowest range since September 1977. Thereafter, the price fluctuated below the $200-per-flask level and ended the year at $158 to $170 per flask. In late September, some foreign producers halted or cut back sales in an attempt to bolster prices (see "World Review" section).

Table 6.—Average prices of mercury at New York and London

(Per flask)

Period	New York	London
1982	$370.93	$376.96
1983	322.44	313.33
1984	314.38	306.40
1985	310.96	288.56
1986:		
January	264.95	246.44
February	245.00	228.56
March	248.10	229.31
April	269.09	229.39
May	270.00	226.06
June	262.33	219.06
July	232.86	194.72
August	196.29	152.33
September	173.10	125.94
October	196.59	145.83
November	215.11	163.81
December	220.00	164.11
Average	232.79	193.80

Sources: Metals Week (New York) and Metal Bulletin (London).

FOREIGN TRADE

Imports for consumption of mercury and mercury-bearing waste and scrap, which included imports for immediate consumption plus material withdrawn from bonded warehouses, increased 7% owing to increased demand for lower cost foreign material. Spain continued to be the leading supplier, followed by China, Turkey, Japan, and Algeria. The average unit value of imports was $206.87 per flask, compared with $282.53 per flask in 1985.

Table 7.—U.S. imports for consumption of mercury and mercury-bearing waste and scrap, by country

Country	1984		1985		1986	
	Flasks	Value (thousands)	Flasks	Value (thousands)	Flasks	Value (thousands)
Algeria	8,201	$2,441	1,938	$580	1,251	$208
Australia	--	--	--	--	39	7
Canada	14	33	5	26	10	53
China	350	112	2,382	662	4,741	863
Denmark	14	8	--	--	--	--
Finland	120	54	--	--	--	--
France	--	--	1	7	1,003	255
Germany, Federal Republic of	--	--	500	148	--	--
Italy	800	196	--	--	--	--
Japan	500	120	2,502	630	2,202	318
Malaysia	--	--	380	81	--	--
Mexico	21	9	214	38	655	150
Netherlands	1,556	392	--	--	--	--
Spain	11,749	3,344	7,955	2,322	5,824	1,310
Turkey	2,002	564	3,012	842	4,328	975
United Kingdom	(1)	1	(1)	1	2	2
Venezuela	--	--	--	--	132	35
Total	25,327	7,274	[2]18,890	5,337	20,187	4,176

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

Source: Bureau of the Census.

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, 1986, from countries with most-favored-nation status was 6.3 cents per pound ($4.79 per flask).[8] A duty of 25 cents per pound ($19.00 per flask) applied to other countries.

WORLD REVIEW

World mine production, excluding U.S. production, was equivalent to 53% of available capacity.

Mine producers in Algeria and Spain met periodically during 1986 to review the mercury market situation. The meetings were in response to the exporting of about 15,000 flasks of mercury by the U.S.S.R. to European countries at "dumping prices." The producers agreed to suspend spot sales through yearend in an attempt to bolster prices. Spain's producer took further steps and filed an antidumping claim against the U.S.S.R. with the European Commission. The Commission investigated the claim, but had not made a final ruling by yearend. Meanwhile, the U.S.S.R. announced it would not export mercury in 1987.

Canada.—Five mercury-cell chlor-alkali plants operated in 1986. The producers and locations were as follows: Canada Occidental Petroleum Ltd., Squamish, British Columbia; C-I-L Inc., Dalhousie, New Brunswick, and Cornwall, Ontario; Canso Chemicals Ltd., Abercrombie Point, Nova Scotia; and PPG Industries Canada Ltd., Beauharnois, Quebec.[9] Canada Occidental acquired its plant during the year from FMC of Canada Ltd.

China.—According to the Ministry of Geology and Mineral Resources, China has the largest mercury resources in the world. Guizhou is known as the mercury province; its five mines accounted for about 90% of the national output. China National Nonferrous Metals Industry Corp. marketed mercury of 99.99% and 99.999% purity, and its subsidiary, Gem Mineral Corp., marketed cinnabar as crystal specimens.

Japan.—According to the Ministry of International Trade and Industry (MITI), Japan has phased out, over the past 13 years, its mercury-cell chlor-alkali plants through closures or conversions to the ion-exchange membrane-cell and diaphragm-cell processes. According to MITI, Japan was the first major industrialized country to totally abandon the mercury-cell process.

The Clean Japan Center contracted with Nomura Kosan Co. to operate a demonstration plant for the disposal and recycling of mercury containing waste, especially dry cell batteries. The plant is in Itomuka, Hokkaido Prefecture. It has a feed capacity of about 20 metric tons per day of mercury containing waste. When the batteries arrive at the plant they are crushed and then calcined in a rotary kiln to a temperature between 600° and 800° C to produce a mercury vapor. The vapor is then cooled, collected, and processed into mercury for reuse. The plant will be in the demonstration stage through September 1987.

Mexico.—Four mercury-cell chlor-alkali plants remained in operation during 1986. The producers and locations of the active mercury-cell plants were as follows: Guanos y Fertilizantes de México S.A., Salamanca; Pennwalt S.A. de C.V., Santa Clara; Celulosa y Derivados S.A. de C.V., Monterrey; and Industria Química del Istmo S.A., Pajaritos. The Guanos y Fertilizantes de México's San Cristobal (Ecatepee) plant was dismantled during 1986.[10]

Spain.—Minas de Almadén y Arrayanes S.A. (MAYASA), a mining company owned by the Spanish Government, cut back mercury production at its Almadén Mine and suspended spot sales in response to poor market conditions. MAYASA operated three mines in the Almadén region: Almadén, El Entredicho, and Las Cuevas.

The Almadén Mine, about 2,000 years old, will be phased out by 1989. According to MAYASA officials, El Entredicho opencast mine supplies an estimated 70% to 80% of Spain's annual mercury output. Indications were that after the surface ore is exhausted, mining at El Entredicho Mine could continue underground. Development work continued at Las Cuevas underground mine, with startup scheduled for 1988. Officials predicted that the mine could produce 10,000 to 15,000 flasks per year.

The low-grade ores from El Entredicho and Las Cuevas Mines require more intensive processing than the ore from the Almadén Mine. New flotation and smelter facilities were planned for a site near El Entredicho Mine. MAYASA estimated that the reserves at the two new mines will be adequate to maintain the present production level for about 20 years.

U.S.S.R.—The Soviet trading firm Raznoimport Association negotiated contracts to sell a total of about 15,000 flasks of mercury during 1986. Reportedly,[11] Philipp Brothers Inc. signed a contract with Raznoimport for a substantial quantity of the mercury.

The U.S.S.R. planned to convert an existing 110,000-metric-ton-per-year caustic soda plant at Volgograd from the mercury-cell chlor-alkali technology to the ion-exchange membrane technology and double its capacity.

Yugoslavia.—U.S. and Yugoslav scientists completed a 3-year project, funded under the U.S.-Yugoslav Science and Technology Cooperation Program, which demonstrated that the underhand cut-and-fill mining method could be used at Yugoslavia's Idrija mercury mine. The scientists also studied and developed an air-filtering helmet that reduces the amount of mercury vapor inhaled by miners.

It was reported[12] that the Yugoslav Mining Institute of Ljubljana was considering closing its Idrija Mine because of depressed international prices. The closing would be in stages, the lowest levels of the mine closing by 1989, with minimal output maintained for several years until permanent closure.

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[1]Mineral specialist, Division of Nonferrous Metals.
[2]Flask, as used throughout this chapter, refers to the 76-pound flask.
[3]Federal Register. Hazardous Waste Management System: General; Identification and Listing of Hazardous Waste; Standards for Generators of Hazardous Waste; Standards for Transportation of Hazardous Waste; EPA Administered Permit Programs; Authorization of State Hazardous Waste Programs. V. 50, No. 56, Mar. 24, 1986, pp. 10146-10176.
[4]Environmental Protection Agency. Understanding the Small Quantity Generator Hazardous Waste Rules: A Handbook for Small Business. EPA/530-SW-86-019, Sept. 1986, 32 pp.
[5]Alaska Office of Mineral Development, Alaska Division of Geology and Geophysical Surveys, Division of Mining. Alaska's Mineral Industry, 1985. Spec. Rep. No. 39, Fairbanks, AK, 1986, pp. 27, 66.
[6]Redistilled mercury is primary mercury further processed or refined to a higher grade and is sometimes referred to as triple distilled mercury.
[7]American Paint and Coatings Journal. Occidental Petroleum Acquires Diamond Shamrock Chemicals. V. 71, No. 11, Sept. 29, 1986, p. 12.
[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]The Chlorine Institute Inc. North American Chlor-Alkali Industry Plants and Production Data Book. Pam. 10, Jan. 1987, 20 pp.
[10]Work cited in footnote 9.
[11]Metal Bulletin (London). Phibro Takes Russian Mercury. No. 7110, Aug. 12, 1986, p. 10.
[12]Metals Week. Idrija Mercury Mine May Close. V. 57, No. 50, Dec. 15, 1986, p. 8.

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

(Flasks)

Country	1982	1983	1984	1985^p	1986^e
Algeria	11,000	^{e}10,000	23,000	$^{r\,e}$23,000	23,000
China^e	20,000	20,000	20,000	20,000	20,000
Czechoslovakia	4,380	4,177	4,409	^{e}4,400	4,400
Dominican Republic	49	$^{r\,e}$60	$^{r\,e}$80	121	120
Finland	2,068	1,857	2,292	^{e}2,300	2,300
Germany, Federal Republic of	1,537	2,005	--	--	--
Italy	4,612	--	--	--	--
Mexico	8,558	6,411	11,140	11,430	10,000
Spain	48,808	41,075	44,090	45,042	42,000
Turkey	7,129	^{r}4,680	5,272	^{e}6,000	6,000
U.S.S.R.^{e}	64,000	64,000	64,000	65,000	66,000
United States	25,760	25,070	19,048	16,530	W
Yugoslavia^e	--	1,500	2,000	2,000	2,000
Total	197,901	^{r}180,835	195,331	195,823	175,820

^{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. 21, 1987.

Mica

By Lawrence L. Davis[1]

In 1986, a total of 148,000 short tons of scrap and flake mica was reported produced in the United States, a 7% increase from 1985 production.

Nearly all sheet mica supply continued to be imported. Consumption of muscovite mica block decreased slightly to 50,300 pounds. Consumption of mica splittings decreased 6% to 2.2 million pounds. The value of sheet mica exports decreased 11% to $4.7 million. Imports for consumption of sheet mica increased 49% to 4.0 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 89% of the production shown in table 1. Of the 16 operations to which the ground mica production form was sent, 13 operations, or 81%, responded, representing 85% of the production shown 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 94% of the consumption shown in table 1. Of the 12 canvassed operations to which the mica splittings consumption form was sent, 9 operations, or 75%, responded, representing 84% of the splittings consumption shown in table 1. Consumption for the nonrespondents was estimated using prior year production data.

Table 1.—Salient mica statistics

	1982	1983	1984	1985	1986
United States:					
Production (sold or used by producers):					
Scrap and flake mica ---- thousand short tons--	106	140	161	138	148
Value ---- thousands--	$6,398	$6,479	$7,139	$6,330	$7,108
Ground mica ---- thousand short tons--	96	130	146	136	127
Value ---- thousands--	$16,106	$18,702	$21,334	$21,256	$23,872
Consumption:					
Block, muscovite ---- thousand pounds--	86	74	62	51	50
Value ---- thousands--	$1,325	$961	$842	$751	$755
Film ---- thousand pounds--	W	W	W	W	W
Value ---- thousands--	W	W	W	W	W
Splittings ---- thousand pounds--	2,639	2,120	2,366	2,361	2,226
Value ---- thousands--	$2,032	$1,394	$1,679	$1,610	$1,252
Exports ---- thousand short tons--	12	11	9	10	8
Imports ---- do----	10	8	13	11	13
World: Production ---- thousand pounds--	r476,564	535,231	608,700	p557,649	e579,146

eEstimated. pPreliminary. rRevised. W Withheld to avoid disclosing company proprietary data.

Legislation and Government Programs.—The Government inventory of stockpile-grade natural sheet mica remained at 22.4 million pounds.

Table 2.—Stockpile goals and Government inventories for mica, December 31, 1986

(Thousand pounds)

Material	Goal	Inventory: Stockpile grade	Inventory: Nonstockpile grade	Available for disposal	1986 sales
Block:					
Muscovite, Stained and better	6,200	5,008	207	--	--
Phlogopite	210	17	114	--	--
Film: Muscovite, 1st and 2d qualities	90	1,179	1	1,034	--
Splittings:					
Muscovite	12,630	14,653	--	262	--
Phlogopite	930	1,519	--	--	--

DOMESTIC PRODUCTION

Scrap and Flake Mica.—U.S. production of scrap (flake) mica[2] was 148,000 tons valued at $7.1 million. North Carolina remained the major producing State with 60% of the total. The remainder was produced in Connecticut, Georgia, New Mexico, Pennsylvania, South Carolina, and South Dakota. Most of the scrap (flake) mica was recovered from mica schist, high-quality sericite schist, and as a byproduct of kaolin, feldspar, and lithium beneficiation. The five leading 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 five companies produced 61% of the national total.

Unimin entered the mica industry by purchasing two operations in Spruce Pine, NC. In February, Unimin acquired Harris Mining Co. In December, Unimin purchased, from Applied Industrial Materials Corp., the feldspar-mica-silica operation near Spruce Pine that had been previously owned by International Minerals & Chemical Corp.

Kings Mountain Mica Co. Inc. and affiliated companies reorganized to combine operations under one name. The new name of the company is KMG Minerals Inc.

Ground Mica.—Production (sold or used) of ground mica, from scrap and flake mica, decreased 7% to 127,000 tons, valued at $23.9 million. Dry-ground mica, 83% of the total, decreased 14%. Reduced demand for mica used in well-drilling muds was the main reason for the decrease. Wet-ground mica production increased 69%.

Twelve companies operated fifteen grinding plants. Eleven plants produced dry-ground and 4 produced wet-ground mica. Leading producers 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. These five companies produced 68% of the national total.

Unimin announced that its grinding facilities at Spruce Pine, NC, would be upgraded to double the capacity. A new plant, featuring advanced process controls, was scheduled to begin operation in the spring of 1987.[3]

In December, KMG Minerals purchased USG's dry-ground mica plant at Kings Mountain, NC. The acquisition increased KMG Mineral's grinding capacity to about 50,000 tons per year.

Production of low-quality sericite, primarily for use in brick manufacturing, was 42,000 tons valued at $190,000. Approximately 41,000 tons of ground sericite valued at $313,000 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
1982	106	6,398
1983	140	6,479
1984	161	7,139
1985	138	6,330
1986:		
North Carolina	89	4,641
Other States[2]	59	2,467
Total	148	7,108

[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
1982	85	11,604	11	4,502	96	16,106
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	106	14,752	22	9,120	[2]127	23,872

[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 50,300 pounds, a slight decrease from that of 1985. Of the total muscovite block fabricated, 74% went into electronic uses; of this, the majority was used in vacuum tubes. Consumption of Stained quality decreased, although it remained in greatest demand, accounting for 69% of consumption. Consumption of grades No. 5-1/2 and 6 decreased while consumption of other sizes increased.

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 72% of the total.

Phlogopite block fabrication increased compared with that of 1985. The block was consumed by five companies in five States.

Consumption of mica splittings decreased 6% to 2.2 million pounds. Muscovite splittings from India accounted for 99% of the consumption. The remainder was phlogopite splittings from Madagascar. The splittings were fabricated into various built-up mica products by 11 companies operating 11 plants in 9 States.

Built-Up Mica.—The primary use of this mica-base product, made by mechanical or hand setting 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 4% from that of 1985. Segment plates and molding plates were the major end products, accounting for 31% and 28% of the total, respectively. Other end products included flexible plates, heater plates, and tapes.

Reconstituted Mica (Mica Paper).—Four companies consumed 4.1 million pounds of scrap mica to produce 2.6 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. WearEver-ProctorSilex, Mount Airy, NC, ceased manufacturing mica paper in 1985.

Ground Mica.—The major end uses were joint cement, 50%; paint, 17%; and well-drilling muds, 4%. Other end uses included agricultural products, molded electrical insulation, plastics, roofing, rubber, textile and decorative coatings, and welding rods.

Table 5.—Fabrication of muscovite block mica in the United States in 1986, by quality and end product use

(Pounds)

Quality	Electronic uses	Nonelectronic uses	Total
Good Stained or better	1,800	3,400	5,200
Stained	W	W	34,900
Lower than Stained[1]	W	W	10,200
Total	37,100	13,200	50,300

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 1986, by quality

(Pounds)

Quality	No. 4 and larger	No. 5 and smaller	Total
Good Stained or better	4,300	900	5,200
Stained	6,300	28,600	34,900
Lower than Stained	2,600	7,600	10,200
Total	13,200	37,100	50,300

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:						
1982	2,576	1,775	63	257	2,639	2,032
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
Stocks on Dec. 31:						
1982	1,922	NA	42	NA	1,964	NA
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

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	1985		1986	
	Quantity	Value	Quantity	Value
Flexible (cold)	193	810	190	803
Heater plate	69	182	63	132
Molding plate	654	2,397	624	2,326
Segment plate	723	2,974	686	2,940
Tape	266	1,675	253	1,559
Other	399	1,796	392	1,741
Total[2]	2,304	9,835	2,209	9,501

[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	1985 Quantity	1985 Value	1986 Quantity	1986 Value
Joint cement	68	10,372	63	10,499
Paint	20	3,451	22	3,676
Plastics	2	498	1	252
Well-drilling mud	16	1,730	5	576
Other[1]	29	5,205	36	8,868
Total[2]	136	21,256	127	23,872

[1]Includes mica used for agricultural products, molded electrical insulation, roofing, 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 increased 15% to 1.5 million pounds; of this, mica splittings represented 89% and mica block represented 11%.

PRICES

Average reported values of consumed muscovite sheet mica changed as follows: Block increased 33% to $19.52 per pound; film increased 30% to $4.91 per pound; and splittings decreased 19% to $0.52 per pound. The average value of phlogopite block decreased 32% to $4.69 per pound while the value of phlogopite splittings increased 9% to $4.00 per pound.

The average value of crude scrap (flake) mica, including high-quality sericite, was $47.97 per ton. The average value per ton for North Carolina scrap (flake) mica, predominantly a flotation product, was $51.97.

Table 10.—Average reported price for dry- and wet-ground mica sold or used by U.S. producers in 1986

(Dollars per short ton)

Kind	Price
Wet-ground	419
Dry-ground	140
End uses:	
Joint cement	167
Paint	165
Plastics	216
Well-drilling mud	108
Other[1]	247

[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 was a net importer of ground mica in 1986, importing 12.0 million pounds valued at $2.3 million while exporting 11.7 million pounds valued at $1.8 million. About 97% of the imported ground mica came from Canada. Ground mica was exported to 28 countries. Leading countries of destination were Canada, 31%; Mexico, 20%; Spain, 16%; and Venezuela, 5%.

Imports of unmanufactured block, film, and splittings increased 11% to 1.9 million pounds. India remained the dominant source, providing 98% of the imports.

The total value of exported cut, stamped, and built-up mica was $4.5 million, a decrease of 12%. Canada continued to be the leading country of destination, accounting for 36%. Mexico received 26%; the Netherlands, 9%; Brazil, 7%; and the remainder went to 34 countries. The total value of imports of these materials increased 54% to $4.9 million. The large increase was primarily mica plates and mica paper imported from Belgium.

The combined value of all mica exports was $6.9 million, a decrease of 9%. The total value of imported mica increased 27% to $9.1 million.

Table 11.—U.S. exports of mica and manufactures of mica in 1986, 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	300	30	--	--	--	--	22
Australia	122	15	62	9	--	--	222
Bahamas	--	--	--	--	--	--	108
Brazil	--	--	--	--	2	2	305
Canada	3,654	390	302	43	--	--	1,626
France	164	13	--	--	--	--	7
Germany, Federal Republic of	278	34	64	10	14	16	50
India	--	--	--	--	--	--	116
Italy	88	7	280	34	--	--	65
Japan	430	91	336	68	18	65	46
Korea, Republic of	250	77	--	--	18	46	53
Mexico	2,390	577	1,938	275	2	3	1,171
Netherlands	294	57	--	--	10	24	424
Saudi Arabia	--	--	--	--	--	--	43
South Africa, Republic of	230	24	--	--	--	--	21
Spain	1,924	231	--	--	--	--	55
Sweden	--	--	--	--	--	--	42
Taiwan	120	13	--	--	--	--	21
United Kingdom	348	41	110	16	10	26	3
Venezuela	638	75	--	--	--	--	--
Other[2]	456	85	114	18	24	16	102
Total[3]	11,686	1,758	3,206	472	98	196	4,502

[1]Some shipments of ground mica are included in this category.
[2]Includes Belgium, Bermuda, Bolivia, the Cayman Islands, Chile, China, Colombia, Denmark, the Dominican Republic, Ecuador, Egypt, El Salvador, the French Pacific Islands, Guatemala, Honduras, Hong Kong, Indonesia, Israel, Jamaica, Kuwait, the Leeward and Windward Islands, Malaysia, the Netherlands Antilles, Norway, Panama, Peru, the Philippines, Singapore, Switzerland, and the Turks and Caicos Islands.
[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
1984	10,384	985	12,814	2,266
1985	7,960	718	12,097	2,202
1986:				
Canada	44	1	11,713	2,067
India	9,813	1,204	243	41
Japan	--	--	44	207
Madagascar	79	19	--	--
Other[1]	9	1	17	9
Total	9,945	1,225	12,017	2,324

[1]Includes Belgium, Italy, Mexico, and the United Kingdom.

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
1984	68	151	1,368	458	44	35
1985	55	112	1,624	957	5	11
1986:						
Brazil	1	12	--	--	--	--
China	--	--	--	--	1	3
France	5	30	(2)	7	--	--
Germany, Federal Republic of	(2)	3	--	--	--	--
India	4	11	1,799	525	25	7
Taiwan	--	--	25	48	6	3
United Kingdom	(2)	4	--	--	--	--
Total[3]	11	61	1,824	580	32	13

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

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				Plates and built-up		Articles not especially provided for	
	Not over 0.006 inch in thickness		Over 0.006 inch in thickness					
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1984	114	517	152	610	467	1,007	123	702
1985	60	510	120	560	729	1,540	69	544
1986:								
Belgium	--	--	--	--	1,524	2,936	31	120
France	--	--	(1)	1	69	129	5	10
Germany, Federal Republic of	--	--	--	--	45	89	117	196
India	31	345	47	181	16	50	136	405
Japan	--	--	17	73	20	104	36	94
Other[2]	1	3	2	36	3	21	6	65
Total	32	348	66	291	1,677	3,329	331	[3]891

[1]Less than 1/2 unit.
[2]Includes Belize, Canada, Hong Kong, Italy, the Netherlands, Spain, Switzerland, Taiwan, and the United Kingdom.
[3]Data do not add to total 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				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	Quantity	Value
Exports:								
1982	16,746	2,144	5,254	742	294	296	NA	5,499
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
Imports for consumption:								
1982	10,824	1,724	5,030	427	3,173	1,449	724	2,936
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

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 4% to 579 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. began expansion of its phlogopite mica operations. Lacana announced a plan to double production of high-aspect-ratio mica, to modernize research facilities, and to increase efforts to develop new products. New products mentioned included nickel-coated mica for use as a reinforcing filler in plastic housings used to prevent electromagnetic interference in computers and other electronic equipment. Development of new grades of mica for use in reaction-injection-molded plastics was also under consideration because of the large growth potential for automotive plastics.[4]

India.—The Mica Trading Corp. of India Ltd. (MITCO) began production at its new 660-ton-per-year mica paper plant. The plant is under obligation to export 50% of production to Japan. Construction of a second plant was started in June and was scheduled for completion in 1988.[5] During the 1985-86 financial year, MITCO's export sales of mica were about 24,000 tons, a record-high level.[6]

U.S.S.R.—The U.S.S.R. continued to be the largest importer of Indian sheet mica. As India's major export market, the U.S.S.R. purchases about 60% of India's total mica block exports and about 25% of its splittings and film.[7]

[1]Physical scientist, Division 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). No. 224, May 1986, p. 14.
[4]———. No. 225, June 1986, p. 9.
[5]U.S. Embassy, New Delhi, India. State Dep. Telegram 24272, Oct. 3, 1986.
[6]Page 72 of work cited in footnote 3.
[7]Industrial Minerals (London). No. 222, Mar. 1986, pp. 19, 21.

Table 16.—Mica: World production, by country[1]

(Thousand pounds)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Argentina:					
Sheet	53	62	26	[e]34	34
Waste, scrap, etc	481	628	613	[e]620	600
Brazil	1,936	7,926	7,939	4,189	6,600
Canada[e]	22,000	23,000	23,000	25,000	26,000
France	17,527	20,472	23,929	[e]22,000	20,000
India:[e]					
Exports:					
Block	2,400	2,400	2,400	[r]2,600	2,600
Film and disk	440	440	440	[r]550	550
Splittings	8,800	7,000	7,000	[r]8,800	8,800
Scrap	17,600	15,500	15,500	[r]24,200	24,200
Powder	11,000	9,000	9,000	[r]10,400	10,400
Manufactured	660	1,100	1,100	[r]2,200	2,200
Domestic consumption, all forms	6,600	6,600	6,600	7,700	7,700
Total	47,500	42,040	42,040	[r]56,450	56,450
Korea, Republic of (all grades)	44,875	31,751	53,872	44,189	44,100
Madagascar (phlogopite)	2,866	1,585	1,587	1,299	1,300
Mexico (all grades)	1,124	3,439	3,695	3,188	3,100
Morocco	1,129	[e]1,100	2,646	3,175	3,300
Mozambique	326	681	[e]660	[e]660	550
Namibia	--	220	198	--	--
Peru[e]	1,200	1,200	1,200	1,200	1,100
South Africa, Republic of:					
Sheet	--	--	--	179	--
Scrap	[r]3,885	5,891	9,872	4,568	4,600
Spain	7,557	2,866	2,183	1,603	1,100
Sri Lanka (scrap)	642	377	[e]440	[e]440	440
Sudan	364	22	22	[e]22	22
Taiwan	97	686	670	[e]250	250
Tanzania (sheet)	11	(3)	(3)	(3)	(3)
U.S.S.R. (all grades)[e]	106,000	108,000	108,000	110,000	110,000
United States:					
Sheet	NA	NA	NA	NA	NA
Scrap and flake[4]	212,000	280,000	322,000	275,100	[5]296,300
Yugoslavia	3,093	2,086	[e]2,100	[e]2,200	2,200
Zimbabwe	1,898	1,199	2,008	1,283	1,100
Grand total	[r]476,564	535,231	608,700	557,649	579,146

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.
[1]Table includes data available through May 12, 1987.
[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]Less than 1/2 unit.
[4]Excludes U.S. production of low-quality sericite.
[5]Reported figure.

Molybdenum

By John W. Blossom[1]

Domestic and foreign molybdenum markets decreased in 1986 and worldwide mine production exceeded demand. Domestic producer and consumer stocks remained level. U.S. mine output of molybdenum decreased compared with that of 1985 and represented 46% of the world production. Reported end-use consumption of molybdenum in raw materials and apparent domestic demand decreased compared with that of 1985. In general, exports of all forms of molybdenum from the United States decreased during 1986. Domestic producer stocks of molybdenum remained level, but confronted with stock inventories equivalent to about 7 year's consumption, domestic producers' prices were weak. World market prices were below those of most U.S. producer quoted price listings for most of the year.

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 10 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)

	1982	1983	1984	1985	1986
United States:					
Concentrate:					
Production	84,381	33,593	103,664	108,409	93,976
Shipments	76,135	48,805	102,405	111,936	95,006
Value	$504,089	$166,612	$326,780	$347,812	$240,484
Reported consumption	49,444	27,014	54,843	W	53,061
Imports for consumption	3,115	1,673	28	112	1,120
Stocks, Dec. 31: Mine and plant	38,510	11,637	12,450	9,322	8,715
Primary products:					
Production	65,381	37,533	79,689	87,436	41,490
Shipments	47,884	50,562	65,527	73,861	57,855
Reported consumption	27,665	27,225	34,792	33,451	31,898
Stocks, Dec. 31: Producers	49,402	28,352	22,155	21,014	20,699
World: Mine production	r209,385	r140,616	214,275	p216,364	e206,192

eEstimated. pPreliminary. rRevised. W Withheld to avoid disclosing company proprietary data.

DOMESTIC PRODUCTION

Domestic mine production of molybdenum decreased to a total of 94 million pounds of contained molybdenum, compared with 108 million pounds in 1985. The country's two largest producers were AMAX Inc. and Cyprus Minerals Co. Domestic producers attempted to correct oversupply conditions by reducing production.

Table 2.—Production, shipments, and stocks of molybdenum products in the United States

(Thousand pounds of contained molybdenum)

	1985	1986	1985	1986	1985	1986
	Molybdic oxides[1]		Metal powder		Ammonium molybdate	
Received from other producers	9,989	37,224	--	--	W	W
Gross production during year	69,978	25,445	5,416	5,382	W	W
Used to make other products listed here	21,228	19,298	1,682	1,126	1,999	1,749
Net production	48,750	6,147	3,734	4,256	W	W
Shipments	58,984	43,347	3,968	4,208	W	W
Producer stocks, Dec. 31	16,281	16,459	W	W	W	W
	Sodium molybdate		Other[2]		Total	
Received from other producers	W	W	1,734	2,378	11,723	39,602
Gross production during year	W	W	12,042	10,663	87,436	41,490
Used to make other products listed here	W	W	626	1,363	25,535	23,536
Net production	W	W	9,417	7,550	61,901	17,953
Shipments	W	W	10,909	10,300	73,861	57,855
Producer stocks, Dec. 31	W	W	4,733	4,240	21,014	20,699

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 1985. 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 36 million pounds of molybdenum. The total reported end-use consumption of molybdenum in raw materials decreased about 5% from that of 1985. Molybdenum consumed in oxide form (technical-grade, purified, and briquets) accounted for about 58% of total reported consumption; in ferromolybdenum, 13%; and in other forms, 29%.

Molybdenum reported as consumed in the production of steel accounted for 51% of total consumption. Approximately 27% 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 22% of total consumption. Three end-use areas remained about the same in molybdenum consumption when compared with those of 1985. Five areas decreased in consumption in 1986—these areas were stainless and heat resisting steel; full alloy steel; high-strength, low-alloy steel; cast iron; and superalloys.

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]
1985					
Steel:					
Carbon	704	138	--	--	842
Stainless and heat resisting	4,946	627	--	167	5,740
Full alloy	7,773	798	--	28	8,599
High-strength, low-alloy	1,342	1,075	--	W	2,417
Tool	1,204	418	--	W	1,622
Cast irons	W	1,049	--	W	1,049
Superalloys	1,368	W	--	1,788	3,156
Alloys (excludes steels and superalloys):					
Welding and alloy hard-facing rods and materials	--	168	--	W	168
Other alloys[3]	200	129	W	135	464
Mill products made from metal powder	--	--	--	4,621	4,621
Chemicals and ceramics:					
Pigments	W	--	W	--	W
Catalysts	1,977	--	W	299	2,276
Other	4	4	--	732	740
Miscellaneous and unspecified	697	144	766	150	1,757
Total	20,215	4,550	766	7,920	33,451
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	663	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[3]	18,546	4,094	1,761	7,497	31,898

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

STOCKS

Total industry stocks, which include those of producers and consumers, decreased to 34 million pounds of contained molybdenum. Inventories of molybdenum in concentrate at mine locations decreased from 9.3 to 8.7 million pounds. Producer stocks of molybdenum in consumer products, such as oxide, ferromolybdenum, molybdate, metal powders, and other types, remained level with that of 1985 at 21 million pounds. Compared with apparent consumption, yearend producer stocks of these materials totaled about an 11-month supply. Domestic consumers held inventories of about 4 million pounds throughout most of the year, representing approximately a 1.5-month supply compared with average monthly reported consumption.

Table 4.—Industry stocks of molybdenum materials, December 31

(Thousand pounds of contained molybdenum)

Material	1982	1983	1984	1985	1986
Concentrate: Mine and plant	38,510	11,637	12,450	9,322	8,715
Producers:					
Molybdic oxides[1]	41,855	22,991	17,295	16,281	16,459
Metal powder	443	503	594	W	W
Ammonium molybdate	1,072	1,038	684	W	W
Sodium molybdate	48	79	W	W	W
Other[2]	5,984	3,741	3,582	4,733	4,240
Total	49,402	28,352	22,155	21,014	20,699
Consumers:					
Molybdic oxides[1]	2,103	1,467	1,552	2,020	2,168
Ferromolybdenum[3]	616	570	721	597	618
Ammonium and sodium molybdate	76	70	80	47	129
Other[4]	1,386	1,567	1,540	1,778	1,654
Total[5]	4,181	3,674	3,893	4,441	4,569
Grand total	92,093	43,663	38,498	34,777	33,983

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 molybdic oxide (per pound of contained molybdenum) increased from $2.60 in January to $2.85 at the end of February, then declined to $2.65 in April, again increased to the year's high in mid-October, then declined to $3.15 at the end of December. The average price of oxide was $2.92 or $0.41 less than the average price in 1985.

Table 5.—Domestic price listings for molybdenum

(Per pound)

	1985	1986
Producer quotes:		
Concentrate	$3.18	$2.50
Ferromolybdenum-export	3.91	3.52
Oxide	3.33	2.92

Source: Metals Week.

FOREIGN TRADE

Exports.—Exports of molybdenum in concentrate and oxide decreased compared with that of 1985. Molybdenum concentrate exports were about 52% of domestic mine production. Approximately 99% of reported concentrate and oxides was shipped to Belgium-Luxembourg, Canada, the Federal Republic of Germany, Japan, the Netherlands, Sweden, and the United Kingdom. The calculated molybdenum content of all exports was 59 million pounds in 1986. Total value of exports decreased from $316 million in 1985 to $185 million in 1986.

Imports.—Approximately 6 million pounds of molybdenum in various forms was imported into the United States, an increase of 1 million pounds over that of 1985. Total value of all forms of molybdenum imported increased from $26 million in 1985 to $27 million in 1986. In terms of both value and quantity, the major forms imported were as concentrate, material in chief value molybdenum, and molybdenum compounds. The principal originating countries for these imports were Canada and Chile.

Table 6.—Molybdenum reported by producers as shipments for export from the United States

(Thousand pounds of contained molybdenum)

	1985	1986
Molybdenite concentrate	38,646	18,267
Molybdic oxide	36,268	21,325
All other primary products	1,385	836

Table 7.—U.S. exports of molybdenum ore and concentrates (including roasted concentrates), by country

(Thousand pounds of contained molybdenum and thousand dollars)

Country	1984		1985		1986	
	Quantity	Value	Quantity	Value	Quantity	Value
Austria	--	--	31	50	--	--
Belgium-Luxembourg	5,146	22,629	5,743	30,114	3,088	8,782
Brazil	82	258	153	627	222	761
Canada	281	632	780	1,979	3,662	8,149
Chile	208	679	102	377	93	130
Germany, Federal Republic of	6,576	14,936	3,379	7,758	2,028	4,299
Japan	6,896	25,979	7,031	26,202	5,818	16,555
Mexico	([1])	1	71	135	22	137
Netherlands	34,914	150,558	40,076	160,250	24,997	75,802
Sweden	789	1,674	949	2,896	2,792	6,047
United Kingdom	7,863	23,057	4,991	15,463	6,243	14,499
Other	611	2,367	552	1,840	188	845
Total[2]	63,366	242,770	63,859	247,690	49,153	136,006

[1]Less than 1/2 unit.
[2]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	1985		1986	
	Quantity	Value	Quantity	Value
Ferromolybdenum:[1]				
Australia	14	73	--	--
Canada	86	285	40	154
Japan	72	149	187	406
Malaysia	--	--	1	4
Mexico	34	93	101	346
Other	1,055	2,098	5	19
Total[2]	1,262	2,698	332	929
Metal and alloys in crude form and scrap:				
Belgium-Luxembourg	--	--	1	17
Canada	15	114	34	317
France	1	13	2	34
Germany, Federal Republic of	145	438	148	790
India	2	19	2	9
Japan	170	700	220	923
Mexico	67	174	9	105
Netherlands	21	206	139	171
United Kingdom	30	265	344	592
Other	122	436	101	153
Total[2]	574	2,365	1,000	3,111
Wire:				
Argentina	8	78	3	76
Belgium-Luxembourg	85	190	8	349
Brazil	21	366	42	750

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	1985		1986	
	Quantity	Value	Quantity	Value
Wire —Continued				
Canada	29	573	46	760
France	2	38	14	199
Germany, Federal Republic of	119	1,470	97	1,096
India	1	34	(3)	8
Italy	36	449	66	886
Japan	71	1,395	96	1,989
Mexico	11	340	19	107
Netherlands	(3)	8	2	23
Singapore	1	8	6	51
South Africa, Republic of	(3)	1	(3)	9
Spain	51	203	19	234
Sweden	15	201	22	277
United Kingdom	33	277	26	471
Other	62	499	28	386
Total[2]	546	6,130	494	7,671
Powder:				
Belgium-Luxembourg	(3)	2	71	485
Canada	10	103	14	175
France	11	111	64	357
Germany, Federal Republic of	45	147	16	195
Italy	(3)	6	5	60
Japan	45	335	210	278
Mexico	5	60	1	6
Netherlands	126	477	333	330
Sweden	--	--	7	51
Taiwan	116	886	49	437
United Kingdom	5	47	45	91
Other	5	124	41	356
Total[2]	369	2,298	854	2,821
Semifabricated forms, n.e.c.:				
Australia	2	54	11	216
Belgium-Luxembourg	7	153	3	148
Brazil	15	430	45	855
Canada	13	347	20	571
France	16	681	31	914
Germany, Federal Republic of	79	1,215	83	1,497
Japan	55	351	7	223
Mexico	8	141	(3)	14
Netherlands	34	933	34	1,145
Philippines	(3)	4	--	--
Singapore	(3)	7	(3)	2
South Africa, Republic of	1	81	10	385
United Kingdom	90	2,085	75	1,752
Other	89	1,909	167	1,398
Total[2]	408	8,390	486	9,119
Molybdenum compounds:				
Argentina	(3)	3	--	--
Australia	274	676	1	3
Belgium-Luxembourg	2,755	4,797	546	824
Brazil	6	30	11	40
Canada	137	494	138	411
Germany, Federal Republic of	3,113	5,421	3,234	4,219
Japan	4,018	10,063	1,880	4,027
Mexico	7	76	60	129
Netherlands	6,956	12,946	3,262	4,532
Sweden	1,600	2,970	1,879	2,450
Switzerland	--	--	(3)	2
United Kingdom	3,000	5,547	4,347	5,479
Other	1,903	3,087	1,703	2,882
Total[2]	23,769	46,109	17,063	24,997

[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.	1985			1986		
		Gross weight	Contained molybdenum	Value	Gross weight	Contained molybdenum	Value
Ore and concentrate	601.33	182	112	566	1,740	1,120	3,057
Material in chief value molybdenum	603.40	4,173	2,239	7,329	1,786	1,102	3,284
Ferromolybdenum	606.31	1,424	945	3,721	1,599	1,077	3,626
Waste and scrap	628.70	NA	517	2,830	NA	529	2,870
Unwrought	628.72	NA	145	2,370	NA	191	2,510
Wrought	628.74	94	NA	2,301	102	NA	2,701
Ammonium molybdate	417.28	386	223	1,028	528	318	1,320
Molybdenum compounds	419.60	872	578	2,563	1,870	1,236	4,913
Potassium molybdate	420.20	--	--	--	40	27	134
Sodium molybdate	421.10	365	205	721	434	403	758
Mixtures of inorganic compounds, chief value molybdenum	423.88	38	7	88	127	38	212
Molybdenum orange	473.18	2,154	NA	2,278	1,651	NA	1,754
Total[1]		9,686	4,969	25,794	9,878	6,040	27,138

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, 1986	Most favored nation (MFN) Jan. 1, 1987	Non-MFN Jan. 1, 1986
Molybdenum ore and concentrate	601.33	9.4 cents per pound	9 cents per pound	35 cents per pound.
Material in chief value molybdenum	603.40	6.5 cents per pound plus 2% ad valorem.	6 cents per pound plus 1.9% ad valorem.	50 cents per pound plus 15% ad valorem.
Ferromolybdenum	606.31	4.9% ad valorem	4.5% ad valorem	31.5% ad valorem.
Molybdenum:				
Waste and scrap	628.70	6.6% ad valorem	6% ad valorem	50% ad valorem.
Unwrought	628.72	6.7 cents per pound plus 2.2% ad valorem.	6.3 cents per pound plus 1.9% ad valorem.	50 cents per pound plus 15% ad valorem.
Wrought	628.74	7.3% ad valorem	6.6% ad valorem	60% ad valorem.
Molybdenum chemicals:				
Ammonium molybdate	417.28	4.5% ad valorem	4.3% ad valorem	29% ad valorem.
Calcium molybdate	418.26	4.7% ad valorem	Free	24.5% ad valorem.
Molybdenum compounds	419.60	3.3% ad valorem	3.2% ad valorem	20.5% ad valorem.
Potassium molybdate	420.22	3.1% ad valorem	3% ad valorem	23% ad valorem.
Sodium molybdate	421.10	3.9% ad valorem	3.7% ad valorem	25.5% ad valorem.
Mixtures of inorganic compounds, chief value molybdenum	423.88	2.9% ad valorem	2.8% ad valorem	18% ad valorem.
Molybdenum orange	473.18	3.9% ad valorem	3.9% ad valorem	25% ad valorem.

WORLD REVIEW

World mine production of molybdenum was 206 million pounds, a decrease of 10 million pounds from that in 1985. Canada, Chile, the U.S.S.R., and the United States accounted for more than 89% 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 declined during 1986.

Canada.—Molybdenum production (shipments) in Canada increased 64% in 1986 over that in 1985.

Chile.—Molybdenum production decreased 11% compared with that of 1985. Much of the Corporación Nacional del Cobre de Chile production came from the Chuquicamata Mine, the largest copper mine in the world.

[1] Physical scientist, Division of Ferrous Metals.

Table 11.—Molybdenum: World mine production, by country[1]

(Thousand pounds of contained molybdenum)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Bulgaria[e]	375	420	420	420	400
Canada (shipments)	30,779	22,474	25,479	17,311	28,440
Chile	44,198	33,651	37,172	40,541	[3]35,971
China[e]	4,400	4,400	4,400	4,400	4,000
Japan[e]	214	214	324	215	--
Korea, Republic of	796	313	348	734	660
Mexico	11,442	12,932	8,938	8,292	7,720
Mongolia[e]	1,830	2,120	2,200	2,200	2,200
Niger[e]	[3]93	88	73	[r]44	44
Peru	[r]6,427	[r]5,825	6,557	8,898	[3]7,681
Philippines	150	86	--	--	--
U.S.S.R.[e]	24,300	24,500	24,700	24,900	25,100
United States	84,381	33,593	103,664	108,409	93,976
Total	[r]209,385	[r]140,616	214,275	216,364	206,192

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

[1]Table includes data available through June 16, 1987.

[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 Peter G. Chamberlain[1]

A general drop in nickel demand characterized the 1986 nickel market in the United States, with the exception of nickel consumption in the various copper-nickel alloys. The low nickel demand extended beyond the U.S. borders. Most estimates of nickel consumption in market economy countries pointed toward a decline in consumption among those countries, but it was not as significant as the decline in the United States.

Although world nickel producers cut mine production in partial response to several years of oversupply, nickel output from nickel smelters and refineries continued to rise. This increased output, plus a sharp increase in exports from the U.S.S.R., placed surplus nickel on world markets, driving nickel prices to a 4-year low by yearend.

The sole U.S. integrated nickel mine-smelter complex succumbed to the continuing low nickel price and permanently closed

Table 1.—Salient nickel statistics

(Short tons of contained nickel unless otherwise specified)

	1982	1983	1984	1985	1986
United States:					
Mine production:					
Nickel ore (gross weight)	432,488	--	1,674,600	868,100	603,400
Shipments	3,203	--	14,540	6,127	1,175
Plant production:					
Smelter, from domestic ores (includes byproduct nickel)	3,456	W	9,604	5,214	1,651
Refinery, from imported matte	41,500	33,400	35,329	31,168	--
Secondary recovery, from purchased scrap:[e]					
From ferrous scrap	30,034	30,076	35,760	[r]36,690	[p]35,320
From nonferrous scrap	12,934	19,776	19,407	[r]16,955	[p]8,406
Exports:					
Primary (unwrought)	37,356	23,359	31,638	21,745	2,812
Total (gross weight)	57,029	43,913	58,525	51,429	23,269
Imports for consumption:					
Primary	129,787	152,333	176,715	157,690	129,094
Primary (gross weight)	177,493	215,361	249,929	220,349	159,298
Total (gross weight)	186,913	225,537	264,778	236,001	172,683
Consumption:					
Reported:					
Primary	103,981	127,845	136,861	119,907	107,062
Secondary (purchased scrap)[e]	35,690	42,034	49,649	42,295	[p]31,826
Apparent:					
Primary	138,032	[r]150,879	155,395	[r]157,795	137,582
Secondary (purchased scrap)[e]	42,968	49,852	55,167	[r]53,645	[p]43,726
Stocks, yearend:					
Government	32,209	32,209	32,209	37,222	37,222
Producer	62,000	38,500	37,300	[r]17,400	10,300
Consumer:					
Primary	18,853	20,448	20,934	19,106	16,557
Secondary[e]	10,004	10,304	6,520	6,302	[p]4,669
Employment, yearend:					
Mine	160	160	130	130	--
Smelter	230	230	170	170	--
Refinery	420	420	420	--	--
Price (cathode):[1]					
New York dealer, per pound	$2.24	$2.20	$2.22	$2.26	$1.86
World: Mine production	[r]685,022	[r]743,663	848,947	[p]884,251	[e]864,114

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Weighted average calculated by Metals Week.

Riddle, OR. A copper refinery producing byproduct nickel also closed during the year.

Domestic Data Coverage.—Domestic primary production data for nickel are obtained by the Bureau of Mines from a survey of the single integrated nickel mine-smelter and from another survey of the two copper refineries that produced byproduct nickel. Domestic consumption data for nickel are developed by the Bureau from a voluntary survey of U.S. plants. Of the 338 plants to which a survey request was sent, 316 responded, representing 78% of the apparent primary nickel consumption shown in table 4. Apparent consumption of primary nickel was estimated using U.S. primary production plus imports minus exports plus adjustments for Government and industry stock changes.

Legislation and Government Programs.—The General Accounting Office (GAO) issued a report on the "Adequacy of National Security Council (NSC) Study for Setting Stockpile Goals." The report challenged some assumptions used by the NSC in developing its revised stockpile recommendations during 1985. Legislation designed to transfer management of the stockpile to Congress and to change the method of calculating stockpile goals was defeated. Instead, Department of Defense Authorization Act, 1987, Public Law 99-661, required the President to appoint a National Defense Stockpile Manager and did not alter the method of calculating goals. The law extended the freeze on reducing stockpile goals below their 1984 quantities until October 1, 1987.

The U.S. Department of the Treasury, Bureau of the Mint, purchased 2 million pounds of nickel under five solicitations. The nickel cost from $1.7365 to $1.8675 per pound, considerably lower than the amounts paid in 1985.

The U.S. Liberty Coin Program authorized 25 million copper-nickel clad half-dollars to be minted during the year. About one-third of the revenue from them supported repair work on the Statue of Liberty under auspices of the Statue of Liberty-Ellis Island Foundation.

The Deep Seabed Hard Mineral Resources Reauthorization Act of 1986 (Public Law 99-507) enabled the National Oceanic and Atmospheric Administration to continue researching and regulating seabed mining. Four consortia have received exploration licenses under the act; no commercial recovery permits could be issued until 1988.

The U.S. Department of the Interior's Geological Survey (USGS) continued exploring metallic sulfide deposits occurring around hydrothermal vents in seafloor-spreading zones. Samples retrieved during cruises over the Gorda Ridge, off the coast of California, revealed that vent chimneys contained copper sulfides, iron, and zinc, but insignificant nickel.

The Pacific Ocean cobalt-rich manganese crusts continued to attract interest. These crusts are oxide deposits on midocean-plate seamounts, some within the Exclusive Economic Zone. The USGS retrieved a 6.7-ton bulk sample from a seamount near Johnson Island, south of Hawaii, for evaluating extraction procedures. The Bureau of Mines received some of the material for testing as part of this evaluation. Nickel content reportedly averaged 0.5% in the crusts.

The President signed Public Law 99-499, Superfund Amendments and Reauthorization Act of 1986, on October 17. The act reauthorized Superfund expenditures of $8.5 billion to clean hazardous wastesites over a 5-year period. Of interest to the scrap industry, recycled nickel was exempted from the chemical feedstock tax, used to finance cleanup efforts, although primary nickel had been listed with the taxable materials.

The Environmental Protection Agency published regulations on solid mine waste as required under the Resource Conservation and Recovery Act. The regulations essentially exempt mine wastes from the classification "hazardous wastes," with the attendant tough disposal requirements.[2]

According to the "Agreed Report of the Joint U.S.-U.S.S.R. Commercial Commission," December 5, 1986, the delegates agreed in principle on a resolution of the embargo of Soviet nickel from being shipped into the United States. Soviet nickel had been banned since December 1983 by the U.S. Department of the Treasury, Office of Foreign Assets Control, because of the U.S.S.R.'s refusal to certify that its nickel did not contain Cuban nickel. Nickel originating from Cuba had been banned since 1963 under section 5(b) of the Trading With the Enemy Act and the Cuban Assets Contol Regulations.

The Comprehensive Anti-Apartheid Act of 1986, Public Law 99-440, banned imports of iron and steel products from the Republic of South Africa. After considerable deliberation, Treasury—assigned responsibility to enforce the act—interpreted it to exempt ferroalloys from the embargo. The act also charged the Administration with preparing a report on U.S. reliance on the Republic of South Africa for critical and strategic materials (including nickel) by the end of the year. This report was intended to form the foundation for subsequent decisions on other sanctions that may be imposed against the Republic of South Africa. Such decisions could directly affect the nickel imported into the United States from the Republic of South Africa as well as that transshipped through it from Zimbabwe.

Under title III of the Defense Production Act, the U.S. Department of Defense initiated a procurement to stimulate domestic recycling of superalloys to recover strategic metals. The procurement, targeted for nickel and chromium, will be executed in two phases. The first will identify sources with the capability of producing acceptable grades of pure metals for strategic applications in sufficient quantity; the second will include negotiations for fixed price contracts for up to two sources that successfully demonstrate capabilities under the first phase.

A U.S. Customs Service surcharge of 0.22% on all imports was implemented on December 1 to help defray Customs operating expenses. Several countries protested the tax, claiming that it violated the General Agreement on Tariffs and Trade (GATT).

DOMESTIC PRODUCTION

M. A. Hanna Co. mined ore from the Nickel Mountain Mine near Riddle, OR, until the end of May. This ore was the first processed through the new wet screening and slurry transport systems, installed late in 1985. In June, Hanna closed the mine and fired two furnaces in the nearby smelter to test the smelting characteristics of ore processed through the new systems. Upon completing the test run in mid-August, the company closed the smelter to evaluate test results. By the end of the fourth quarter, the company decided that the nickel price would not rebound to a profitable level in the foreseeable future; the nickel operation was permanently closed. Also, AMAX Inc.'s Cateret, NJ, plant—one of two copper refineries producing byproduct nickel—closed in October. The closures virtually eliminated the United States as a primary nickel producer.

Interstrat Resources Inc. announced that Davy McKee Corp. had completed a detailed engineering report on a possible mining-processing operation for Interstrat's Pine Flat laterite deposit. The deposit, on the Oregon-California border, could profitably produce 7,000 short tons of nickel per year along with magnesium and cobalt, according to the report. Construction would cost an estimated $257.7 million; a 13-year mine life was planned. The report recommended pilot plant testing and establishing an environmental data base.

The State of Minnesota, Department of Natural Resources, conducted a copper, nickel, and associated minerals lease sale with the bid opening on December 11, 1986. Areas offered for lease included tracts in the Duluth Gabbro Complex, which hosts the Nation's largest resources of nickel as well as substantial quantities of cobalt, copper, and precious metals.

Falconbridge Ltd., Canada, evaluated the Madison Mine in Missouri for possible cobalt and nickel production under an agreement with Anschutz Mining Corp., the mine owner. Results of the drilling and testing program, however, led Falconbridge to decline options to reopen the mine owing to inadequate ore reserves.

After a successful testing program, AMAX Nickel Inc. began commercially recovering cobalt and nickel as hydroxides from spent petroleum catalysts at its Port Nickel refinery in Braithwaite, LA. The nickel hydroxides were sent out of the country for smelting and refining into pure nickel. Primary nickel production at the refinery had ceased in November 1985. The catalyst recycling production reached 70% of the design capacity by yearend 1986. The plant is near gulf coast petrochemical refineries, which must dispose of the spent catalysts.

In contrast to the scant domestic production of primary nickel, the production of domestic secondary nickel in the form of scrap contributed a major 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 amount of nickel recovered and consumed as stainless steel scrap gained over the quantity recovered in 1985. Recovery of other forms of nickel in scrap sharply declined, reflecting the severe drop in primary nickel prices. This drop made primary nickel a more attractive choice where either material could be charged to furnaces. The nickel recovered from stainless steel scrap was calculated from the gross weight of the scrap and an estimated nickel content of 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[r]	1986[p]
KIND OF SCRAP		
Aluminum-base	111	109
Copper-base	2,505	2,031
Ferrous-base	36,690	35,320
Nickel-base	14,339	6,266
Total	53,645	43,726
FORM OF RECOVERY		
Aluminum-base alloys	115	128
Chemical compounds	W	W
Copper-base alloys	11,512	6,301
Ferrous alloys	36,690	35,367
Nickel-base alloys	5,328	1,930
Total	53,645	43,726

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Copper-base alloys."

CONSUMPTION

Reported domestic primary nickel consumption dropped 11% below that consumed in 1985. Consumption shrank in all product categories except copper-nickel alloys. The total apparent primary nickel consumption fell along with reported consumption because the percentage of companies reporting to the Bureau did not change significantly between 1985 and 1986.

The consumption decline countered the general state of the Nation's economy. The U.S. Department of Commerce's composite index of economic activity in 1986 gained over the index in 1985. Gross national product (GNP)—deflated to 1982 dollars—likewise grew 2.6% above its value in 1985. Several key industries that demand nickel either showed a higher or stable output value. For instance, construction spending, home appliance shipments, aerospace sales, machine tool sales, and domestic automotive sales were higher than they were in 1985; factory shipments, chemical shipments, and truck sales were fairly stable.

Considering these positive factors in the economy, at least a modest growth in nickel consumption should have been expected. Instead, the declining consumption pointed toward a decreasing intensity of use of nickel. This marked the first significant decline since 1982. Part of it resulted from the continuing growth in the service sector of the GNP, which boosted the value of the GNP without affecting materials consumption. Part could be attributed to higher imports of certain forms of stainless steel. Imports of finished goods (for example, consumer electronics) likewise directly reduced domestic consumption of nickel. Substitution continued to slightly erode some nickel markets.

Several negative factors in nickel consumption emerged. The largest drop was in plating, as platers continued a trend toward thinner layers of plating material. The next biggest drop in primary nickel consumption could be attributed to a decline in consumption in making stainless steel, the largest single end use for nickel. Although stainless steel production reported by the American Iron and Steel Institute remained the same in 1986 as it was in 1985, the primary nickel consumption in stainless steel dropped 8%. Part of this paradox could be explained by a continuing shift to non-nickel grades of stainless steel from nickel-bearing (austenitic) grades. In 1985, austenitic grades comprised 70.4% of the total stainless steel produced; in 1986, the relative amount fell to 68.1%. This represented a probable loss of 3,200 tons of nickel consumption. The rest of the loss in consumption of primary nickel in stainless steel resulted from an increase in the consumption of nickel in stainless steel scrap.

Commercially pure unwrought nickel (Class I) in the form of electrolytic cathodes, pellets, briquets, or powder again dominated the forms of primary nickel consumed (figure 1). These forms comprised most of the nickel consumed in all products except in stainless and heat-resistant steels wherein they were a major but not dominant source. Cathodes and pellets comprised 75% of the pure unwrought nickel consumed. The Class II materials—ferronickel, nickel oxide, oxide sinter, and utility-grade nickel—were primarily used in producing stainless and heat-resistant steels.

Consumption of nickel in scrap was a major form of consumption in stainless steel production. The nickel consumed as outside scrap (old and new scrap received by the consumer from outside sources, generally through purchases) and recycled steel mill wastes contributed an estimated 40% of the total nickel consumed in producing stainless steel. Consumption statistics include only this outside scrap to avoid double counting.

The use of scrap nickel in producing nonferrous alloys dropped to about one-fifth of the nickel consumed in these alloys. About one-half of nickel in cast iron originated as outside scrap. For chemicals, essentially none of the nickel was secondary. For alloy steels, excluding stainless and heat-resistant classifications, less than 5% of the nickel was consumed in the form of outside scrap.

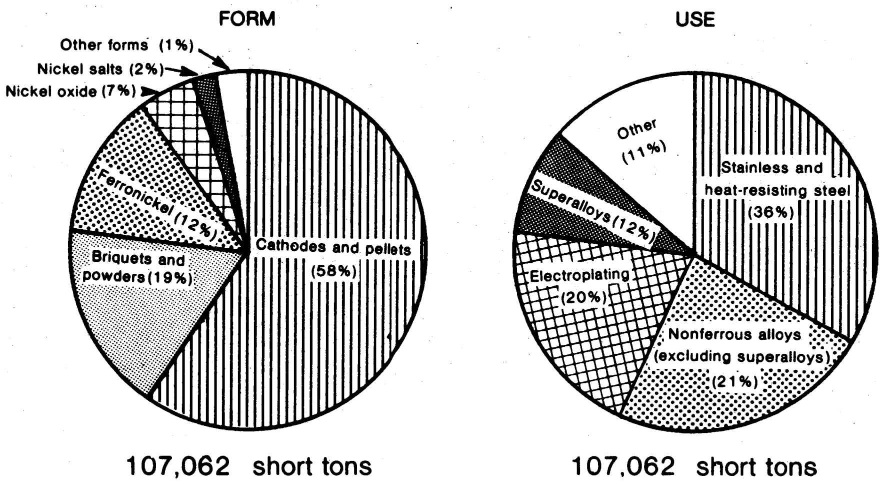

Figure 1.—U.S. nickel consumption in 1986, by form and use.

Table 3.—Reported U.S. consumption of nickel, by form

(Short tons of contained nickel)

Form	1982	1983	1984	1985	1986
Primary:					
Ferronickel	15,426	15,595	18,419	17,993	13,256
Metal	79,032	96,981	104,958	90,379	82,884
Oxide powder and oxide sinter	4,196	9,670	7,087	6,297	7,357
Salts[1]	3,874	4,402	2,962	2,770	2,416
Other	1,453	1,197	3,435	2,468	1,149
Total primary	103,981	127,845	136,861	119,907	107,062
Secondary (scrap)[2]	35,690	42,034	49,649	42,295	[p]31,826
Grand total	139,671	169,879	186,510	162,202	138,888

[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 1986, 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	594	353	61	W	254	1,262	1,350	2,612
Chemicals and chemical uses	1,490	--	116	97	162	1,865	--	1,865
Electric, magnet, expansion alloys	338	--	--	--	--	338	47	385
Electroplating (sales to platers)[1]	18,824	W	W	2,150	25	20,999	--	20,999
Nickel-copper and copper-nickel alloys	3,916	--	2	--	373	4,291	6,301	10,592
Other nickel and nickel alloys	18,013	131	26	W	27	18,197	1,739	19,936
Steel:								
Stainless and heat-resistant	19,259	12,346	6,708	--	130	38,443	21,720	60,163
Alloys (excludes stainless)	7,100	405	242	--	124	7,871	350	8,221
Superalloys	12,540	W	W	W	47	12,587	159	12,746
Other[2]	810	21	202	169	7	1,209	160	1,369
Total reported by companies canvassed	82,884	13,256	7,357	2,416	1,149	107,062	31,826	138,888
Total all companies, apparent	XX	XX	XX	XX	XX	[3]137,582	43,726	181,308

[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 U.S. producers, foreign producers with U.S. sales offices, and metal trading companies with U.S. sales offices again decreased sharply during the year. A major factor was the closure of Hanna's nickel mine and smelter in Oregon. At yearend, these stocks represented slightly less than 1 month's domestic consumption.

Nickel stocks on the London Metal Exchange (LME) increased slightly to about 8,100 tons, compared with 7,100 tons at yearend 1985.

Consumer stocks declined steadily during the year from the relatively high levels carried over from 1985. Following previous years' patterns, a December buying spree increased the yearend stocks to relatively high levels. The yearend 1986 stocks were, however, down 13% from the yearend 1985 stocks, again representing about 6 weeks' consumption. Stocks of nickel held in stainless steel scrap were considerably lower at yearend than they were at yearend 1985.

The National Defense Stockpile remained at 37,222 tons, considerably less than the 200,000-ton goal.

Table 5.—Nickel in consumer stocks in the United States, by form

(Short tons of contained nickel)

Form	1982	1983	1984	1985	1986
Primary:					
Ferronickel	1,122	893	692	1,930	1,028
Metal	16,743	17,359	17,479	13,754	11,829
Oxide and oxide sinter	488	1,677	2,259	3,059	3,281
Salts	226	268	229	184	175
Other	274	251	275	179	244
Total primary	18,853	20,448	20,934	19,106	16,557
Secondary (scrap)	10,004	10,304	6,520	6,302	[p]4,669
Grand total	28,857	30,752	27,454	[r]25,408	21,226

[p]Preliminary. [r]Revised.

PRICES

The world nickel price continued its long decline. By yearend, it had reached its lowest value since December 1982. Several factors interacted to push the price down. The major factor was the large growth in exports of nickel from the U.S.S.R. into European and Japanese markets. In the first half of the year, labor strife at several major operations created enough concern over nickel supplies to hold the price relatively steady. By summer, however, most of the labor disagreements had been settled, and it became obvious that a surplus of nickel existed on the market. As Soviet shipments swelled, the LME price slid to a low of $1.655 per pound for a December average. The growth in Soviet exports was attributed to the sharp decline in oil prices, which forced the U.S.S.R. to export more nonpetroleum products to obtain foreign revenue. A rather listless demand, particularly the drop in U.S. consumption, intensified the price decline.

The LME price remained the leading nickel price indicator. For 1986, this price averaged $1.761 per pound, down 22% from that of 1985. In the United States, the New York dealer price for electrolytic cathode nickel best indicated prices paid by U.S. consumers. At a weighted average of $1.855 per pound for 1986, as calculated by Metals Week, the New York dealer price dropped about the same amount from its 1985 value as did the LME price. Although North American producers continued to list their nickel prices at about $3.20 per pound, they discounted the actual selling prices from 10 to 15 cents per pound above the New York dealer prices. One producer, for instance, reported an average realized price of $2.02 per pound for primary nickel in 1986, down from the $2.39 realized in 1985.

For the first time since 1981, Inco Ltd. posted a new producer price for nickel, this one for utility-grade nickel sold to European stainless steel producers. The price of $1.75 per pound was established in December.

The price of stainless steel scrap, the largest source of secondary nickel for consumption, followed the price of primary nickel. According to Iron Age, the price of stainless steel bundles in Pittsburgh fell from a range of $515 to $525 per ton at the beginning of the year down to a range of $485 to $495 by yearend. The American Metal Market market performance indices for various forms of scrap revealed that stainless steel scrap prices performed the worst in 1986 after performing the best, according to the indices, in 1985.

FOREIGN TRADE

The closure of the AMAX Nickel refinery late in 1985 and the Hanna smelter in 1986 substantially altered the nickel trade patterns for the United States. The net import reliance rose to 75% as 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. Botswana became an insignificant source after AMAX Nickel stopped importing matte for its refinery.

Although it was an insignificant amount, the 600 tons of cathode nickel imported from China could portend future shifts in nickel trade. In 1984, China imported most of its nickel requirements. Strenuous efforts by the Government of China to double its 1985 nickel output by 1990 yielded surplus nickel, which was sold to market economy countries. This material appeared at the same time that the U.S.S.R. was flooding the market with nickel, forcing prices down to 4-year low levels.

Preliminary negotiations in Geneva laid the foundations for a new round of trade negotiations under GATT to be held in Punte del Este, Uruguay. None of the issues that were identified at the negotiations were expected to change nickel tariffs in the United States.

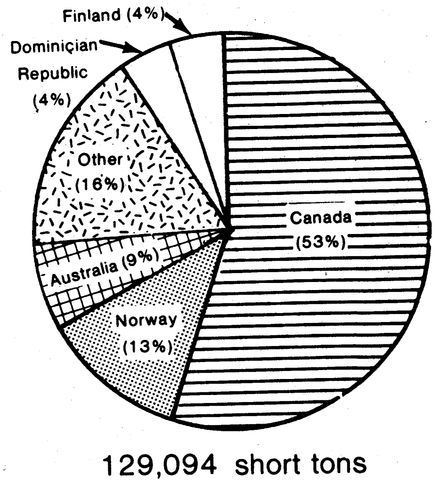

Figure 2.—Major sources of U.S. primary nickel imports in 1986.

Table 6.—U.S. exports of nickel and nickel alloy products, by class

(Gross weight unless otherwise specified)

Class	1984		1985		1986	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Primary:						
Cathodes, pellets, briquets, and shot (unwrought)	25,997	$118,453	17,761	$86,596	1,936	$12,542
Electroplating anodes	140	965	132	965	108	961
Ferronickel	7,880	NA	5,355	NA	455	NA
Powder and flakes	1,790	12,062	1,106	8,942	584	5,913
Total	35,807	131,480	24,354	96,503	3,083	19,416
Nickel content[1]	31,638	XX	21,745	XX	2,812	XX
Wrought:						
Bars, rods, angles, shapes, sections	3,342	34,808	4,253	45,060	2,239	29,735
Plates, sheets, strip	1,968	21,316	2,645	28,726	3,676	25,151
Tubes, pipes, blanks, fittings, hollow bar	428	7,929	303	6,356	684	6,430
Wire	1,119	11,166	954	9,147	844	8,520
Nickel-compound catalysts	2,718	15,156	3,523	22,811	2,243	10,631
Nickel waste and scrap	13,143	23,566	15,397	26,705	10,500	15,012
Grand total	58,525	245,421	51,429	235,308	23,269	114,895

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	1984 Quantity (short tons)	1984 Value (thousands)	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)
Primary:						
Smelter products:						
Ferronickel	43,048	$68,429	36,528	$60,253	37,901	$53,672
Salts and other (including slurry)	82,509	116,956	68,210	101,101	9,170	19,281
Refined nickel:						
Cathodes, pellets, briquets, and shot (unwrought)	103,017	461,371	97,779	446,009	99,017	407,210
Flakes	759	3,306	242	1,151	600	2,420
Oxide and oxide sinter	5,526	22,413	5,079	20,722	2,868	4,372
Powder	15,070	75,430	12,511	66,566	9,742	48,631
Total	249,929	747,905	220,349	695,802	159,298	535,586
Nickel content[1]	176,715	XX	157,690	XX	129,094	XX
Wrought:						
Bars, plates, sheets, anodes	2,000	18,036	3,177	32,276	2,310	17,048
Pipes, tubes, fittings	1,171	11,034	3,744	33,984	1,487	16,616
Rods and wire	5,419	28,544	2,990	22,103	2,640	19,228
Shapes, sections, angles	60	506	189	1,297	153	1,002
Nickel waste and scrap	6,199	20,542	5,552	16,430	6,795	19,581
Grand total	264,778	826,567	236,001	801,892	172,683	609,061

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 1986, 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 1986	Total 1985
Australia	7,458	2,550	1,875	--	--	11,883	18,537
Botswana	253	--	--	--	--	253	11,244
Canada	58,394	6,731	604	13	3,278	69,020	70,679
China	586	1	--	--	54	641	--
Colombia	--	--	--	3,137	--	3,137	676
Dominican Republic	--	--	--	5,654	--	5,654	7,761
Finland	5,303	--	--	--	59	5,362	4,771
France	2,227	287	--	--	172	2,686	2,094
Germany, Federal Republic of	98	98	--	1	119	316	820
Japan	24	--	--	436	9	469	175
New Caledonia	--	--	--	3,797	--	3,797	3,772
Norway	16,669	--	--	--	--	16,669	24,166
Philippines	1,433	--	--	--	--	1,433	1,299
South Africa, Republic of	2,736	438	--	17	--	3,191	7,159
United Kingdom	386	155	--	--	6	547	650
Zimbabwe	3,045	--	--	--	--	3,045	2,150
Other	405	82	--	--	504	991	[r]1,737
Total	99,017	10,342	2,479	13,055	4,201	129,094	157,690

[e]Estimated.

Sources: Bureau of the Census and Journal of Commerce.

WORLD REVIEW

Although world nickel producers have operated at approximately 75% of nameplate capacity for the last 2 years, a chronic oversupply of nickel persisted. Early in 1986, labor-related closures among several major producers spawned hope that supply would match demand for the year. Such a balance did not materialize. While nickel production in market economy countries declined, nickel production and net exports from centrally planned economy countries into market economy countries more than offset these cutbacks.

Representatives from the major nickel producing and consuming countries seeking to form an International Nickel Discussion Group (INDG) continued to finalize rules and procedures. At a meeting in Geneva, April 14-18, the representatives agreed to formally charter the organization when at least 15 countries representing 50% or more of the world trade in nickel accepted the "terms of reference." The terms of reference were provided to the Secretary General of the United Nations, who forwarded copies to the participating governments. The governments were asked to respond by September 20, 1986, so that an inaugural meeting could be held by the end of October. Although many governments expressed interest in joining the INDG, the lengthy approval processes resulted in delaying the inaugural meeting until 1987.

Albania.—Construction continued on a nickel-cobalt refinery being built near Elbasan by the West German company Salzgitter AG using technology supplied by Inco.

The Government announced a new 5-year plan for 1986-90 that called for a 30% to 40% increase in ferronickel production, mostly from the opening of a new mine at Betinchi.

Australia.—Agnew Mining Co. Pty. Ltd. shelved plans to develop an open pit mine near its Agnew Mine while rehabilitating the Agnew Mine after a 1985 rockfall. Instead, the company closed the Agnew Mine indefinitely on August 15, citing continuing financial losses as the reason.

Also citing the financial burden created by low nickel prices, Western Mining Corp. Ltd. closed five of its high-cost mines in the Kambalda District and one mine in the Windarra District. The actions were expected to cut nickel production by 10% while eliminating 200 jobs. The announcement triggered a 6-week strike among mine workers in the Kambalda District in April and May. The company imposed a 4-week vacation shutdown of all operations in December.

Queensland Nickel Pty. Ltd. and Nikko Nickel Cobalt Refining Co., Japan, terminated their contract under which Queensland supplied nickel-cobalt sulfides to the Japanese refinery for cathode nickel and cobalt production. Queensland subsequently contracted to sell all of its byproduct sulfides to Outokumpu Oy for Outokumpu's refinery in Kokkola, Finland. Queensland also began testing ore from Indonesia and New Caledonia at the Yabulu refinery to determine possible future sources of ore after the company's mine reserves are exhausted (expected to be within the next 5 years). The company began considering constructing a pier at the refinery's port near Townsville to accommodate such foreign ores.

Bolivia.—The Eastern Bolivian Mineral Exploration Project (also known as Proyecto Precambrico), established in 1975 between the Bolivian Geological Service and the British Geological Survey, delineated a significant lateritic nickel deposit, the Rincon del Tigre. Although most of the deposit exhibited nickel grades of 1% to 2%, exploration sampling late in 1985 at Cerro Pelon uncovered portions with grades up to 11%. Approximately 5.5 million tons of material averaging 1% nickel has been delineated. The exploration project expired in April.

Botswana.—Financial difficulties continued to plague Bamangwato Concessions Ltd. (BCL) despite the new sales contracts negotiated with Falconbridge Ltd. and others in 1985. During 1986, longer customs procedures imposed by the Republic of South Africa reportedly delayed BCL matte transported through the country to South African ports. The procedures allegedly were adopted in response to the call for sanctions against the Republic of South Africa by several interior countries that export via rail lines through the Republic of South Africa.

Brazil.—Cia. Níquel Tocantins continued expanding its operations toward a target capacity of 11,000 tons of nickel cathodes by 1988.

A bill introduced into the Brazilian legislature would require at least a majority Brazilian equity in companies developing "strategic" minerals in the country. The bill defined nickel as strategic. The effect of such legislation on existing operations was not clear; foreign interests own the largest Brazilian nickel mine-smelter complex.

BP Mineração S.A., a subidiary of British Petroleum Co. Ltd., announced that it was evaluating a possible mine-refinery complex at Forteleza de Minas, Minas Gerais. The plant could be producing nickel by 1990 if a Brazilian partner is found early in 1987. The nickel deposit contains 5.3 million tons of material averaging 2.6% nickel. The plant would produce 11,000 tons of nickel per year as cathodes.

Cia. Vale do Rio Doce (CVRD) reported that the Carajas Mineral Province, noted for its huge iron ore deposits, also contains at least five lateritic nickel deposits. The largest, Vermelho, contains 44 million tons averaging 1.56% nickel. Nickel deposits were not expected to be developed for at least 5 years.

Canada.—Production of nickel from mines and refineries increased over that of 1985. Canada remained the second largest nickel producing country in the world and the largest among market economy countries.

Falconbridge settled a 5-day strike of clerical and other office workers in May with a 3-year contract. By September, the continuing depressed nickel prices prompted the company to consider several means to reduce costs in addition to the drastic cost cuts of recent years. The work force in Sudbury was cut by 200 (approximately 10%), most through early retirement. The company also imposed salary cuts on management personnel and announced the closure of the East Mine by 1988.

Falconbridge acquired the Kenty Lake nickel-platinum claims in the Ungava nickel belt in northern Quebec. Work on the claims emphasized surface exploration. The region's remoteness precluded any short-range development.

Inco, the largest nickel producer among market economy countries, boosted its annual production by 6% over that of 1985. This increase, plus continuing efforts to cut high-cost production, enabled the company to break even despite a sharp decline in the prices realized for its nickel. Key cost-cutting measures included halting production at the Clarabelle open pit, Creighton No. 3, Stobie, and Shebandowan Mines as the year began. The Sudbury and Manitoba Districts also were closed for a 5-week summer vacation shutdown. A rock fall at the Garson Mine caused the company to suspend mining activities at the mine for the rest of the year.

Inco began producing nickel from its new Thompson open pit mine, Manitoba, in April. The mine, formally inaugurated in September, required dredging and draining Thompson Lake to gain access to the ore body, which remained as a crown pillar above the Thompson underground mine. Estimated production costs at the mine averaged 50% lower than costs at the company's underground mines. The company also committed Can$25 million toward rehabilitating the Crean Hill Mine.

As part of its program to reduce sulfur dioxide emissions from the Copper Cliff smelter, Inco announced development of a new technique for removing most of the sulfide mineralization as pyrrhotite while the ore is being milled. The company also studied a new bulk smelting technique for smelting the nickel and copper together into one matte.

In an attempt to stabilize nickel prices, Inco negotiated a list price of $1.75 per pound for utility-grade nickel with European stainless steel producers. The price, first new list price for the company since 1981, will become effective for first-quarter 1987 purchases.

Hudson Bay Mining and Smelting Co. Ltd. and Outokumpu Oy, Finland, signed a letter of intent to establish a joint venture to develop the Namew Lake nickel deposit near Flin Flon, Manitoba. Hudson Bay sank a shaft on the property to provide material for bulk metallurgical testing.

Sherritt Gordon Mines Ltd. refined a company record high 26,500 tons of nickel after completing significant process changes at its Fort Saskatchewan, Alberta, refinery. The company also modified its coinage processing facility at the refinery for its contract with the Canadian mint to produce blanks for a new bronze-coated-nickel Can$1 coin.

China.—China began exporting nickel as a consequence of its program to boost annual nickel production to 44,000 tons by 1990. Production had only been 15,000 tons in 1984. Expansion of nickel production from Jin Chuan District in the Gansu Province provided most of the increase. from an importer to a net exporter of nickel. Although most of China's nickel exports were to Japan, 600 tons were exported to the United States.

China and Japan agreed upon a 5-year joint exploration and development program, which included exploring for nickel in the Dayangqi District in Heilongjiang Province, northeastern China.

Colombia.—Cerro Matoso S.A. achieved its highest annual production, 20,500 tons. The company apparently overcame the furnace problems that had plagued its nickel smelter in previous years. The smelter produced at approximately 85% of its capacity.

Cuba.—The new Che Guevara nickel refinery at Punta Gorda, which began production in February, produced only 1,300 tons of nickel for the year. The production difficulties caused the refinery to revise its target date for achieving capacity production in the first furnace line to late 1987. The difficulties also delayed startup of a second line until at least 1988.

The Government of Cuba announced that operations at the Commandante Pedro Sotto Alba (Moa) refinery and the two open pit mines that feed it would be streamlined, eliminating one-third of the 1,600 jobs at the mining complex.

Dominican Republic.—Falconbridge Dominicana C. por A. workers struck for 5 weeks beginning on April 1 over bonus pay issues. The strike at the nickel mine and smelter at Bonao contributed to a nearly 15% decline in ferronickel production for the year.

Finland.—Outokumpu began processing nickel-cobalt sulfide from Queensland's Yabulu refinery in Australia. Outokumpu refined the material, a residue from Queensland's nickel oxide production, at its Kokkola refinery into nickel and cobalt salts.

A widespread but short-lived strike of Finnish laborers, including those of Outokumpu, halted nickel production for several days in March. A furnace leak at the Harjavalta smelter also thwarted production for an unreported time period during October.

At the Keretti Mine, Outokumpu opened a nickel-cobalt ore body above the main cobalt-copper-zinc deposit.

France.—Establissement Montaire de Pessac, the French mint, began producing and then withdrew a new nickel 10-franc coin. The mint apparently decided to redesign the coin. Eramet-SLN had supplied 860 tons of nickel for the first year's production.

Greece.—Larco S.A. experienced a series of work stoppages at its ferronickel smelter and mines. The labor difficulties began in August when the Government of Greece announced fringe-benefit cuts and reductions in the work force at the state-owned operations. The announcement triggered an immediate 1-day strike followed by a protracted string of partial stoppages beginning in September. In December, workers and company officials resolved their differences and uninterrupted production resumed. For these reasons, ferronickel production for 1986 dropped lower than it was in 1985. The company began considering a plan to convert part of the ferronickel capacity into ferrochromium production to use the smelter more cost-effectively.

Indonesia.—Despite productivity improvements and lower fuel costs, P.T. International Nickel Indonesia reportedly continued to operate at a loss. The company installed a Pierce-Smith converter in its nickel smelter to replace its outdated top-blown rotary ones. The operation observed a 6-week summer shutdown, one-half for vacation and one-half for balancing production with demand.

Japan.—Ferronickel production dropped sharply as demand from the stainless steel industry fell.

The two pure nickel refineries experienced difficulties in obtaining raw material feedstock. Nikko Nickel Cobalt Refining, owned by Nippon Mining Co. Ltd., lost its contract to obtain nickel-cobalt sulfide residues from Queensland's Yabulu refinery in Australia. Consequently, nickel and cobalt production at the Hitachi refinery halted at the end of September. By yearend, Sumitomo Metal Mining Co. Ltd. also had to cut back nickel production by 10% per month at its Niihama refinery. This occurred because the Nonoc Mining and Industrial Corp. (Philippines), a major supplier of nickel feedstock to Sumitomo, failed to reopen its operation following a labor dispute that began in March.

Despite the difficulties, production of pure nickel exceeded that of 1985.

The Ministry of International Trade and Industry (MITI) initiated a financing program to help Japanese companies explore for rare metals (including nickel) overseas. A key provision stipulated "repayment upon success." MITI formed an agreement with the Government of China to explore for nickel and other base metals in the Heilongjiang Province of China. In 1986, the Japanese market became the major target for marketing the increased nickel production from the Jin Chuan District in China.

MITI submitted plans for revamping the national ferroalloy stockpile. Under the new plan, instead of a 60-day supply in three stockpiles, nickel would be included in two stockpiles—one controlled by the Government with a 42-day supply of ferroalloys;

the other under industry control with an 18-day supply of material. The stockpile would also be expanded to include metals necessary for the electronics and superalloy industries. Of the stockpile goal, only 26.4 days' supply was on hand by the end of the fiscal year.

Tokai University scientists discovered a large cobalt- and nickel-rich manganese crust off the coast of Minami-Torishima Island. A 1-ton sample was retrieved for testing and analysis.

New Caledonia.—Société Métallurgique Le Nickel-SLN cut production of ferronickel and matte by 10% below the amounts produced in 1985 to better balance output with demand.

Separatist violence of the previous 2 years lingered on as Kanak natives reportedly smashed generators and damaged a crushing plant at a small nickel mine operated by the General Trading and Mining Co. (Ballande Group).

Nickel ore exports to Japan, the major outlet for the small-mine operators on the island, dropped compared with those of 1985. Japanese consumers were faced with declining demand, and Chinese nickel began to appear on Japanese markets. The small operators made up part of their lost offshore sales with extra sales to SLN's Doniambo smelter.

Norway.—Falconbridge Nikkelverk A/S locked out workers at its Kristiansand nickel refinery during a labor dispute between several of the country's unions and the Employers Association of Norway, of which the company is a member. The lockout lasted for 1 week in early April. The refinery produced slightly more cathode nickel in 1986 than it did in 1985.

Philippines.—Nonoc continued to produce nickel from its mining and processing facilities near Surigao early in the year. At the end of January, the company asked for an $11 million loan from the Government to upgrade the facilities. In February, the loan was approved by the outgoing Government of the Philippines and, a few days later, by the new Government. Workers struck on March 20 when they did not receive back wages, and the entire operation was closed. The company claimed that it could not pay the wages because the Government banks had not released the funds approved under the loan. Although the company and striking workers eventually agreed on terms for settling the strike, the workers refused to return until the company paid all back wages. In August, the company and the Government renegotiated for a $20 million loan so that back wages could be paid and facilities upgraded. Although the Government also approved this loan, it apparently would advance only $10 million. The operation remained closed at yearend while other sources of funding were being sought.

South Africa, Republic of.—Western Platinum Ltd. officially opened its new base metal refinery at Marikana near Rustenberg, Transvaal, in December. The refinery had a rated capacity of 2,200 tons of nickel in sulfates. Falconbridge increased its share in Western Platinum to 49% by purchasing the 24% held by Mobil Oil Corp.

Labor strife hampered the mine output of Impala Platinum Holding (Pty.) Ltd., which produced byproduct nickel. On January 1, three-fourths of the workers at all four company mines struck over wages. Although workers at one mine returned on the next day, the company fired over 20,000 from the remaining mines. The process of hiring and training replacements caused an estimated 25% decline in ore production from the mines during the first quarter.

A 4-month dispute between the National Union of Mine Workers and the Chamber of Mines, which represented most of the major mining companies (including those that produce byproduct nickel), ended with an agreement on a new labor contract in October. Workers reportedly received a raise of 23.5% plus additional fringe benefits.

Rustenburg Platinum Mines Ltd. suffered an explosion at its Rustenburg smelter in December. The casualty cut nickel output only slightly as the smelter was not running at capacity when it happened. Damage was expected to require 2 months to repair.

U.S.S.R.—Sharply increased exports of nickel from the Soviet Union to market economy countries throughout 1986 helped push world nickel prices downward. Exports jumped from approximately 27,000 tons in 1985 to an estimated 44,000 to 66,000 tons in 1986. Market analysts attributed the surge of exports to the sharp decline in world oil prices. Since the U.S.S.R. relied upon oil sales for obtaining foreign currency, the decline in oil revenues necessitated increased sales of alternative products such as nickel. Philipp Brothers Inc. emerged as the prime sales agent for Soviet nickel to market economy countries, reportedly handling about 2,200 tons per month.

Mining consortia from each of three countries—Finland, Norway, and Sweden—met with Soviet Government officials to discuss possible acquisition of Soviet mineral rights on the Kola Peninsula in exchange for mining and processing technology.

United Kingdom.—Wiggins Alloys Ltd., a subsidiary of Inco, purchased two electroslag refining furnaces to be installed in a new electroslag refinery commissioned during the second quarter of 1986. The plant will produce nickel-based superalloys for the aerospace industry.

Yugoslavia.—Incontra, Switzerland, reportedly ended its sales contract with Rudnik i Topionica Feronikl when Rudnik's Kosovo nickel smelter failed to provide the minimum amount of nickel specified in the contract. The smelter operated considerably below its rated capacity of 13,000 tons of nickel in ferronickel.

Zimbabwe.—Economic sanctions urged by the British Commonwealth and strongly supported by Zimbabwe against the Republic of South Africa reportedly triggered tighter controls on materials, including nickel, being transported from Zimbabwe to South African ports. In August, shortly after the sanctions were announced, the Republic of South Africa imposed lengthy inspections and costly customs deposits on transshipments from Zimbabwe. The South African ports represented the only reliable access to ocean shipping for most of the southern interior countries.

Concern over the vulnerability of their exports to South African politics led an alliance of nine countries, called the Southern African Development Coordination Conference, to undertake a major program of upgrading the Mozambique port, Beira. Twenty years ago, the port was a prime access from interior countries to the Indian Ocean. Years of guerrilla war in Mozambique, however, had ruined the railway system feeding the port, and economic woes had led to a general degradation of the port itself. In the first phase of renovation, the Conference sponsored laying new tracks on the railway linking the port to Harare, Zimbabwe, repairing wharves, and deepening the port. In addition to its role as a member of the Conference, Zimbabwe also stationed 12,000 troops along the rail corridor to Beira to protect it from guerrilla raids.

Table 9.—Nickel: World mine production, by country[1]

(Short tons of nickel content)

Country	1982	1983	1984	1985[p]	1986[e]
Albania (content of ore)[e]	[r]6,600	[r]7,900	[r]10,100	[r]10,600	10,700
Australia (content of concentrate)	96,510	84,465	84,793	94,531	77,000
Botswana (content of matte)	19,573	20,079	20,507	21,567	22,000
Brazil (content of ore)	15,929	17,153	25,940	22,377	25,400
Burma (content of speiss)[e]	22	22	22	22	22
Canada[2]	97,644	141,220	192,017	187,361	199,077
China[e]	13,200	14,300	15,400	[r]27,600	28,100
Colombia (content of ferroalloys)	[r]1,984	[r]19,243	24,124	17,013	24,300
Cuba (content of oxide, sinter, sulfide)	39,790	41,487	35,087	[e]35,700	36,000
Dominican Republic	5,926	21,552	26,371	27,992	24,300
Finland (content of concentrate)	6,980	5,858	7,638	8,730	7,200
German Democratic Republic[e]	2,800	2,400	2,200	1,800	1,700
Greece (recoverable content of ore)[e 3]	5,500	18,500	18,400	[r]20,600	19,300
Indonesia (content of ore)[3]	50,578	54,430	52,474	44,754	48,300
Morocco (content of nickel ore and cobalt ore)	140	--	--	--	--
New Caledonia (recoverable content of ore)	66,250	50,885	64,293	[e]80,400	71,700
Norway (content of concentrate)	[r]430	[r]397	358	485	440
Philippines	21,643	15,322	14,993	31,039	15,000
Poland (content of ore)[e]	2,300	2,300	2,300	2,200	2,200
South Africa, Republic of[e]	24,250	22,600	27,600	27,600	27,600
U.S.S.R. (content of ore)[e]	182,000	187,000	192,000	198,000	205,000
United States (content of ore shipped)	3,203	--	14,540	6,127	[4]1,175
Yugoslavia (content of ore)[e]	4,400	3,300	4,400	5,500	5,500
Zimbabwe (content of concentrate)[e]	[r]17,370	[r]13,250	[r]13,390	[r]12,253	12,100
Total	[r]685,022	[r]743,663	848,947	884,251	864,114

[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 May 12, 1987.

[2]Refined nickel and nickel content of oxides and salts produced, plus recoverable nickel in exported mattes and speiss.

[3]Includes a small amount of cobalt not reported or recovered separately.

[4]Reported figure.

Table 10.—Nickel: World plant production, by country[1]

(Short tons of nickel content)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Australia[3]	50,630	46,077	42,615	44,982	46,200
Brazil[4]	3,826	9,165	10,127	14,680	[5]14,840
Canada[3]	[5]64,635	96,100	114,600	100,300	[5]126,730
China[e]	13,200	14,300	15,400	[r]24,800	24,800
Colombia[4]	1,455	14,396	18,810	13,007	20,500
Cuba[6]	9,922	10,298	9,311	[e]9,370	8,490
Czechoslovakia[e]	1,700	3,300	5,000	5,000	5,000
Dominican Republic[4]	5,812	23,369	26,698	28,450	[5]24,239
Finland	13,906	16,355	16,846	17,306	17,600
France	8,114	[r]5,401	5,751	7,738	[5]11,023
German Democratic Republic[e]	3,300	3,300	3,300	3,300	3,300
Germany, Federal Republic of[e 7]	1,320	1,320	1,100	[r]800	--
Greece	[e]5,000	14,174	17,448	17,584	13,200
Indonesia[4]	5,523	5,352	5,320	5,293	5,500
Japan[8]	[r]99,822	[r]90,556	98,489	102,175	[5]97,882
New Caledonia[4]	30,871	23,939	32,141	39,797	[5]36,377
Norway	28,476	[r]31,547	39,185	41,351	[5]42,108
Philippines	12,371	6,721	3,889	18,732	[5]2,288
Poland[e]	2,300	2,300	2,300	2,300	2,300
South Africa, Republic of	15,900	[e]18,740	22,597	[e]22,000	22,000
U.S.S.R.[e]	198,400	204,000	[r]211,000	[r]218,000	237,000
United Kingdom	7,606	25,574	24,582	19,621	[5]34,130
United States	44,956	33,400	44,933	36,382	[5]1,651
Yugoslavia[e]	1,700	1,700	2,200	3,300	3,300
Zimbabwe	14,661	11,184	11,300	10,340	10,000
Total	[r]645,406	[r]712,568	784,942	806,608	810,458

[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 May 12, 1987.
[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 have 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: 1982—54,444; 1983—54,900 (estimated); 1984—56,330; 1985—56,858; and 1986—54,000 (estimated); Botswana: 1982—19,573; 1983—20,080; 1984—20,507; 1985—21,567; and 1986—20,500 (estimated); Indonesia: 1982—15,156; 1983—20,159; 1984—25,149; 1985—27,498; and 1986—27,600 (estimated); and New Caledonia: 1982—7,875; 1983—5,046; 1984—6,219; 1985—6,040 (revised); and 1986—3,812.
[3]Refined nickel plus the nickel content of oxide.
[4]Nickel content of ferronickel only. (No refined nickel was produced.)
[5]Reported figure.
[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: 1982—12,952; 1983—12,723; 1984—9,804; 1985—9,900 (estimated); and 1986—11,000 (estimated). Output of processed sulfide was as follows, in short tons: 1982—16,916; 1983—18,466; 1984—15,971; 1985—16,400 (estimated); and 1986—16,500 (estimated).
[7]Includes nickel content of nickel alloys.
[8]Includes nickel content of ferronickel, refined nickel, and nickel oxide.

TECHNOLOGY

Mining and Processing.—Inco began developing a computer-controlled underground haulage vehicle for its Sudbury District mines. The company selected a 70-ton side-dump truck for the first prototype.

Inco received a Can$1 million, 4-year Government contract under the Productivity and Technology program, within the Canadian-Ontario Mineral Development Agreement, to construct a three-dimensional numeric model. The model was expected to simulate structural responses of mine rock to bulk mining operations at depth. It would allow operators to predict mine stability and to evaluate mining techniques that could lower costs.

After extensive testing at its experimental mine, Inco installed a portable crusher at its Stobie Mine. The crusher, developed under a Bureau of Mines contract, cut crushing costs in half. It also cut development time by eliminating the need to sink a shaft to its final depth for placement of a full-size crusher because the portable crusher essentially could follow the mining operations downward from the top of the ore body.

Nickel and copper mines in Finland benefited from several innovations introduced in 1986. A mechanized cable-bolting machine made by Tamrock, Finland, gained acceptance in Finnish mines where ore bodies are surrounded by weak gangue rock. At the Enonkoski Mine, Outokumpu also experimented with a new computer-controlled machine for drilling long blast holes. The drill controlled the hole depth and automatically changed the drilling steel so that the operator could leave the drill unattended. The drill also monitored its water pressure and flow rate to prevent the drilling steel from becoming stuck.[3]

Finnish miners adopted another technical innovation, the freezing of waste rock and fill placed in mined-out stopes. The frozen fill provided structural support so that the adjacent pillars could be mined. Miners froze the wetted fill by drilling long holes into it and installing pipes that carried calcium chloride solution at -25° C. The fill required 3 months to freeze.[4]

Inco developed several possible strategies for meeting sulfide emission standards at its nickel smelters. Furthest advanced was a technique for separating pyrrhotite (an iron sulfide) from the nickel minerals in the concentrator. Mill operators thus remove most of the sulfide before the concentrate reaches the smelter. The company began constructing a commercial-scale test circuit of the technique at its Copper Cliff mill with partial funding from the Canadian Government under the Industrial and Regional Development Program. Inco also tested a "bulk smelting" method of smelting nickel and copper together to a bulk matte. Subsequent converter operations using a new oxygen burner reportedly allowed more economical recovery of sulfide emissions as sulfuric acid.

Several companies began negotiating with two Montana College of Mineral Science and Technology professors to use their technology for recovering nickel, cobalt, and chromium from electroplating waste. The technique essentially involves precipitating the valuable metals from a waste stream with phosphate. Beside providing an economic product from the waste, the process helps solve a potential disposal problem.

In addition to the implementation of a commercial process by AMAX, other researchers continued to test methods of recycling spent hydrogenation catalysts that contain nickel. A promising method developed by Georgia Institute of Technology researchers featured pretreating the catalysts with hydrogen sulfide and then extracting the metals from the catalysts with sulfuric acid containing ferric ions. Gulf Chemical & Metallurgical Corp. roasted and leached spent catalysts with sodium hydroxide to leave nickel, cobalt, and other metals in a refinable residue. In this latter method, the catalysts alternatively could be leached with soda ash solutions and the residue from this step could be releached with acid to recover the nickel and cobalt.[5]

Nickel Products.—Approximately 40 companies entered cooperative programs with Oak Ridge National Laboratories to produce nickel aluminides, developed by Oak Ridge as a possible replacement for superalloys. A major breakthrough in developing the aluminides was the addition of trace amounts of boron to improve ductility. Benefits of the nickel aluminides over available superalloys included lower density, simpler composition, easier heat treating, higher yield strength with higher temperature in the 650° to 750° C range, excellent oxidation resistance up to 1,000° C, and better weldability. The alloy will be targeted for turbines, aircraft fasteners, bellows, appliances, auto pistons, and turbochargers.[6]

Allied Corp. continued developing amorphous-metal-powder alloys. For example, Allied developed one type, Devitrium 7025, for making cutting tools for aluminum. This powder alloy, extruded into bars by Amax Specialty Metals Corp., contains 50% nickel, 36% molybdenum, 12% iron, and 2% boron. Allied claimed that the alloy offered superior resistance to molten aluminum, high strength, hardness while hot, wear resistance, and good machinability.[7]

Two stainless steel developments gained acceptance as solutions to the problem of chloride stress-corrosion-cracking in common stainless steels. One was the formulation of high-nickel (25% to 30%) austenitic stainless steel containing 3% to 6% molybdenum. The other was a new generation of duplex stainless steel—that containing one-half austenitic grain structure and one-half ferritic structure. The duplex steels offer two or three times the yield strength of the common stainless steel, as well as superior resistance to chloride pitting and cracking. The new generation ones featured the addition of small amounts of nitrogen to improve weldability and corrosion resistance. Recipes for duplex steel listed nickel at 5% to 6%.[8]

End Uses.—Colored stainless steel began making inroads into European architecture. Coloring was added to stainless steel by dipping it into a hot chromic acid-sulfuric acid solution, which formed a thin chromic oxide layer on the surface. Interference of incident light passing through the film provided the coloring. The colored surfaces were not affected by exposure to light, weathering, or temperature to 200° C; the coloring will not crack or peel. Beside offering interesting architectural possibilities, the material adapted well to constructing solar energy panels. Since stainless steel was the biggest consumer of nickel, new applications for stainless steel control much of the future demand for nickel.[9]

Chrysler Corp. began nickel flashing its terne-coated steel fuel tanks. The nickel undercoat improved the quality of the terne coating and provided greater resistance to internal corrosion in the fuel tanks.

In another automotive application, Mazda Motor Corp. introduced a process for integrating a nickel-foam ring into an aluminum cast piston, increasing the power of its turbocharged diesel engines by 15%. The nickel ring also cut engine wear over 10% and tripled piston life.[10]

Although plastic generally competes with nickel in many applications, the tremendous growth of plastic in the video, telecommunications, and computer fields provided a new market for nickel. Plastic housings on instruments used in these industries are transparent to much electromagnetic radiation. Nickel provides an excellent shield against this interference. Nickel-coated graphite fibers have been mixed in the plastic housings to provide shielding. Nickel-bearing pigments and emulsions were also used to block stray radiation. The market could reach 1.8 million pounds of nickel per year if one-half of the inferior materials comprising the current shields are replaced with nickel.[11]

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[1]Physical scientist, Division of Ferrous Metals.

[2]Federal Register. Environmental Protection Agency. Regulatory Determination for Wastes From the Extraction and Beneficiation of Ores and Minerals. V. 51, No. 128, July 3, 1986, pp. 24496-25502.

[3]Pearse, G. Mechanized Drilling and Cable Bolting in Finland. Min. Mag., v. 155, No. 1, July 1986, pp. 45-48.

[4]Work cited in footnote 3.

[5]Ernst, W. R., L. H. Hiltzik, A. R. Garcia, M. D. Franke, A. S. Myerson, and J. D. Carruthers. The GTRC Process for the Removal of Inorganic Impurities From Spent HDS Catalysts (SME Annual Meeting, New Orleans, LA, Mar. 2-6, 1986). Soc. Min. Eng. AIME preprint 86-10, 1986, 8 pp.

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[6]Kear B. H. Advanced Metals. Sci. Am., v. 255, No. 4, Oct. 1986, pp. 159-167.

[7]Peters, H. Glassy Metals Turn To Powder. Met. Bull. Mon., No. 183, Mar. 1986, pp. 55-57.

[8]Redmond, J. D. Selecting Second-Generation Duplex Stainless Steels. Chem. Eng., v. 93, No. 20, pp. 153-155.

[9]Piesslinger-Schweiger, S. View Increased Sales for Colored Stainless Steel. Nickel, v. 2, No. 1, Sept. 1986. p. 4.

[10]Nakazawa, G., Nickel-Foam-Integrated Piston Helps Power Mazda Diesel Truck. Nickel, v. 2, No. 1, Sept. 1986, p. 4.

[11]Gerson, F. T. Fight Electromagnetic Interference by Nickel Plating Graphite Fibers. Nickel, v. 2, No. 1, Sept. 1986, pp. 4-5.

Nitrogen

By Charles L. Davis[1]

U.S. production of anhydrous ammonia, 82.2% nitrogen, decreased considerably from that of 1985. The total value of ammonia produced and sold was about $1.2 billion. The value of apparent consumption was about $1.4 billion. Production and apparent consumption values were based on average annual 1986 f.o.b. gulf coast spot prices, which decreased considerably during the year. Imports of ammonia also decreased; however, the total quantity imported remained relatively high. Ammonia exports decreased significantly because some former markets were no longer available in 1986.

Domestic Data Coverage.—Domestic production data for ammonia were developed by the Bureau of the Census, U.S. Department of Commerce, and published monthly in Current Industrial Reports, Inorganic Fertilizer Materials and Related Products, M28B. The Department of Commerce surveyed approximately 62 firms manufacturing inorganic fertilizer chemicals. Production estimates were supplied for reports not received in time for tabulation. These data are shown in table 1.

Table 1.—Salient ammonia statistics

(Thousand short tons of contained nitrogen)

	1982	1983	1984	1985	1986[p]
United States:					
Production[1 2]	13,029	11,297	13,368	13,238	11,499
Exports	610	298	438	1,010	531
Imports for consumption	1,737	2,169	2,699	2,306	2,048
Consumption[2 3]	14,145	13,719	15,346	14,439	13,305
World: Production	[r]83,686	[r]87,565	94,933	[p]96,978	[e]95,946

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Synthetic anhydrous ammonia and coke oven ammonia.
[2]Coke oven ammonia not available for 1985 and 1986.
[3]Includes producers' stock changes in synthetic anhydrous ammonia and coke oven ammonia.

DOMESTIC PRODUCTION

The highest level of production in 1986 occurred in May, nearly 1.3 million short tons, and the lowest in July, slightly more than 1.0 million tons. Some plants were retrofitted with low-cost modifications to cut energy consumption. Modifications made on standard plant designs substantially reduced the pressure drop in the ammonia converter, allowing the use of small high-activity catalysts. Other plants closed indefinitely, and a few plants were sold. The ammonia industry had an estimated 4 million tons per year of long-term idle capacity. Ammonia was produced by 43 companies at 54 plants in 22 States.

Table 2.—Fixed nitrogen production in the United States

(Thousand short tons of contained nitrogen)

	1982	1983	1984	1985	1986p
Ammonium compounds, coking plants:					
Ammonia liquor[1]	5	5	5	NA	NA
Ammonium phosphate[1]	(2)	(2)	(2)	NA	NA
Ammonium sulfate[1]	56	46	54	NA	NA
Anhydrous ammonia, synthetic plants[3]	12,968	11,246	13,309	13,238	11,499
Total	13,029	11,297	13,368	13,238	11,499

pPreliminary. NA Not available.
[1]Quarterly Coal Report, U.S. Department of Energy, Jan.-Mar. 1985, published July 1985.
[2]Included with ammonium sulfate to avoid disclosing company proprietary data.
[3]Current Industrial Reports, Bureau of the Census.

Table 3.—Major nitrogen compounds produced in the United States

(Thousand short tons, gross weight)

Compound	1984	1985	1986p
Acrylonitrile	1,101	1,173	1,157
Ammonium nitrate	7,009	6,907	5,569
Ammonium phosphate	14,468	12,373	10,039
Ammonium sulfate[1]	2,107	2,049	2,084
Nitric acid	8,016	7,808	6,561
Urea	7,138	6,478	6,005

pPreliminary.
[1]Excludes ammonium sulfate from coking plants.

Sources: Bureau of the Census and International Trade Commission.

Table 4.—Domestic producers of anhydrous ammonia in 1986

(Thousand short tons per year of ammonia)

Company	Location	Capacity
Agrico Chemical Co	Donaldsonville, LA	467
Do	Verdigris, OK	837
Air Products and Chemicals Inc	New Orleans, LA	244
Do	Pace Junction, FL	99
Allied Chemical Corp	Hopewell, VA	339
American Cyanamid Co	Fortier, LA	579
Arcadian Corp	Geismar, LA	339
Do	La Platte, NE	172
Borden Chemical Co	Geismar, LA	398
Carbonaire Co. Inc	Palmerton, PA	35
Cargill Inc	Columbus, MS	68
Center Plains Industries Inc	Dumas, TX	160
C.F. Industries Inc	Donaldsonville, LA	1,735
Chevron Chemical Co	Pascagoula, MS	528
Do	El Segundo, CA	20
Do	Fort Madison, IA	95
Columbia Nitrogen Corp	Augusta, GA	508
Cominco American Incorporated	Borger, TX	400
CPEX Pacific Inc	St. Helens, OR	90
The Dow Chemical Co	Freeport, TX	115
E. I. du Pont de Nemours & Co. Inc	Beaumont, TX	519
Farmland Industries Inc	Fort Dodge, IA	209
Do	Dodge City, KS	209
Do	Enid, OK	837
Do	Lawrence, KS	339
Do	Pollock, LA	418
First Mississippi Corp	Donaldsonville, LA	400
Georgia-Pacific Corp	Plaquemine, LA	196
Goodpasture Inc	Dimmitt, TX	40
W. R. Grace & Co	Woodstock, TN	339
Grace-Oklahoma Nitrogen	Woodward, OK	449
Green Valley Chemical Corp	Creston, IA	35
Hawkeye Chemical Co	Clinton, IA	220
Hooker Chemical Co	Tacoma, WA	28
International Minerals & Chemical Corp	Sterlington, LA	829
Jupiter Chemical Co	Lake Charles, LA	78

Table 4.—Domestic producers of anhydrous ammonia in 1986 —Continued

(Thousand short tons per year of ammonia)

Company	Location	Capacity
Mississippi Chemical Corp	Yazoo City, MS	392
Monsanto Co	Luling, LA	459
N-Ren Corp	Pryor, OK	94
Do	East Dubuque, IL	237
Olin Corp	Lake Charles, LA	489
Pennwalt Chemical Co	Portland, OR	8
Phillips Pacific Chemical Co	Kennewick, WA	154
Phillips Petroleum Co	Beatrice, NE	229
PPG Industries Inc	Natrium, WV	50
J. R. Simplot Co	Pocatello, ID	107
Sohio Chemical Co	Lima, OH	475
Tennessee Valley Authority	Muscle Shoals, AL	74
Terra Chemicals International Inc	Port Neal, IA	209
Triad Chemical Co	Donaldsonville, LA	363
Union Chemical Co	Kenai, AK	1,097
Do	Brea, CA	279
U.S.S. Agri-Chemicals Inc	Cherokee, AL	174
Wycon Chemical Co	Cheyenne, WY	162
Total		17,425

Source: Economics and Marketing Research Section, Tennessee Valley Authority. World Fertilizer Capacity, Ammonia. Muscle Shoals, AL, July 4, 1986.

CONSUMPTION AND USES

Reduced crop acreage and imports of nitrogen fertilizers decreased the demand for domestically produced ammonia-based chemicals for the farm market. Imports of anhydrous ammonia decreased 11%, while ammonia exports decreased 47%. Approximately 80% of the ammonia consumed was used in fertilizers. Ammonia was also used to produce plastics, fibers, and resins, 10%; explosives, 4%; and numerous other chemicals, 6%.

STOCKS

Producers' stocks of ammonia on hand at the beginning of the year totaled about 1.8 million tons of contained nitrogen. At yearend, stocks totaled about 1.5 million tons of contained nitrogen. Ending stocks of ammonia were lower in 1986 than in 1985 because production and demand remained low throughout the year.

PRICES

Ammonia prices began the year at an annual high of $110 per ton, f.o.b. gulf coast. The price declined steadily until the annual low of $66 per ton, f.o.b. gulf coast, was reached in mid-December 1986. Large quantities of low-cost ammonia imports contributed to the decrease in ammonia prices.

Table 5.—Price quotations for major nitrogen compounds at yearend 1986

(Per short ton)

Compound	Price
Ammonium nitrate: Delivered Corn Belt	$100-$120
Ammonium sulfate: F.o.b. Corn Belt	88- 119
Anhydrous ammonia:	
Delivered Corn Belt	100- 115
F.o.b. gulf coast	71- 73
Diammonium phosphate: F.o.b. central Florida	120
Urea:	
Delivered Corn Belt	90- 110
F.o.b. gulf coast, granulated	76- 80
F.o.b. gulf coast, prilled	75- 78

Source: Green Markets, Fertilizer Market Intelligence Weekly, Dec. 22, 1986.

FOREIGN TRADE

Anhydrous ammonia exports decreased 47% from the 1.01 million tons of contained nitrogen exported in 1985. The decrease was attributed to the loss of foreign markets that were available in 1985. The gross weight of downstream nitrogen compounds exported for industrial and fertilizer uses decreased 28%. Diammonium phosphate, ammonium sulfate, and anhydrous ammonia led in export tonnage of nitrogen compounds.

Imports of anhydrous ammonia for fertilizer use decreased 11%. Canada was the leading foreign supplier of ammonia to the United States with about 1.1 million tons. The U.S.S.R. supplied about 740,977 tons; Trinidad and Tobago, 389,862 tons; and Italy, 166,101 tons. Ammonia imports from Canada and the U.S.S.R. remained about the same. Tonnage from Mexico and Trinidad and Tobago decreased, while imports from Italy continued to increase.

Table 6.—U.S. exports and imports for consumption of major nitrogen compounds in 1986

(Thousand short tons and thousand dollars)

Compound	Gross weight	Nitrogen content	Value
EXPORTS			
Fertilizer materials:			
Ammonium nitrate	154	52	NA
Ammonium sulfate	1,157	243	NA
Anhydrous ammonia	646	531	NA
Diammonium phosphate	4,542	817	NA
Nitrogen solutions	97	31	NA
Sodium nitrate	12	2	NA
Urea	549	253	NA
Mixed chemical fertilizers	26	3	NA
Other ammonium phosphates	515	57	NA
Other nitrogen fertilizers	48	10	NA
Industrial chemicals:			
Ammonia, aqua (ammonia content)	1	1	162
Ammonium nitrate	1	(1)	91
Ammonium phosphate	2	(1)	3,915
Ammonium sulfate	4	1	101
Total	7,754	2,001	[2]4,269
IMPORTS			
Fertilizer materials:			
Ammonium nitrate	561	188	48,378
Ammonium nitrate-limestone mixtures	(1)	(1)	45
Ammonium sulfate	291	61	20,506
Anhydrous ammonia	2,491	2,048	272,921
Calcium cyanamide or lime nitrogen	3	1	902
Calcium nitrate	146	22	13,028
Diammonium phosphate	35	7	5,505

See footnotes at end of table.

Table 6.—U.S. exports and imports for consumption of major nitrogen compounds in 1986 —Continued

(Thousand short tons and thousand dollars)

Compound	Gross weight	Nitrogen content	Value
IMPORTS —Continued			
Fertilizer materials —Continued			
Nitrogen solutions	334	107	26,140
Potassium nitrate	51	7	10,726
Potassium nitrate-sodium nitrate mixtures	17	3	2,282
Sodium nitrate	118	19	12,294
Urea	3,478	1,600	306,194
Mixed chemical fertilizers	117	12	21,634
Other ammonium phosphates	108	12	16,514
Other nitrogen fertilizers	96	19	13,713
Industrial chemicals:			
Ammonium nitrate	52	18	5,852
Ammonium phosphate	1	([1])	834
Ammonium sulfate	([1])	([1])	97
Anhydrous ammonia and chemical-grade aqua	4	3	341
Total	7,903	4,127	777,906

NA Not available.
[1]Less than 1/2 unit.
[2]Total includes chemicals only.

Source: Bureau of the Census.

WORLD REVIEW

Many countries had plans to construct new ammonia plants in an effort to achieve self-sufficiency or to produce ammonia for the export market. Argentina, Australia, Brazil, Canada, Chile, Iraq, Nigeria, Norway, Sweden, Trinidad and Tobago, the U.S.S.R., the United Arab Emirates, the United Kingdom, and Venezuela collectively planned to construct more than 5 million tons of ammonia capacity. Some plants in Italy, the U.S.S.R., and the United States planned to revamp or retrofit existing plants to improve plant operating efficiency. Ammonium bicarbonate has been the staple fertilizer for China; however, Chinese ammonium bicarbonate production declined while urea production increased. Emphasis was placed on the production of urea with increased nitrogen content.

Sixteen independent French fertilizer producers formed an organization to improve their return on sales and to increase their share of the French market.

In the 1980's, there has been a surge in countertrade, especially in fertilizers. Urea dominated the fertilizer countertrade in 1986.

Canada.—Cominco Ltd. and Alberta Energy Co. Ltd. received approval from the Alberta Energy Resources Conservation Board to build an ammonia unit at Joffre, Alberta. Construction was scheduled for completion in 1987. The plant was designed to produce 350,000 tons per year of anhydrous ammonia.[2]

Malaysia.—Asean-Bintulu Fertilizers Ltd. commissioned an ammonia and urea plant that began commercial production in February 1986. The 1,000-ton-per-day facility was designed to operate on natural gas feedstock.[3]

Syria.—M. W. Kellogg Ltd. of the United Kingdom was to revamp a 1,000-ton-per-day ammonia plant situated at Homs. The plant was to be converted from naphtha feedstock to natural gas. Work was scheduled for completion in early 1987.[4]

Trinidad and Tobago.—Construction began on a new 500,000-ton-per-year ammonia plant owned by the Government and W. R. Grace & Co.[5]

United Kingdom.—Two new ammonia plants with a total capacity of 300,000 tons per year were under construction to replace older, inefficient units. These plants, owned by Imperial Chemical Industries PLC, were part of the Severnside site near Bristol.[6]

Table 7.—Ammonia: World production, by country[1]

(Thousand short tons of contained nitrogen)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Afghanistan[e]	9	9	[3]45	[r]50	50
Albania[e]	84	84	88	88	88
Algeria	181	145	161	[e]165	165
Argentina	64	63	56	[e]55	55
Australia	270	424	414	[e]413	413
Austria[e]	535	546	550	550	500
Bangladesh	201	197	389	395	390
Belgium	561	495	498	[r e]430	440
Brazil	555	814	[e]830	[e]830	830
Bulgaria	1,138	1,238	1,254	1,254	1,257
Burma[e]	56	59	63	139	143
Canada	2,273	3,183	3,851	3,991	3,900
China[e]	14,010	15,200	15,400	16,500	17,000
Colombia	108	112	103	110	110
Cuba	108	95	189	[r e]210	220
Czechoslovakia[e]	937	937	937	882	882
Denmark	34	13	17	[e]17	17
Egypt	704	[r]713	756	754	760
Finland	71	75	76	[e]77	77
France[e]	2,200	[r]2,200	[r]2,600	[r]2,200	2,200
German Democratic Republic	[r]1,282	[r]1,329	1,326	1,329	1,300
Germany, Federal Republic of	1,731	1,877	2,164	2,103	1,800
Greece	246	[r]250	[r e]250	[r e]250	250
Hungary	873	[e]896	897	872	880
Iceland[e]	8	8	8	8	8
India[4]	3,824	3,930	4,382	4,766	5,300
Indonesia	1,133	1,268	1,828	2,265	2,300
Iran[e]	29	32	24	[r]295	295
Iraq[e]	88	88	88	66	66
Ireland	409	324	409	364	390
Israel	54	59	63	63	63
Italy	1,153	1,169	1,334	1,342	1,300
Japan	1,821	1,703	1,839	1,794	1,700
Korea, North[e]	500	500	500	500	500
Korea, Republic of	599	474	512	487	[3]470
Kuwait	202	[r]345	319	356	360
Libya	[r]269	[r]491	545	453	450
Malaysia	31	32	43	59	60
Mexico	2,237	2,134	1,954	2,049	2,100
Netherlands	1,824	[r]1,922	2,549	2,630	2,280
New Zealand	--	48	64	66	66
Norway	[r]579	[r]565	702	505	550
Pakistan	1,033	1,211	1,243	1,220	1,220
Peru[e]	93	94	94	94	66
Philippines	16	22	18	[r e]19	19
Poland	1,521	1,571	1,647	[e]1,382	1,380
Portugal[e]	146	149	154	[r]154	149
Qatar	478	[r]531	572	580	580
Romania	2,852	3,006	3,154	3,175	3,200
Saudi Arabia	229	[r]323	452	464	464
South Africa, Republic of	629	634	639	[e]639	639
Spain	593	678	[e]683	[e]672	660
Sri Lanka	114	69	[e]77	[e]33	--
Sweden	85	[r]54	54	20	22
Switzerland[e]	36	36	33	33	33
Syria	72	125	132	[e]132	132
Taiwan	350	342	296	228	[3]292
Trinidad and Tobago	773	1,095	1,190	1,197	1,200
Turkey	281	307	320	239	250
U.S.S.R.[e]	15,400	[r]17,100	[r]17,400	[r]18,400	19,000
United Arab Emirates	--	--	249	311	311
United Kingdom	1,892	1,896	2,024	1,948	1,800
United States[5]	13,029	11,297	13,368	13,238	[3]11,499
Venezuela	485	418	[e]510	[e]513	510
Yugoslavia	465	452	[e]440	[e]460	440
Zambia	30	31	31	19	19
Zimbabwe	93	78	76	76	76
Total	[r]83,686	[r]87,565	94,933	96,978	95,946

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

[1]Table includes data available through May 12, 1987.

[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]Data are for years beginning Apr. 1 of that stated.

[5]Synthetic anhydrous ammonia and coke oven ammonia. Coke oven ammonia data not available for 1985 and 1986.

TECHNOLOGY

Deshen International, of Newton, MA, proposed to mount a small-scale nitrogen-fixation unit on the back of a truck that would move into remote areas to make fertilizer using energy from the local power grid. The nitrogen-fixing process is based on the Birkeland and Eyde (B&E) electric arc process developed in Norway at the turn of the century. The B&E process is less energy-efficient than the Haber-Bosch process, but in many countries transportation costs add 300% to the cost of fertilizer.[7]

Low-cost modifications that reduce energy consumption and improve the performance of existing fertilizer ammonia plants were developed by M. W. Kellogg. The vertical split-flow basket modification changes the direct-quench design to a low-energy intercooled design. The converter utilizes a cold-wall pressure shell with an internal basket housing the exchangers and catalyst beds. M. W. Kellogg selected the vertical split-flow converter for ammonia plant retrofitting.[8]

A new catalyst shape developed by Haldor Topsoe A/S was central to the success of its new low-energy process for ammonia production. Haldor Topsoe introduced the catalyst R-67-7H, a different-shaped version of the well-known steam reforming catalyst R-67. The new shape, a cylinder with seven holes and dished ends, has provided higher conversion, lower pressure drop, and colder tubes.[9]

C. D. Pickett and J. Talarmin of the United Kingdom's Agricultural and Food Research Council Unit of Nitrogen Fixation have demonstrated a more practical method of converting atmospheric nitrogen to ammonia. Since certain chemical compounds take up nitrogen gas and form dinitrogen complexes, an electric current driving the system is able to regenerate the tungsten-dinitrogen-tertiary phosphine complex, making the system cyclic.[10]

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[1]Physical scientist, Division of Industrial Minerals.
[2]Nitrogen (London). Plant and Project News. No. 159, Jan.-Feb. 1986, p. 12.
[3]Work cited in footnote 2.
[4]Fertilizer Focus. V. 3, No. 9, Oct. 1986, p. 4.
[5]Green Markets. Grace, Trinidad Break Ground for Tringen Two Ammonia Plant. V. 10, No. 7, Feb. 17, 1986, p. 1.
[6]Fertilizer Focus. Ammonia Development Plans in Europe Move Ahead. V. 3, No. 5, June 1986, p. 8.
[7]Chemical Week. Old Know-How Is Tapped for New Fertilizer Units. V. 139, No. 9, Aug. 27, 1986, p. 60.
[8]European Chemical News. Kellogg Reveals Low-Cost Ammonia Retrofit Method. V. 47, No. 1240, Sept. 1, 1986, p. 23.
[9]European Chemical News Fertilizers & Agrochemicals Supplement. Low-Energy Key to Ammonia Process. Aug. 1986, p. 28.
[10]Fertilizer Focus. Farm-Based Ammonia Plants a Possibility? V. 2, No. 12, Jan. 1986, p. 41.

Peat

By Charles L. Davis[1]

Peat production in the United States increased slightly in 1986. In decreasing order of quantity, Florida, Michigan, Illinois, Indiana, and Colorado were the major peat producing States. Reed-sedge peat was the most common kind produced, followed by humus, hypnum, sphagnum, and unclassified. Peat sold in both bulk and packaged forms by domestic producers increased in quantity and value. Apparent consumption increased 22%. Imports for consumption, primarily from Canada, increased 16% and represented a large part of apparent consumption. The predominant end use of peat was for agricultural and horticultural purposes.

Domestic Data Coverage.—Domestic production data for peat are developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the 110 operations to which a survey request was sent, 95 responded, representing 93% of the total production shown in table 1. Production for the 15 nonrespondents was estimated using prior year production levels adjusted for regional production trends and inflation.

Table 1.—Salient peat statistics

	1982	1983	1984	1985	1986
United States:					
Number of active operations	93	94	101	99	92
Production thousand short tons	798	704	800	839	886
Sales by producers do	769	725	814	882	1,012
Bulk do	259	223	373	396	496
Packaged do	511	503	441	486	516
Value of sales thousands	$16,871	$18,667	$19,907	$21,892	$23,560
Average per short ton	$21.94	$25.73	$24.47	$24.81	$23.27
Average per short ton, bulk	$16.34	$18.34	$20.47	$20.29	$16.42
Average per short ton, packaged or baled	$24.77	$29.00	$27.85	$28.49	$29.86
Imports for consumption thousand short tons	370	419	485	477	553
Consumption, apparent[1] do	1,080	1,042	1,146	1,255	1,537
Stocks, yearend producers' do	357	438	577	638	540
World: Production do	[r]283,396	[r]282,159	277,615	[p]266,304	[e]271,839

[e]Estimated. [p]Preliminary. [r]Revised.
[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. Ten operations with capacities greater than 25,000 short tons per year (3 reed-sedge operations and 1 humus operation in Michigan, 4 reed-sedge operations and 1 humus operation in Florida, and 1 reed-sedge operation in Illinois) accounted for 51% of production. Reed-sedge production decreased from 72% in 1985 to 65% of total output in 1986. Humus accounted for 28%; hypnum, 5%; sphagnum, 2%; and unclassified, less than 1%.

Table 2.—Relative size of peat operations in the United States

Size in short tons per year	Active operations		Production (thousand short tons)	
	1985	1986	1985	1986
25,000 and over	11	10	446	451
15,000 to 24,999	7	8	116	155
10,000 to 14,999	7	10	84	122
5,000 to 9,999	17	13	115	85
2,000 to 4,999	15	16	48	50
1,000 to 1,999	15	11	21	14
Under 1,000	27	24	10	7
Total[1]	99	92	839	886

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

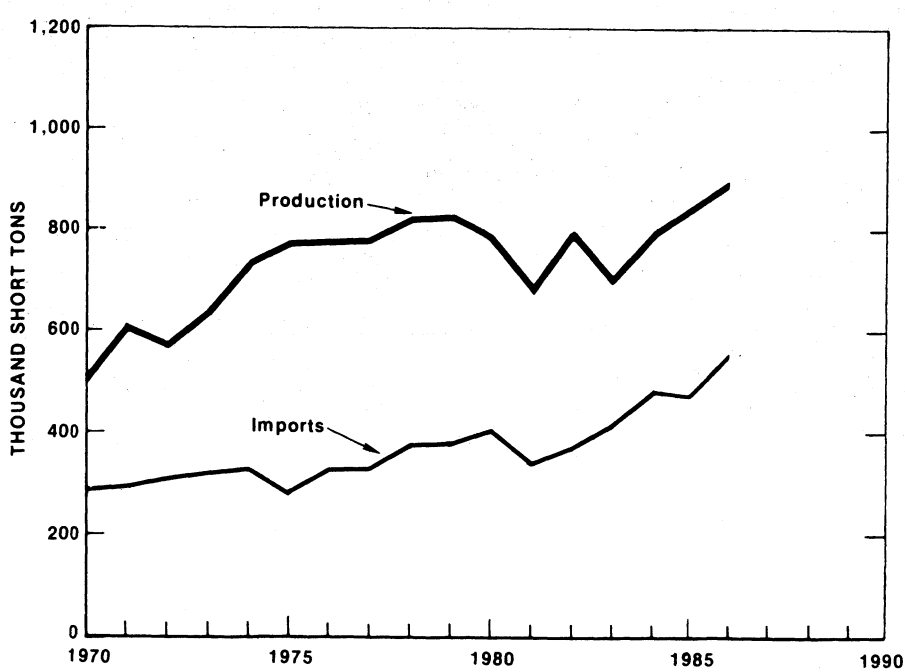

Figure 1.—Production and imports of peat in the United States.

CONSUMPTION AND USES

U.S. peat producers' domestic sales increased 15% and consisted of 69% reed-sedge, 26% humus, 4% hypnum, 2% sphagnum, and less than 1% unclassified. Sales of both bulk peat and packaged peat increased. Sales of bagged or baled peat were 51% of total sales and consisted of 80% reed-sedge, 15% humus, 3% hypnum, and 2% sphagnum. Sales increased for peat used as an earthworm culture medium, for general soil improvement, as an ingredient for potting soils, for nurseries, as packing for flowers, as a seed inoculant, and for vegetable growing. Peat sales decreased for golf courses, mixed fertilizers, mushroom beds, and other uses. Apparent consumption of peat increased as a result of an increase in demand.

Table 3.—U.S. peat sales by producers in 1986, 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	3,197	$39	200	$5	3,397	$44
General soil improvement	168,197	2,613	459,331	12,034	627,528	14,646
Golf courses	26,422	576	67	7	26,489	584
Ingredient for potting soils	87,150	1,320	42,525	1,825	129,675	3,146
Mixed fertilizers	9,375	120	--	--	9,375	120
Mushroom beds	3,107	43	--	--	3,107	43
Nurseries	186,815	2,898	6,112	360	192,927	3,258
Packing flowers, plants, shrubs, etc	3,360	78	--	--	3,360	78
Seed inoculant	3,807	348	2,765	909	6,572	1,256
Vegetable growing	4,851	116	1,882	101	6,733	218
Other	--	--	3,240	168	3,240	168
Total[1]	496,281	8,151	516,122	15,409	1,012,403	23,560

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

Table 4.—U.S. peat production and sales by producers in 1986, 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	99
Colorado	4	W	W	W	44
Florida	15	356	365	$5,743	15
Georgia	2	W	W	W	98
Illinois	5	W	W	W	95
Indiana	5	37	70	W	80
Iowa	4	20	14	381	40
Maine	1	W	W	W	--
Maryland	1	W	W	W	10
Massachusetts	1	W	W	W	100
Michigan	16	220	298	6,170	73
Minnesota	4	W	W	W	86
Montana	1	W	W	W	100
New Jersey	5	W	W	542	88
New York	4	W	W	W	86
North Carolina	1	18	15	W	100
North Dakota	1	W	W	W	100
Ohio	4	W	6	W	2
Pennsylvania	8	19	19	532	22
South Carolina	1	W	W	W	36
Washington	3	W	W	W	--
Wisconsin	4	W	9	W	29
Total[2] or average	92	886	1,012	23,560	51

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 1986, 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	--	--	--	--	--	--	1,802	3,554	$24
General soil improvement	17,347	95,058	$958	22,501	56,910	$731	500,434	1,023,566	11,698
Golf courses	690	2,300	16	4,500	11,000	79	9,832	19,269	185
Ingredient for potting soils	--	--	--	--	--	--	82,305	188,668	2,547
Mixed fertilizers	--	--	--	--	--	--	--	--	--
Mushroom beds	--	--	--	300	1,000	15	2,807	5,347	28
Nurseries	41	150	1	3,300	12,000	180	87,486	171,760	1,702
Packing flowers, plants, shrubs, etc	--	--	--	2,000	5,000	60	975	1,870	14
Seed inoculant	--	--	--	--	--	--	6,263	11,933	1,120
Vegetable growing	--	--	--	4,090	10,400	102	227	454	6
Other	--	--	--	--	--	--	3,240	6,000	168
Total[2]	18,078	97,508	976	36,691	96,310	1,167	695,371	1,432,421	17,492

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	1,595	2,990	$20	--	--	--	3,397	6,544	$44
General soil improvement	85,626	122,016	1,244	1,620	3,300	$15	627,528	1,300,850	14,646
Golf courses	11,467	21,584	303	--	--	--	26,489	54,153	584
Ingredient for potting soils	47,370	79,726	599	--	--	--	129,675	268,394	3,146
Mixed fertilizers	9,375	15,000	120	--	--	--	9,375	15,000	120
Mushroom beds	--	--	--	--	--	--	3,107	6,347	43
Nurseries	102,100	172,511	1,375	--	--	--	192,927	356,421	3,258
Packing flowers, plants, shrubs, etc	385	670	4	--	--	--	3,360	7,540	78
Seed inoculant	309	561	136	--	--	--	6,572	12,494	1,256
Vegetable growing	2,416	3,546	110	--	--	--	6,733	14,400	218
Other	--	--	--	--	--	--	3,240	6,000	168
Total[2]	260,643	418,604	3,911	1,620	3,300	15	1,012,403	2,048,143	23,560

[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.

Table 6.—U.S. peat production and producers' yearend stocks in 1986, by kind

Kind	Active operations	Production (short tons)	Percent of production	Yearend stocks (short tons)
Sphagnum moss	5	13,272	1.5	5,393
Hypnum moss	8	42,269	4.8	21,550
Reed-sedge	52	581,061	65.5	441,355
Humus	28	248,710	28.1	70,304
Other	2	620	.1	1,500
Total	[1]92	885,932	100.0	540,102

[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, decreased 6%. The unit price for bulk peat decreased 19% and that for packaged peat increased slightly. The price per ton of imported sphagnum peat increased slightly.

Table 7.—Prices[1] for peat in 1986

(Dollars per unit)

	Sphagnum moss	Hypnum moss	Reed-sedge	Humus	Other	Average
Domestic:						
Bulk:						
Per short ton	20.18	24.87	19.94	12.40	8.98	16.42
Per cubic yard	7.95	9.75	9.48	7.68	4.41	8.70
Packaged or baled:						
Per short ton	77.78	36.24	27.80	43.37	--	29.86
Per cubic yard	10.50	13.56	13.65	28.76	--	13.86
Average:						
Per short ton	53.96	31.81	25.16	15.00	8.98	23.27
Per cubic yard	10.00	12.12	12.21	9.34	4.41	11.50
Imported, total, per short ton[2]	125.67	XX	XX	XX	XX	125.67

XX Not applicable.
[1]Prices are f.o.b. plant.
[2]Average customs value.

Table 8.—Average density of domestic peat sold in 1986

(Pounds per cubic yard)

	Sphagnum moss	Hypnum moss	Reed-sedge	Humus	Other
Bulk	788	784	951	1,238	982
Packaged	270	748	981	1,326	--
Bulk and packaged	371	762	971	1,245	982

FOREIGN TRADE

Peat imports for domestic consumption increased 16% in quantity and 20% in value. More than 99% of the imports was sphagnum moss peat from Canada. Canadian sphagnum moss peat was in demand because of consumer loyalty to brand and because in most areas domestic sphagnum moss peat still had not entered the U.S. retail market. Almost 44% of the imported peat entered the United States through customs districts in New York. Large quantities also entered through customs districts in Maine, Michigan, Montana, North Dakota, Vermont, and Washington. Minor quantities of peat were imported from France, the Federal Republic of Germany, and New Zealand.

Table 9.—U.S. imports for consumption of peat moss in 1986, 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	12,238	$1,403	540,495	$68,009	552,733	$69,412
France	11	15	103	21	114	36
Germany, Federal Republic of	20	10	15	2	35	12
New Zealand	53	14	--	--	53	14
Other[1]	45	10	116	23	161	33
Total[2]	12,367	1,452	540,729	68,054	553,096	69,506

[1]Includes Cameroon, Costa Rica, Finland, Gabon, Ireland, Italy, Morocco, the Netherlands, Peru, and Sweden.
[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 1986, by customs district

Customs district	Poultry- and stable-grade		Fertilizer-grade		Total	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Boston, MA[1]	3	$6	--	--	3	$6
Buffalo, NY[1]	3,121	346	62,505	$7,930	65,626	8,276
Charleston, SC	--	--	10	5	10	5
Chicago, IL	83	13	8	4	91	17
Dallas, TX[1]	--	--	22	4	22	4
Detroit, MI[1]	8,284	937	57,597	7,105	65,881	8,042
Duluth, MN[1]	--	--	1,926	346	1,926	346
Great Falls, MT[1]	--	--	73,783	11,928	73,783	11,928
Houston, TX	--	--	75	12	75	12
Los Angeles, CA	1	2	14	2	15	4
Miami, FL	53	14	2	4	55	18
New York, NY	11	15	26	6	37	21
Norfolk, VA[1]	--	--	48	12	48	12
Ogdensburg, NY[1]	84	10	176,930	18,443	177,014	18,453
Pembina, ND	--	--	62,827	9,205	62,827	9,205
Portland, ME[1]	417	57	52,732	5,980	53,149	6,037
St. Albans, VT[1]	--	--	32,860	3,767	32,860	3,767
St. Louis, MO[1]	20	4	--	--	20	4
San Francisco, CA	16	2	--	--	16	2
San Juan, PR[1]	253	42	112	16	365	58
Seattle, WA[1]	21	5	19,250	3,282	19,271	3,287
Tampa, FL	--	--	2	3	2	3
Total[2]	12,367	1,452	540,729	68,054	553,096	69,506

[1]Predominantly of Canadian origin.
[2]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

WORLD REVIEW

Use of peat has grown steadily in Finland since 1976. About 10 million megawatt hours per year of electrical energy is generated from peat. The Finnish industry uses the equivalent of 4 million megawatt hours per year, and by 1995, it is expected to use an estimated 10 to 12 million megawatt hours. In central and northern Finland, many towns use peat for thermal energy. Estimates indicate that by 1995 about 33 million cubic yards of peat will be used for heating. About 1.3 million cubic yards per year of peat is used for agriculture. Because of Finland's expertise in peat production and use, it has become involved in peat projects in Burundi, Canada, Ireland, Sweden, and the United States.[2]

Table 11.—Peat: World production, by country[1]

(Thousand short tons)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Argentina: Agricultural use	4	4	3	[e]3	3
Australia	[r]11	[r]11	15	[e]15	15
Burundi	15	15	15	11	12
Canada: Agricultural use	537	583	[e]550	709	647
Denmark: Agricultural use[3]	40	[e]37	35	43	55
Finland:					
Agricultural use	637	303	248	[e]220	220
Fuel	6,063	3,698	2,991	[e]3,300	3,300
France: Agricultural use[e]	132	121	250	220	240
Germany, Federal Republic of:					
Agricultural use	2,030	2,059	1,575	1,671	1,850
Fuel	279	285	305	313	290
Hungary: Agricultural use[e]	77	77	77	77	77
Ireland:					
Agricultural use	105	[e]105	106	106	105
Fuel	5,819	[e]7,330	8,746	2,897	3,300
Israel: Agricultural use[e]	22	22	22	22	22
Netherlands[e]	441	441	496	500	440
Norway:[e]					
Agricultural use	[r]33	[r]33	[r]33	[r]33	33
Fuel	1	1	1	1	1
Poland: Fuel and agricultural use[e]	220	220	220	220	220
Spain	66	44	61	60	57
Sweden: Agricultural use[e]	[r]66	[r]66	[r]66	[r]44	66
U.S.S.R.:[e]					
Agricultural use	200,000	200,000	200,000	200,000	210,000
Fuel	66,000	66,000	[r]61,000	[r]55,000	50,000
United States:					
Agricultural use	798	703	789	828	[4]886
Fuel	--	1	11	11	--
Total	[r]283,396	[r]282,159	277,615	266,304	271,839
Fuel peat included in total	78,382	77,535	73,274	61,742	57,111

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through June 19, 1987.
[2]In addition to the countries listed, Austria, Iceland, and Italy produce negligible quantities of fuel peat, the German Democratic Republic is a major producer, and Venezuela produces small amounts of peat for agricultural use, but output is not officially reported, and available information is inadequate for formulation of reliable estimates of output levels.
[3]Sales.
[4]Reported figure.

TECHNOLOGY

Minnesota Power and Ekono Oy, a Finnish company, cooperated on an extensive peat-burning test. The test involved burning blends of peat and coal. Peat was also burned without coal admixtures on a scale equal to that required by a utility plant. Test results were expected to supply information to determine the best burn method.[3]

The Iron Range Resources and Rehabilitation Board conducted a project to determine the potential of fuel peat production in Minnesota and to promote the use of peat as a fuel. Milled peat was determined to be less expensive to produce than sod peat, making milled peat a desirable fuel for small users. Tests verified that existing boilers would require modification to improve efficiency. Modifications included boiler capacity reduction, additional air supply for combustion, and more effective fuel handling.[4]

[1]Physical scientist, Division of Industrial Minerals.
[2]Mining Magazine (London). Peat: A Significant Contributor to Finland's Energy Requirements. V. 155, No. 2, Aug. 1986, pp. 73-74.
[3]The Energy Daily. Minnesota Power Experiments With Peat. V. 14, No. 50, Mar. 14, 1986, p. 3.
[4]The Resourcer. Peat: A Fuel for the Future. V. 5, No. 3, Apr. 1986, p. 1.

Perlite

By A. C. Meisinger[1]

U.S. production of processed perlite declined slightly from 518,000 short tons (revised) in 1985 to 507,000 tons valued at $15.6 million. Sales of expanded perlite, however, increased from 459,000 tons to 479,000 tons valued at $83.7 million. The quantity of processed perlite imported from Greece continued to increase and was 60,000 tons compared with 52,000 tons in 1985. Construction related uses continued to dominate the domestic market for expanded perlite with nearly 71% 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 13 mining operations to which a request was sent, 12 were active and 10 responded, representing 97% of the total processed ore sold and used shown in table 1. Mine data for the two nonrespondents were estimated using prior year production levels adjusted by trends in employment and other guidelines. Of the 67 expanding plants canvassed, 62 were active; of these, 46 plants, or 74%, responded, representing 69% of the total expanded perlite sold and used shown in table 1. Plant data for the 16 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
1982	623	263	8,755	243	7,289	506	433	428	63,600
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	r309	r10,714	r209	r6,821	r518	461	459	r81,100
1986	735	303	9,536	204	6,110	507	480	479	83,700

rRevised.
[1]Crude ore mined and stockpiled for processing.

DOMESTIC PRODUCTION

Processed Perlite.—Perlite mined for processing by 11 companies from 12 operations in 6 Western States totaled 735,000 tons, an increase of 8% over that of 1985. New Mexico, with five mine operations, accounted for 88%. The remaining 12% came from Arizona, California, Colorado, Idaho, and Nevada.

Production of processed perlite declined from 518,000 tons (revised) sold and used valued at $17.5 million (revised) in 1985 to 507,000 tons valued at $15.6 million. New Mexico operations accounted for 85% of the U.S. total processed perlite sold and used.

Ore producers were Harborlite Corp., Nord Sil-Flo Inc., and Perlite Co. in Arizona; American Perlite Co. in California; Persolite Products Inc. in Colorado; Oneida Perlite Corp. in Idaho; Delamar Perlite Co. in Nevada; and Grefco Inc., Manville Products Corp., Silbrico Corp., and USG Corp. in New Mexico.

In August 1986, Nord Resources Corp., Dayton, OH, purchased the mining and processing operations of Sil-Flo Corp., Superior, AZ, and the Sil-Flo expanding plant, Fort Worth, TX, for a reported price of $2 million.

In December, Oglebay Norton Co., Cleveland, OH, acquired the mining, processing, and expansion facilities of Oneida Perlite, Malad City, ID. The new operation will be called National Perlite Products Co. with product marketing based in Arlington, TX.

During the year, Perlite Co., a subsidiary of Wonder Industries, began mining perlite near Superior, AZ. The ore was expanded in the company's plant in Santa Fe Springs, CA.

Expanded Perlite—The quantity of expanded perlite produced by 62 plants in 32 States was 480,000 tons, a 4% increase over that of 1985. Expanded perlite sales increased by 20,000 tons in quantity and $2.6 million in value compared with that of 1985. Leading States in descending order of sales were Mississippi, Georgia, Pennsylvania, California, Illinois, Florida, Kentucky, Virginia, 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	1985				1986			
	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]
Arkansas	W	W	W	W	W	W	W	W
California	47,300	46,300	$8,516	$184	40,100	41,500	$7,696	$186
Florida	26,400	26,400	4,831	183	27,600	27,500	5,171	188
Indiana	[r]22,800	[r]22,900	[r]5,573	[r]244	19,800	19,200	4,932	256
Kansas	800	800	200	250	1,100	1,100	301	274
Massachusetts	2,300	2,200	708	322	2,000	2,000	644	329
Pennsylvania	48,300	48,100	8,260	172	W	W	W	W
Texas	27,900	27,400	5,915	216	22,500	21,900	5,033	230
Utah	W	W	W	W	1,300	1,300	350	260
Wisconsin	1,200	1,200	296	250	1,000	1,000	270	270
Other[2]	[r]284,500	[r]283,800	46,800	165	364,000	363,600	59,228	163
Total[3]	461,000	459,000	[r]81,100	177	480,000	479,000	83,700	175

[r]Revised. 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, Colorado, Georgia, Idaho, Illinois, Iowa, Kentucky, Louisiana, Maine, Michigan, Minnesota (1986), Mississippi, Missouri, Nevada, New Jersey, New York, North Carolina, Oregon, Tennessee, Virginia, Wyoming, and items 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 declined to 537,000 tons compared with 550,000 tons (revised) in 1985. Domestic consumption of expanded perlite increased slightly from 459,000 tons in 1985 to 479,000 tons, with construction-related uses accounting for 338,500 tons of the total. All major end-use categories except fillers, formed products, and other declined in sales compared with those of 1985.

Table 3.—Expanded perlite sold and used by producers in the United States, by use

(Short tons)

Use	1985	1986
Concrete aggregate	21,400	7,700
Fillers	16,800	18,800
Filter aid	62,400	58,000
Formed products[1]	267,300	309,300
Horticultural aggregate[2]	39,600	37,800
Low-temperature insulation	4,100	2,500
Masonry and cavity-fill insulation	15,200	12,800
Plaster aggregate	[r]11,800	8,700
Other[3]	20,600	23,800
Total[4]	459,000	479,000

[r]Revised.
[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 may not add to totals shown because of independent rounding.

PRICES

The average price of processed perlite sold to expanders declined 9% from $34.67 per ton to $31.47 per ton. The average price of processed perlite used by producers was $29.95 per ton, a decrease of 8% from the 1985 price of $32.64 per ton (revised). The average value of all processed perlite sold and used was $30.86 per ton compared with $33.85 per ton in 1985. The value of expanded perlite sold and used averaged $175 per ton compared with $177 per ton in 1985.

FOREIGN TRADE

Perlite exports, primarily to Canada, increased 50% from 20,000 tons in 1985 to an estimated 30,000 tons. Imports of processed perlite from Greece continued to increase, and were approximately 60,000 tons compared with 52,000 tons in 1985.

WORLD REVIEW

Estimated world production was about 1.8 million tons, or at the same level of 1984 and 1985. Three countries, Greece, the U.S.S.R., and the United States, continued to account for three-quarters of known world production.

Aurun Mines Ltd., Canada's only crude perlite producer, began operation of the company's perlite processing facility at Fraser Surrey, British Columbia, in April 1986. The Fraser plant will process and expand perlite from the company mine in Empire Valley, northwest of Clinton, British Columbia. The plant's expansion furnace system was reported to have a production capacity of 96,000 cubic feet per month.[2]

[1]Industry economist, Division of Industrial Minerals.
[2]Industrial Minerals (London). World of Minerals. No. 227, Aug. 1986, p. 9.

Table 4.—Perlite: World production, by country[1]

(Thousand short tons)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Australia[3]	1	[r]3	[e]2	3	3
Czechoslovakia	50	49	[e]49	[e]49	50
Greece	167	167	196	178	190
Hungary[3]	99	103	113	[e]112	115
Italy[e]	88	83	88	88	80
Japan[e]	83	83	83	83	83
Mexico[3]	36	46	35	41	40
New Zealand[3]	2	1	--	--	--
Philippines	4	2	17	4	4
Turkey	134	32	67	[e]66	66
U.S.S.R.[e]	660	660	660	660	660
United States (processed ore sold and used by producers)	506	474	498	518	[4]507
Total	1,830	[r]1,703	1,808	1,802	1,798

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Unless otherwise specified, figures represent processed ore output. Table includes data available through June 2, 1987.
[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]

Phosphate rock production declined from 50.8 million metric tons in 1985 to 38.7 million tons in 1986. The phosphate rock industry is linked to the demand for phosphate fertilizers from domestic and export markets. The phosphate rock industry controlled inventories by reducing operating schedules and by closing plants as demand remained suppressed throughout 1986. Phosphate rock exports declined by approximately 1.3 million tons compared with those of 1985.

Phosphate rock consumption declined to about 33.3 million tons, with the loss absorbed by Florida and North Carolina producers. Of the 33 phosphate rock mines in the United States, 7 were closed. The Bureau of Mines estimated that the U.S. phosphate rock industry operated at 63% of its capacity of 64.7 million tons per year in 1986. Employment in the phosphate rock mining industry was reduced to 4,400 people as the industry attempted to minimize operating costs and reduce losses.

Table 1.—Salient phosphate rock statistics[1]

(Thousand metric tons and thousand dollars unless otherwise specified)

	1982	1983	1984	1985[r]	1986
United States:					
Mine production (crude ore)	104,135	125,691	163,012	175,227	134,045
Marketable production	37,414	42,573	49,197	50,835	38,710
P_2O_5 content	11,504	13,088	14,889	15,674	11,857
Value	$950,326	$1,021,095	$1,182,244	[2]$1,235,800	[2]$877,600
Average per metric ton	[3]$25.40	[3]$23.98	[3]$24.03	[4]$24.31	[4]$22.67
Sold or used by producers[5]	38,571	46,839	53,277	46,634	40,580
P_2O_5 content	11,814	14,336	16,244	14,363	12,460
Value	$983,465	$1,122,966	$1,278,356	[2]$1,133,675	[2]$919,822
Average per metric ton[4 6]	$25.50	$23.97	$23.99	$24.31	$22.67
Exports[7]	9,842	12,010	11,528	9,136	7,848
P_2O_5 content	3,138	3,839	3,646	2,931	2,521
Value	$293,626	$327,345	$324,784	[2]$263,631	$211,701
Average per metric ton[4]	$29.83	$27.26	$28.17	$28.86	$26.97
Imports for consumption	31	9	[8]9	[8]34	528
C.i.f. value	$1,302	$376	$274	$1,747	$25,435
Average per metric ton	$42.00	$42.69	$31.71	[9]$51.54	[9]$48.18
Consumption[10]	28,760	34,838	41,758	37,532	33,260
Stocks, Dec. 31: Producer	18,287	14,500	11,897	15,534	12,658
World: Production	[r]127,382	[r]139,388	150,163	[p]146,664	[e]137,063

[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.

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 U.S. Congress passed H.R. 9, a bill to designate components of the National Wilderness Preservation System in the State of Florida. The bill directed the U.S. Department of the Interior not to issue phosphate leases in the Osceola National Forest until recommended by the President. The President signed H.R. 9 on September 28, 1986. Several of the lease applicants petitioned the District Court of the United States for the District of Columbia to compel the Department of the Interior to issue phosphate mining leases in the Osceola National Forest in the State of Florida. On February 6, 1986, the court denied the plaintiffs' motion for a summary judgment and dismissed the motion to grant the leases. The litigants have appealed the district court's decision to the U.S. Court of Appeals for the District of Columbia.

The Food Security Act of 1985, which became effective in 1986, could have increased grain exports into world markets and supported farm income by maintaining target prices. The acreage reduction provisions of the act, a 20% and 25% nonpaid reduction maximum for corn and wheat, respectively, did not increase the demand for phosphate fertilizers. The success or failure of the Food Security Act will become apparent in 1987, but the program did not increase the demand for phosphate fertilizer in 1986.

The U.S. fertilizer industry provided information to encourage Congress to bar the Export-Import Bank from making loans to certain foreign competitors to expand or establish production of another nation's export commodities if such products are in world surplus, if they compete directly with U.S. products, or if such loan assistance would cause substantial injury to U.S. producers.

DOMESTIC PRODUCTION

The substantial decline in production of phosphate rock in the United States was from the Florida and North Carolina fields. Production in Tennessee and the Western States was not significantly different from that of 1985 for most of the year.

Florida and North Carolina.—In central Florida, Agrico Chemical Co., Beker Phosphate Corp., Brewster Phosphates, CF Industries Inc., Estech Inc., Gardinier Inc., W. R. Grace & Co., Hopewell Land Corp., International Minerals & Chemical Corp. (IMC), Mobil Mining and Minerals Co., and USS Agri-Chemicals Inc. produced phosphate rock. In north Florida, Occidental Chemical Agricultural Products Inc. produced phosphate rock in Hamilton County.

Several small companies in north-central Florida recovered soft phosphate rock from hard-rock phosphate mine tailing ponds. The combined annual capacity was 45,000 tons. The hard rock was sold as an animal feed supplement.

In North Carolina, Texasgulf Chemicals Co., a subsidiary of Société Nationale Elf Aquitaine, operated the Lee Creek Mine near Aurora. The sale of Agrico's interests in North Carolina to Texasgulf was completed. Texasgulf was the only phosphate rock producing company in North Carolina.

Agrico operated the Saddle Creek Mine and Fort Green Mine in central Florida. The Payne Creek Mine was closed but was scheduled to reopen at yearend. Agrico purchased 14,000 acres of phosphate-bearing land from USS Agri-Chemicals to increase the reserve base of the Fort Green Mine.

AMAX Inc. sold its subsidiary, AMAX Chemical Corp., to FCS Energy Inc. of Leesburg, FL. The sale, which was finalized at yearend, included AMAX's Piney Point fertilizer plant, the closed Big Four phosphate rock mine, the Pine Level phosphate deposit, and the Plant City, FL, animal feed supplement plant.

Beker, operating under chapter 11 of the Federal Bankruptcy Code, produced phosphate rock at its Wingate Creek Mine, trucked the rock to Port Manatee, FL, and barged the rock to Taft, LA, for conversion into phosphoric acid and diammonium phosphate.

Brewster, a partnership of American Cyanamid Co. and Kerr-McGee Corp. leased the Lonesome and Haynsworth Mines to IMC. IMC closed both mines in October and reopened the Haynsworth Mine in 10 days.

IMC acquired the rights to Brewster's reserves.

CF Industries operated the Hardee Complex Mine producing from the North Pasture deposit. CF Industries' plans to develop the phosphate resource in the South Pasture deposit were deferred.

Estech operated the Watson Mine that is two-thirds owned by Zen Noh Phosphate Corp., a Japanese trading company. Estech also owns the closed Silver City Mine, which has been idle for the past 3 years. The Silver City Mine was being prepared for restarting at yearend.

Gardinier operated the Fort Meade Mine and chemical complex south of Tampa, FL, at approximately 70% of capacity throughout the year. Cargill Inc. purchased 80% of Gardinier at yearend 1985.

W. R. Grace and IMC, coowners of the Four Corners Mine, closed the mine in March for at least 2 years, with plans to reopen it January 1988 and produce phosphate rock at the rate of 4.5 million tons per year thereafter. W. R. Grace continued to produce phosphate rock from the Hookers Prairie Mine in Polk County, FL.

Hopewell closed the Lithia Mine in July. The mine had started producing in January but as inventories increased, the decision was made to close until demand for phosphate rock improved.

IMC operated the Clear Springs, Kingsford, and Noralyn-Phosphoria Mines in central Florida. IMC completed arrangements to lease the Lonesome and Haynsworth Mines from Brewster in October, then closed the mines. The Lonesome Mine will remain closed indefinitely and the Haynsworth Mine was reopened after 10 days. The Bureau of Mines estimated that IMC, after acquiring the Brewster mines and including its 50% share of the Four Corners Mine, has about one-third of the Florida phosphate rock mining capacity.

Mobil closed the Nichols Mine in June for an indefinite period. Mobil's Fort Meade Mine operated at reduced capacity. Studies are in progress to determine the feasibility of extending the life of the Fort Meade Mine by pumping either matrix or flotation feed from the South Fort Meade deposit to the Fort Meade beneficiation plant.

Occidental operated the Swift Creek and Suwannee River Mines in northern Florida. Most of the phosphate rock was converted into superphosphoric acid for export to the U.S.S.R.

USS Agri-Chemicals operated the Rockland Mine, a 50-50 partnership with Freeport Chemical Co. The Fort Meade Chemical Products plant, adjacent to the mine, is a 50-50 partnership with W. R. Grace. The Bartow Chemical plant, Bartow, FL, is another USS Agri-Chemicals partnership with W. R. Grace. USS Agri-Chemicals sold the Rich-Waters, Manson-Jenkins, and Iori phosphate rock deposits to Agrico. USX Corp. announced in October that, in a stock-for-assets exchange, it would sell its chemical business to the newly formed Aristech Chemical Corp. Current managers of USS Agri-Chemicals formed Aristech.

Tennessee.—Occidental, Monsanto Co., and Stauffer Chemical Co. mined phosphate rock in Giles, Hickman, Maury, and Williamson Counties. Monsanto closed its mine, beneficiation plant, and electric furnaces at the end of October. Neither Occidental nor Stauffer planned to curtail phosphate rock mining and elemental phosphorus manufacturing.

Western States.—Phosphate rock was mined in Idaho, Montana, and Utah. The rock was mined to produce elemental phosphorus in Idaho and Montana and fertilizer in Idaho.

Cominco American Incorporated produced phosphate rock from the Warm Springs underground mine in Powell County, MT. After impact crushing through a 9.5-millimeter (3/8-inch) screen, the ore was loaded into railroad cars and shipped to Kimberly, British Columbia, Canada. In September, Canadian Pacific Ltd. sold 31% of its 52% shareholding in Cominco to Metallgesellshaft AG of the Federal Republic of Germany, Teck Corp. of Canada, and MIM Holdings Ltd. of Australia. The remainder of Canadian Pacific's holdings were scheduled for sale to the public.

Stauffer, a division of Chesebrough Pond Co., mined phosphate rock from the Wooley Valley Mine north of Soda Springs, ID. The phosphate rock was shipped to Stauffer's electric-furnace plant in Silver Bow, MT. Unilever Bros. USA purchased Chesebrough Pond at the close of 1986 and closed the phosphate rock mine and electric-furnace plant.

The Conda Partnership, a 50-50 partnership of Beker and Western Cooperative Fertilizers Ltd., Calgary, Canada, mined phosphate rock from the Champ deposit in Idaho. After the Champ deposit is depleted, the partnership planned to mine the Mountain Fuel deposit, and finally mine four

Husky leases. Beker filed for reorganization under chapter 11 of the Federal Bankruptcy Code in October and suspended operations at Conda, ID, in May. Beker's phosphate fertilizer plant was closed, and Beker's plant and interest in the Conda Partnership were put up for sale. Western Cooperative closed the Conda Partnership calcining plant in August.

Washington Corp. of Missoula, MT, agreed in September to purchase Beker's interest in the Conda Partnership. Washington Corp. planned that phosphate rock mining would resume and that shipments of rock would be made to the fertilizer complex at Conda, ID, and to Western Cooperative's fertilizer plant in Calgary, Canada.

Chevron Resources Co. mined phosphate rock from the Vernal, UT, mine. Ground phosphate rock slurry was pumped through a 155-kilometer (96-mile) pipeline from Vernal to Chevron Chemical Co.'s fertilizer complex at Rock Springs, WY. Sulfur was received by rail at Rock Springs from Chevron USA's Carter Creek, WY, natural gas plant. In September, the Rock Springs plant started producing merchant-grade phosphoric acid, monoammonium and diammonium phosphate, and superphosphoric acid. The mine at Vernal has the capacity to produce 1 million tons per year of concentrates for the Rock Springs chemical complex.

J. R. Simplot Co. operated the Gay Mine on the Fort Hall Indian Reservation, ID, and the Smoky Canyon Mine in the Caribou National Forest near the Wyoming border. The Smoky Canyon Mine was closed during June and August. The slurry concentrates produced at Smoky Canyon were pumped through a pipeline a distance of 44 kilometers (27 miles) to the Conda, ID, facility. At Conda, the concentrates were dewatered, dried, and calcined before shipping by rail to Simplot's chemical plant at Pocatello, ID, for conversion into phosphoric acid and phosphate fertilizer.

Agreement was reached with the Shoshone and Bannock tribes and FMC Corp., the lease holder, to permit Simplot to mine several additional Gay Mine deposits on the reservation. The additional reserves will permit the mine to produce for another 17 years. FMC received 80% of the Gay Mine production, a 24% to 25% phosphatic shale, for consumption in its 1.13-million-kilogram-per-year elemental phosphorus plant near Pocatello, ID. Simplot uses about 20% of the Gay Mine main bed or high-grade ore to produce phosphoric acid near Pocatello, ID.

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]	
1985[r]	175,227	22,880	7,763	2,312	43,220	13,362	50,835	15,674	1,235,800	15,534
1986:										
January-June:										
Florida and North Carolina	65,720	8,198	2,002	623	15,787	4,899	17,789	5,522	410,392	15,190
Tennessee	1,075	223	49	12	574	147	623	159	13,783	148
Western States[4]	1,609	422	580	167	982	306	1,562	473	48,145	738
Total[2]	68,403	8,842	2,631	802	17,343	5,353	19,974	6,155	[5]472,321	16,077
July-December:										
Florida and North Carolina	62,371	7,705	394	127	16,041	4,926	16,435	5,054	366,584	11,480
Tennessee	1,089	301	52	12	557	145	608	157	14,449	194
Western States[4]	2,183	563	993	278	700	214	1,693	492	32,413	984
Total[2]	65,644	8,568	1,439	417	17,297	5,285	18,736	5,702	[5]413,445	12,658
Grand total[2]	134,045	17,411	4,070	1,219	34,641	10,638	38,710	11,857	[5]877,600	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]Includes Idaho, Montana, and Utah.
[5]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 consumption declined 10% in 1985 from that of 1984 and again declined in 1986 about 11% from that of 1985. The consecutive annual reduction in demand mirrored the depressed farm economy in the United States and the decline in demand for phosphate fertilizers in the world. Both domestic and export demand for food and fiber from the U.S. agricultural sector has been soft for the past several years. In the United States, exceptionally large farm production and limited domestic demand strained available storage capacity for food and feed grains. The export potential for U.S. farm products, if substantial, would have increased the demand for phosphate fertilizer. Improvement in export demand did not develop because several other countries increased their share of the international market for farm commodities and other countries with histories of importing significant quantities of foodstuffs have become self-sufficient in food production. Other, less prosperous, countries simply did not have the means to purchase agricultural products.

Essentially all of the phosphate rock produced in Florida and North Carolina was either converted into phosphate fertilizer or exported. Consumption of phosphate rock from Florida was about 13% less than that consumed in 1985.

All of the phosphate rock mined in Tennessee was consumed in electric furnaces in either Mount Pleasant or Columbia. Consumption was similar to that of 1985. The markets for elemental-phosphorus-derived chemicals have apparently stabilized. About 50% of the elemental phosphorus was used to produce sodium tripolyphosphate (STPP). In both household detergents and industrial or institutional detergents and cleaning compounds, STPP is one of the most important ingredients in that it improves the performance of the detergent. High-purity elemental phosphorus was used to produce technical- and food-grade phosphoric acid and other chemicals.

In the Western States, a limited quantity of phosphate rock produced by Cominco, the Conda Partnership, and Chevron was exported to Canada and converted into phosphate fertilizer. The balance, in about equal proportions, was consumed in either electric furnaces in Idaho and Montana, or in phosphorus fertilizer plants in Idaho or Wyoming.

Table 3.—U.S. phosphate rock sold or used grade distribution pattern

Grade (percent BPL[1] content)	Distribution (percent)				
	1982	1983	1984	1985[r 2]	1986
Less than 60	4.9	8.0	12.1	4.8	3.1
60 to less than 66	15.6	14.6	8.1	13.1	20.9
66 to less than 70	63.8	60.6	63.0	62.9	59.2
70 to less than 72	5.8	8.3	10.1	12.0	8.1
72 to less than 74	6.1	5.5	2.0	4.2	4.1
74 or more	3.8	3.0	4.7	2.9	4.6

[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)				
	1982[2]	1983	1984	1985[r 2]	1986
Less than 60	0.6	3.3	7.8	0.6	--
60 to less than 66	12.2	13.0	7.0	12.8	20.6
66 to less than 70	68.5	64.2	67.5	65.9	60.7
70 to less than 72	6.9	9.6	9.9	12.6	9.0
72 to less than 74	7.2	6.4	2.4	4.8	4.6
74 or more	4.5	3.5	5.4	3.4	5.1

[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 5.—Tennessee phosphate rock sold or used grade distribution pattern

Grade (percent BPL[1] content)	Distribution (percent)				
	1982	1983	1984	1985	1986
Less than 60	38.0	89.4	100.0	100.0	100.0
60 to less than 66	62.0	10.6	--	--	--

[1]1.0% BPL (bone phosphate of lime or tricalcium phosphate)=0.458% P_2O_5.

Table 6.—Western States phosphate rock sold or used grade distribution pattern

Grade (percent BPL[1] content)	Distribution (percent)				
	1982	1983	1984	1985[2]	1986
Less than 60	27.2	25.2	27.0	15.7	1.5
60 to less than 66	29.4	27.5	19.1	19.6	33.3
66 to less than 70	43.4	47.3	39.6	54.2	65.2
70 to less than 72	--	--	14.3	10.4	--

[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 7.—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		
	Rock	P_2O_5 content	Value[3 4]	Rock	P_2O_5 content	Value[3]
January-June 1985	r20,989	6,508	r498,183	669	173	r14,981
July-December 1985	19,868	6,194	r474,564	607	157	r13,567
January-June 1986:						
Below 60	--	--	--	653	168	14,567
60 to less than 66	3,743	1,084	92,401	--	--	--
66 to less than 70	10,441	3,226	213,691	--	--	--
70 to less than 72	1,951	634	48,232	--	--	--
72 to less than 74	552	185	10,222	--	--	--
74 or more	978	337	33,521	--	--	--
Total	17,665	5,466	398,067	653	168	14,567
July-December 1986:						
Below 60	--	--	--	578	150	13,500
60 to less than 66	3,741	1,066	90,697	--	--	--
66 to less than 70	11,625	3,601	238,609	--	--	--
70 to less than 72	1,319	428	31,479	--	--	--
72 to less than 74	1,104	371	26,935	--	--	--
74 or more	879	303	24,642	--	--	--
Total	18,668	5,769	412,362	578	150	13,500

Grade (percent BPL[2] content)	Western States[5]			Total		
	Rock	P_2O_5 content	Value[3]	Rock	P_2O_5 content	Value[3 4]
January-June 1985	r2,691	780	r74,169	r24,348	7,461	r587,333
July-December 1985	r1,810	550	r58,212	r22,285	6,901	r546,343
January-June 1986:						
Below 60	44	11	965	697	179	15,532
60 to less than 66	484	137	8,541	4,227	1,221	100,942
66 to less than 70	1,076	337	40,170	11,517	3,563	253,861
70 to less than 72	--	--	--	1,951	634	48,232
72 to less than 74	--	--	--	552	185	10,222
74 or more	--	--	--	978	337	33,521
Total	1,604	485	49,676	19,922	6,119	462,310

See footnotes at end of table.

Table 7.—Phosphate rock sold or used by producers in the United States, by grade and region[1] —Continued

(Thousand metric tons and thousand dollars)

	Western States[5]			Total		
	Rock	P_2O_5 content	Value[3]	Rock	P_2O_5 content	Value[3 4]
July-December 1986:						
Below 60	--	--	--	578	150	13,500
60 to less than 66	523	146	7,674	4,264	1,212	98,371
66 to less than 70	891	275	23,977	12,516	3,876	262,586
70 to less than 72	--	--	--	1,319	428	31,479
72 to less than 74	--	--	--	1,104	371	26,935
74 or more	--	--	--	879	303	24,642
Total	1,414	421	31,651	20,660	6,340	457,513

[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]F.o.b. mine.
[4]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.
[5]Includes Idaho, Montana, and Utah.

Table 8.—Phosphate rock sold or used by producers in the United States, by use[1]

(Thousand metric tons)

Use	1985 total		1986 January-June		1986 July-December		1986 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	r33,358	r10,252	13,573	4,131	14,405	4,382	27,979	8,512
Normal superphosphate	72	24	185	58	25	8	210	66
Triple superphosphate	r1,274	r415	744	252	548	184	1,292	436
Defluorinated rock	55	19	40	14	38	13	78	27
Direct applications	94	32	482	153	549	173	1,032	325
Elemental phosphorus	2,599	677	1,078	287	1,022	273	2,101	560
Ferrophosphorus	45	12	23	6	19	5	42	11
Total[2]	r37,497	r11,432	16,126	4,900	16,606	5,038	32,732	9,938
Exports[4]	r9,136	r2,931	3,795	1,219	4,053	1,302	7,848	2,521
Grand total[2]	46,634	14,363	19,921	6,119	20,659	6,340	40,580	12,460

[r]Revised.
[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 9.—Phosphate rock sold or used by producers in the United States, by use and region[1]

(Thousand metric tons)

Use	Florida and North Carolina: Rock	Florida and North Carolina: P_2O_5 content	Tennessee: Rock	Tennessee: P_2O_5 content	Western States[2]: Rock	Western States[2]: P_2O_5 content	Total[3]: Rock	Total[3]: P_2O_5 content
1985	40,857	r12,702	1,276	330	4,501	1,331	r46,633	r14,363
1986:								
January-June:								
Domestic:[4]								
Agricultural	14,323	4,387	--	--	701	220	15,024	4,607
Industrial	34	10	653	168	415	115	1,101	293
Total	14,357	4,397	653	168	1,116	335	16,125	4,900
Exports[5]	3,308	1,069	--	--	487	150	3,795	1,219
Total	17,665	5,466	653	168	1,603	485	19,920	6,119
July-December:								
Domestic:[4]								
Agricultural	14,829	4,533	--	--	736	228	15,565	4,760
Industrial	21	6	578	150	442	122	1,041	278
Total	14,850	4,539	578	150	1,178	350	16,606	5,038
Exports[5]	3,818	1,230	--	--	235	71	4,053	1,302
Total[3]	18,668	5,769	578	150	1,413	421	20,659	6,340
Grand total[3]	36,333	11,236	1,230	317	3,017	907	40,580	12,459

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 10.—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
1982	32,806	10,192	$850,794	$25.93
1983	40,223	12,456	944,509	23.48
1984	46,411	14,309	1,089,647	23.48
1985r	40,857	12,702	972,748	23.81
1986	36,333	11,236	810,429	22.31

rRevised.
[1]Data for the same items appearing in this or other tables may not reconcile because of computer rounding.
[2]The total value is based on a weighted value.

Table 11.—Tennessee 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
1982	960	248	$12,972	$13.51
1983	1,187	307	28,935	24.38
1984	1,340	338	32,590	24.32
1985	1,276	330	r28,547	r22.37
1986	1,230	317	28,067	22.82

rRevised.
[1]Data for the same items appearing in this or other tables may not reconcile because of computer rounding.
[2]The total value is based on a weighted value.

Table 12.—Western States 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
1982	4,807	1,375	$119,699	$24.90
1983	5,428	1,573	149,520	27.55
1984	5,526	1,597	156,119	28.25
1985r	4,501	1,331	132,380	29.41
1986	3,017	906	81,326	26.96

rRevised.
[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.

STOCKS

Inventories of marketable phosphate rock were reported to the Bureau of Mines by producing companies each month and semiannually. The data from the monthly surveys permitted the Bureau to publish changes in stocks each month in the monthly "Phosphate Rock Mineral Industry Surveys." The stocks, reported semiannually, provided the respondents an opportunity to adjust or correct the monthly totals if a more precise procedure was used to estimate inventories. The adjusted stock levels were reported in the "Annual Advance Summary Mineral Industry Surveys," the "Crop Year Mineral Industry Surveys," and the "Minerals Yearbook."

The significant decrease in stock levels in 1984 compared with those of prior years was caused by improved demand. Inventories of phosphate rock gradually increased in 1985 as demand declined. Inventories in 1986 were controlled by producers operating on reduced schedules or by periodically closing plants to limit stock buildup.

Table 13.—Marketable phosphate rock yearend stocks

(Million metric tons)

Year	Quantity
1977	13.7
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	12.7

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 a freight, loading, and weighing cost of $6.17 and $7.90, respectively. The severance tax, included in the export price, was $2.51 per ton.

The weighted average 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 14.—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)	1983[3]	1984[4]	1985[5]	1986[6]
68	$27.00	$26.50	$26.00	$25.50
70	28.00	27.50	28.00	27.00
72	30.00	30.50	30.50	31.00
75	35.00	35.00	34.00	33.00

[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 $2.25 severance tax.
[4]Estimated selling price including $2.39 severance tax.
[5]Estimated selling price including $2.52 severance tax.
[6]Estimated selling price including $2.51 severance tax.

Table 15.—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)	1983	1984	1985	1986
Khouribga:				
70 to 71	35.00	36.00	36.00	36.00
76 to 77	45.00	47.00	47.00	45.00
Youssoufia:				
68 to 69	29.00	30.00	30.00	30.50
74 to 75	41.00	43.00	43.00	40.50

[e]Estimated.
[1]1.0% BPL (bone phosphate of lime or tricalcium phosphate)=0.458% P_2O_5.

Table 16.—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)	1985			1986		
	Domestic	Export	Average	Domestic	Export	Average
Less than 60	21.50	--	21.50	--	--	--
60 to less than 66	[r]23.98	20.69	[r]23.66	24.63	21.53	24.47
66 to less than 70	[r]22.77	[r]22.50	[r]22.75	20.32	22.15	20.50
70 to less than 72	[r]22.02	[r]25.97	[r]24.84	18.80	25.18	24.38
72 to less than 74	22.59	30.86	26.17	18.93	24.67	22.43
74 or more	34.44	40.77	38.35	28.87	35.05	31.32
Average	[r]23.08	[r]26.72	[r]23.81	21.64	25.02	22.31

[r]Revised.
[1]1.0% BPL (bone phosphate of lime or tricalcium phosphate)=0.458% P_2O_5.

Table 17.—Price or value of Tennessee phosphate rock, by grade

(Dollars per metric ton, f.o.b. mine)

Grade (percent BPL[1] content)	1985	1986
Less than 60	[r]22.37	22.81

[r]Revised.
[1]1.0% BPL (bone phosphate of lime or tricalcium phosphate)=0.458% P_2O_5.

Table 18.—Price or value of Western States phosphate rock, by grade

(Dollars per metric ton, f.o.b. mine)

Grade (percent BPL[1] content)	1985			1986		
	Domestic	Export	Average	Domestic	Export	Average
Less than 60	14.14	--	14.14	21.93	--	21.93
60 to less than 66	11.81	42.95	20.06	10.04	41.69	16.11
66 to less than 70	31.90	41.79	33.02	27.01	47.87	32.62
70 to less than 72	--	51.20	51.20	--	--	--
Average	24.63	46.58	29.41	20.90	46.21	26.96

[1]1.0% BPL (bone phosphate of lime or tricalcium phosphate)=0.458% P_2O_5.

Table 19.—Price or value of U.S. phosphate rock, by grade

(Dollars per metric ton, f.o.b. mine)

Grade (percent BPL[1] content)	1985			1986		
	Domestic	Export	Average	Domestic	Export	Average
Less than 60	19.66	--	19.66	22.78	--	22.78
60 to less than 66	r22.50	27.76	r23.14	23.13	28.23	23.48
66 to less than 70	r23.51	r24.59	r23.60	20.77	27.26	21.49
70 to less than 72	r22.02	r28.84	r27.05	18.80	25.18	24.38
72 to less than 74	22.59	30.86	26.17	18.93	24.67	22.43
74 or more	34.44	40.77	38.35	28.87	35.05	31.32
Average	r23.20	r28.85	r24.31	21.63	26.97	22.67

rRevised.
[1]1.0% BPL (bone phosphate of lime or tricalcium phosphate)=0.458% P_2O_5.

FOREIGN TRADE

Phosphate rock export tonnage declined again in 1986. From 14.3 million tons in 1980, phosphate rock exports declined in 1981 and 1982, improved in 1983, but resumed their slide thereafter reaching 9.0 million tons in 1986. The decline in phosphate rock exports was attributed to a world recession in agriculture, a world oversupply of farm products, competition from foreign producers, greater availability of high analysis phosphate fertilizers, and increased trade in phosphate fertilizers.

The nature of the phosphate fertilizer market has changed during the 1980's as phosphate rock producers in north Africa and the Middle East increased their capacity to convert phosphate rock into fertilizers and phosphate rock importing countries increased the number of new plants available to produce fertilizers. In 1980-81, the United States was the principal exporter of phosphate fertilizer with 53% of total exports; however, its share of this market was reduced to 47.6% in 1985-86. From the market trend, the U.S. share of the phosphate export market probably will continue to decline.

Phosphate rock and phosphate fertilizer prices weakened throughout the year as an oversupply of the phosphate commodities again dominated the markets. Phosphate rock imports into the United States increased significantly over the 34,000 tons imported in 1985, as reported by the Bureau of the Census in the following tabulation:

Country of origin	Metric tons
Mexico	197
Morocco	38,026
Netherlands	36
Netherlands Antilles	4,240
Togo	479,386
United Kingdom	285
Other	5,608
Total	527,778

NOTE.—Reported imports from Canada are excluded.

Tariffs on U.S. exports of phosphate rock and phosphate fertilizers are substantial and they decrease the competitiveness of U.S. producers in international trade. Although tariffs were imposed on U.S. exports, foreign producers were not penalized when similar products were sold in the United States. Although 1986 data were not available, U.S. fertilizer companies paid $200 million in tariffs on exports in 1985. The Indian Government was paid $40 million in tariffs; Pakistan, $37.5 million; Brazil, $20.5 million; and the Republic of Korea, $19.5 million. China and Canada, the United States second and third largest customers for phosphate commodities, imposed no tariffs.

Table 20.—U.S. exports of phosphate rock, by country

(Thousand metric tons and thousand dollars)

(Schedule B No. 480.4500)

Country	1985 Quantity[1]	1985 Value[1]	1986 Quantity[2]	1986 Value[2]
Australia	98	NA	112	NA
Austria	--		45	
Belgium-Luxembourg	383		449	
Brazil	27		43	
Canada	2,643		2,351	
Finland	162		91	
France	668		787	
Germany, Federal Republic of	665		535	
India	480		278	
Italy	97		95	
Japan	803		966	
Korea, Republic of	1,540		1,374	
Mexico	258		278	
Netherlands	555		51	
New Zealand	116		67	
Philippines	30		32	
Poland	754		521	
Romania	223		91	
Sweden	83		82	
United Kingdom	--		1	
Other	699		927	
Total	[3]10,284	[3]281,515	9,176	294,053

NA Not available.
[1]Individual country exports furnished by Bureau of the Census.
[2]Bureau of the Census data (free alongside ship).
[3]Total quantity and value reported to the Bureau of Mines, f.o.b. mine.

Table 21.—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	1985 Quantity	1985 Value[1]	1986 Quantity	1986 Value[1]
Argentina	3	NA	10	NA
Australia	--		60	
Belgium-Luxembourg	111		43	
Brazil	158		207	
Bulgaria	20		46	
Burma	--		16	
Canada	289		277	
Chile	158		129	
Colombia	17		12	
Costa Rica	9		10	
Czechoslovakia	--		118	
Dominican Republic	31		13	
France	62		--	
Germany, Federal Republic of	58		10	
Ireland	27		30	
Italy	10		--	
Japan	34		38	
Mexico	--		122	
Peru	16		28	
Spain	--		18	
Uruguay	9		15	
Venezuela	1		--	
Other	403		31	
Total	1,416	176,417	1,233	155,774

NA Not available.
[1]All values f.a.s. (free alongside ship).

Source: Bureau of the Census.

Table 22.—U.S. exports of superphosphates, less than 40% P_2O_5, by country

(Schedule B No. 480.7030)

Country	1985 Quantity (metric tons)	1985 Value[1] (thousands)	1986 Quantity (metric tons)	1986 Value[1] (thousands)
Canada	3,651	$79	3,990	$87
Other	457	19	--	--
Total	4,108	98	3,990	87

[1]All values f.a.s. (free alongside ship).

Source: Bureau of the Census.

Table 23.—U.S. exports of diammonium phosphates, by country

(Thousand metric tons and thousand dollars)

(Schedule B No. 480.8005)

Country	1985 Quantity	1985 Value[1]	1986 Quantity	1986 Value[1]
Argentina	59	NA	106	NA
Australia	230	NA	190	NA
Belgium-Luxembourg	482	NA	353	NA
Brazil	35	NA	173	NA
Canada	193	NA	117	NA
Chile	65	NA	67	NA
China	789	NA	542	NA
Colombia	97	NA	91	NA
Costa Rica	25	NA	17	NA
Dominican Republic	38	NA	25	NA
Ecuador	33	NA	28	NA
France	50	NA	26	NA
Germany, Federal Republic of	81	NA	17	NA
Guatemala	18	NA	25	NA
India	1,853	NA	441	NA
Ireland	51	NA	17	NA
Italy	174	NA	196	NA
Japan	349	NA	162	NA
Mexico	186	NA	83	NA
Netherlands	70	NA	--	NA
New Zealand	36	NA	24	NA
Pakistan	326	NA	607	NA
Thailand	34	NA	9	NA
Turkey	230	NA	286	NA
Uruguay	49	NA	32	NA
Yugoslavia	120	NA	24	NA
Other	458	NA	462	NA
Total	6,131	1,048,322	4,120	641,385

NA Not available.
[1]All values f.a.s. (free alongside ship).

Source: Bureau of the Census.

Table 24.—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	1985 Quantity	1985 Value[1]	1986 Quantity	1986 Value[1]
Canada	2		2	
Colombia	6		9	
Germany, Federal Republic of	24		--	
India	378	NA	273	NA
Indonesia	42		46	
Turkey	63		--	
Venezuela	146		106	
Other	55		264	
Total	716	141,162	700	110,010

NA Not available.
[1]All values f.a.s. (free alongside ship).

Source: Bureau of the Census.

Table 25.—U.S. exports of elemental phosphorus, by country

(Schedule B No. 415.3500)

Country	1985 Quantity (metric tons)	1985 Value[1] (thousands)	1986 Quantity (metric tons)	1986 Value[1] (thousands)
Brazil	[r]6,093	$11,279	6,537	
Canada	[r]1,504	1,906	487	
Japan	7,706	11,500	8,436	
Korea, Republic of	718	986	402	NA
Mexico	17	26	2,832	
Taiwan	835	1,047	1,424	
Other	258	280	148	
Total	17,131	27,024	20,266	$33,310

[r]Revised. NA Not available.
[1]All values f.a.s. (free alongside ship).

Source: Bureau of the Census.

Table 26.—U.S. imports for consumption of phosphate rock and phosphatic materials

(Thousand metric tons and thousand dollars)

Fertilizer	TSUS No.[1]	1985 Quantity	1985 Value[2]	1986 Quantity	1986 Value[2]
Phosphates, crude and apatite[3]	480.4500	34	1,593	528	22,265
Phosphatic fertilizers and fertilizer materials	480.7070-480.8095	30	5,929	69	8,351
Dicalcium phosphate	418.2800	1	841	1,420	1,209
Phosphorus	415.3500	2	3,530	1,510	3,548
Phosphoric acid, technical-grade	480.7010	([4])	68	([4])	157
Normal superphosphate	480.7030	1	120	1	204
Triple superphosphate	480.7050	2	304	1	112

[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

The difficulties and problems of the world phosphate rock and phosphate fertilizer industry were attributed by market economy countries to high price supports and other subsidies that have encouraged farmers to produce larger harvests than markets could absorb. Oversupply of farm commodities in Japan, the United States, and Western Europe far exceeded consumption. In the 1970's, there was a worldwide boom in exports as the U.S.S.R. imported grain on a huge scale for animal consumption. Oil price increases directed money into international banks; the banks lent the money to developing countries, which purchased food supplies. World farmers pushed production to higher levels to meet the unprecedented demand. Export markets shrank in the 1980's as the oil price shock in 1979 led the industrialized world into a recession. Poor countries cut back drastically on food imports. High-yielding crop strains developed during the "green revolution" brought many countries to the point of self-sufficiency in food production. Farm exports from the United States, Japan, and the European Communities have declined about 50% during the first part of this decade. The demand for phosphate fertilizers faithfully followed the demand for farm commodities. The phosphate rock mining industry had to adjust to dramatically lower demand for mineral fertilizers.

In an era of phosphate oversupply in the world, there was a limited level of activity involving phosphate rock.

Table 27.—Phosphate rock, basic slag, and guano: World production, by country[1]

(Thousand metric tons)

Commodity and country[2]	Gross weight					P_2O_5 content				
	1982	1983	1984	1985[p]	1986[e]	1982	1983	1984	1985[p]	1986[e]
Phosphate rock:										
Algeria	947	893	[e]1,000	1,207	1,203	289	276	309	[e]381	380
Australia	211	[r]5	15	[r e]7	[3]34	59	1	4	[r e]2	11
Brazil	2,732	3,208	3,855	4,214	[3]4,509	1,141	1,119	1,345	1,475	1,488
China[e]	11,720	12,500	[r]11,800	[r]6,970	6,700	[r]3,164	[r]3,375	[r]3,186	[r]1,882	1,809
Christmas Island (Indian Ocean)	1,328	1,094	1,259	1,200	[3]825	466	385	443	[r e]418	289
Colombia	20	17	11	24	[3]27	4	[r]3	2	5	6
Egypt	711	647	1,043	[e]1,074	[3]1,271	200	205	253	[e]246	292
Finland	233	381	477	510	[3]527	83	141	176	177	180
India	631	688	892	929	[3]750	197	212	294	307	250
Indonesia	5	6	2	[e]3	3	2	2	1	1	1
Iraq[e]	[3]363	1,199	1,000	1,000	1,000	113	261	218	218	218
Israel	2,148	2,969	3,312	[e]4,076	[3]3,673	698	892	995	[e]1,210	1,229
Jordan	4,390	4,749	6,263	6,067	6,249	1,427	1,548	2,042	[e]2,005	2,062
Korea, North[e]	500	500	500	500	500	150	160	160	160	160
Mexico	379	389	375	550	[3]600	[r]114	117	113	166	180
Morocco[4]	17,754	20,106	21,245	20,737	21,178	[e]5,700	[e]6,400	[e]6,762	[e]6,574	6,714
Nauru	1,359	1,684	1,358	1,508	[3]1,494	523	648	523	[e]581	575
Pakistan	--	--	--	--	[3]50	--	--	--	--	17
Peru	29	3	13	12	[3]5	9	1	4	[e]4	2
Philippines	6	4	7	6	6	2	1	2	2	2
Senegal	1,182	1,521	1,912	[e]1,702	[3]1,850	361	534	583	[e]617	641
South Africa, Republic of	3,161	2,887	2,585	2,433	[3]2,920	[e]1,149	996	939	[r e]883	1,060
Sri Lanka	[e]20	16	14	14	15	7	6	5	5	5
Sweden	[r]128	107	133	193	[3]192	[r]49	41	51	74	74
Syria	1,455	1,229	1,514	[e]1,270	1,606	443	375	461	[e]385	446
Tanzania	--	20	15	[e]15	[3]10	--	6	4	[e]4	3
Thailand	4	5	3	4	4	1	1	1	1	1
Togo	2,800	2,081	2,696	[e]2,452	[3]2,314	1,005	755	979	[e]890	833
Tunisia	4,196	5,924	5,346	4,530	[3]5,951	1,213	1,700	1,554	[e]1,303	1,712
Turkey	[5]26	50	96	[e]37	[3]3	9	15	29	[e]12	1
U.S.S.R.[e]	31,300	31,600	31,900	32,200	32,500	9,800	10,000	10,100	[r]10,200	10,300
United States	37,414	42,573	49,197	50,835	[3]38,710	11,504	13,088	14,889	15,674	[3]11,857
Vietnam[e]	110	200	200	[r]250	250	36	66	66	[r]83	83
Zimbabwe	120	133	125	135	[3]134	42	47	44	48	47
Total	[r]127,382	[r]139,388	150,163	146,664	137,063	[r]39,960	[r]43,377	46,537	45,993	42,928

Table 27.—Phosphate rock, basic slag, and guano: World production, by country[1] —Continued

(Thousand metric tons)

Commodity and country[2]	Gross weight					P_2O_5 content				
	1982	1983	1984	1985[p]	1986[e]	1982	1983	1984	1985[p]	1986[e]
Basic (Thomas converter) slag:										
Argentina	1	1	1	[e]1	1	([6])	([6])	([6])	([6])	([6])
Belgium	393	250	254	[e]260	250	71	45	46	[e]47	45
Egypt	10	10	10	[e]10	8	[e]2	[e]2	[e]2	[e]2	2
France	1,343	[r]1,124	1,194	1,165	1,100	242	[r]202	210	[e]210	198
Germany, Federal Republic of	502	409	446	484	380	130	[r]93	62	67	65
Luxembourg	572	586	728	701	650	103	105	131	126	117
United Kingdom	4	4	4	[e]4	--	1	1	1	[e]1	--
Total	2,825	[r]2,384	2,637	2,625	2,389	549	[r]448	452	453	427
Guano:										
Chile	[r]([6])	[r]([6])	NA	3	3	([6])	([6])	([6])	([6])	([6])
Kenya	([6])	([6])	([6])	([6])	([6])	([6])	([6])	([6])	([6])	([6])
Philippines	15	1	1	1	1	3	([6])	([6])	([6])	([6])
Seychelles Islands (exports)	[e]5	[e]5	[e]5	[e]5	5	2	2	2	[e]2	2
Total	[r]20	[r]6	6	9	9	5	2	2	2	2

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

[1]Table includes data available through Apr. 14, 1987. 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]Reported figure.

[4]Production from Western Sahara area included with Morocco.

[5]Run-of-mine ore.

[6]Less than 1/2 unit.

China.—The Dianchi phosphate deposits in Yunnan Province are planned to be expanded during the next 5 years. There are 25 phosphate mines in the Dianchi region in southern China. The present level of production, 3.5 million tons per year, is scheduled to increase threefold to fourfold by 1990. New downstream fertilizer projects are planned. Engineering work on two diammonium phosphate plants was started. Two 264,000-ton-per-year units are planned. One will be erected at Dalian in Liaoning and the other at Nanjing, Jiangxi Province.[2]

Dragados y Construcciones S.A., Spain, was awarded a contract to build a fertilizer complex at Qinhuangdao, Hebei Province, China. The plant will produce 1,600 tons per day of diammonium phosphate or 2,200 tons per day of mixed fertilizer. The plant will be owned by Petrochemical Industries Co., Kuwait (30%); Société Industrielle d'Acide Phosphorique et d'Engrais, Tunisia (30%); and China National Construction Corp. (40%). Tunisia will supply phosphoric acid and potash, and ammonia will be supplied from domestic sources.[3]

Egypt.—Construction started on the El Nasrab phosphate rock beneficiation plant. The plant will process 1.2 million tons per year of crude phosphate rock from the El Mahamid open pit mine, about 25 kilometers from the new plant. The project completion date was yearend 1987.[4]

Morocco.—The new fertilizer complex at Jorf Lasfar near the city of El Jadida was commissioned. The plant and port were completed, doubling Morocco's phosphoric acid capacity. The plant has eight 500-ton-per-day phosphoric acid trains. It will be able to produce 1 million tons per year of diammonium phosphate, 400,000 tons per year of triple superphosphate, and 200,000 tons per year of ammonium sulfate for Morocco's consumption.

U.S.S.R.—Four continuous ship unloading systems, railcar loading systems, and storage facilities for phosphate rock were contracted for the Black Sea port of Yuzhny in the Soviet Union. The port will be able to handle 3.2 million tons per year of phosphate rock with a storage capacity of 210,000 tons. The port probably will be completed by 1987, to receive increasingly larger tonnages of phosphate rock from Morocco.[5]

TECHNOLOGY

Application of the Bureau of Mines polyethylene dewatering technique for phosphate clay wastes in Florida and Tennessee by a number of companies showed that the process has potential for solving the difficult problem of accelerating the separation of water from the colloidal solids. Initial dewatering to obtain 20% to 40% solids was achieved with Florida and Tennessee clay wastes.[6]

In North Carolina, a procedure was developed by Texasgulf to minimize the storage of phosphogypsum and clay wastes derived from the phosphate matrix. Reclaimed phosphogypsum and flocculated waste clay were mixed in a 3-to-1 ratio and pumped into the mined-out pit. The mixture dewaters and consolidates sufficiently within 90 days to permit overburden to be spread over the pit with mobile equipment. The procedure eliminates the need to maintain clay settling ponds and requires construction of relatively small phosphogypsum stacks to supply solids to the process.

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[1]Physical scientist, Division of Industrial Minerals.
[2]Fertilizer International. No. 236, Oct. 9, 1986, p. 6.
[3]Phosphorus & Potassium. No. 145, Sept.-Oct. 1986, p. 15.
[4]Work cited in footnote 2.
[5]Page 5 of work cited in footnote 2.
[6]Pederson, J. R. (ed.). Bureau of Mines Research 1986. BuMines SP 2-86, 1986, p. 69.

Platinum-Group Metals

By J. Roger Loebenstein[1]

World mine production of platinum-group metals (PGM) in 1986 was 7.8 million troy ounces, 95% of which was accounted for by the U.S.S.R. and the Republic of South Africa. The Republic of South Africa remained the leading producer of platinum, and 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)

	1982	1983	1984	1985	1986
United States:					
Mine production[2]	8	6	15	W	W
Value[3] thousand dollars	$819	$1,118	$2,456	W	W
Refinery production:					
Primary refined	9	9	24	r7	34
Secondary:					
Nontoll-refined	344	303	340	259	231
Toll-refined	868	995	1,157	1,038	903
Total refined metal	1,221	1,307	1,521	r1,304	1,168
Stocks, yearend:					
Industry (refined)	1,107	943	1,319	r1,129	1,754
National Defense Stockpile:					
Platinum	453	453	453	453	453
Palladium[4]	1,255	1,255	1,262	1,265	1,265
Iridium[5]	24	28	30	30	30
Exports:					
Refined[6]	439	446	599	526	382
Total	836	1,229	1,162	889	751
Imports for consumption:					
Refined[6]	2,150	2,790	3,928	3,438	3,727
Total	2,494	3,218	4,474	3,990	4,477
Imports, general	2,494	3,218	r4,485	3,990	4,399
Consumption (reported sales to industry)	1,873	1,914	r2,200	r2,271	2,250
Consumption, apparent[7]	1,869	2,813	3,299	r3,358	2,950
Net import reliance[8] as a percent of apparent consumption	81	89	89	92	92
Price, dealer, average, per ounce:					
Platinum	$327	$424	$357	$291	$461
Palladium	$67	$136	$148	$107	$116
World: Mine production[9]	6,424	6,525	7,648	p7,938	e7,834

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 troy ounces purchased in 1984 and 2,400 troy ounces purchased in 1985, but not added to inventory in those years.

[5]Includes 2,400 troy ounces purchased in 1982, another 2,400 troy ounces purchased in 1983, and 1,800 troy ounces purchased in 1984, but not added to inventory in those years.

[6]Includes both unwrought and semimanufactured.

[7]1982-84 includes mine production plus nontoll-refined production plus refined imports for consumption minus refined exports plus or minus changes in Government and industry stocks. 1985-86 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]1985-86 total excludes U.S. mine production in order to avoid disclosing company proprietary data.

A mine workers' strike in January at a major PGM mine in the Republic of South Africa temporarily disrupted production in the first quarter; however, the other two South African producers were believed to be operating at near full capacity, probably negating much of the lost output. The possibility of a disruption of supplies from the Republic of South Africa spurred platinum prices sharply higher; the average monthly dealer price increased from $365 per ounce in January to nearly $600 per ounce in September. The rise in the platinum dealer price was accompanied by a rise in trading volume on the New York Mercantile Exchange (NYMEX) for platinum, which more than doubled from the level of 1985. Exploration for new PGM deposits continued in Australia, Canada, the Republic of South Africa, and other countries.

PGM were used for a number of advanced material applications; platinum-iridium alloys were used in crucibles for growing crystals used in computer memory devices and lasers, and 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 17 refiners to which a survey request was sent, 14 responded, representing an estimated 98% of the total refined metal production shown in tables 1 and 2. Production of refined metal for the three nonrespondents was estimated, using reported prior year production levels.

Legislation and Government Programs.—A new regulation issued by the Environmental Protection Agency (EPA), effective in December, required that used automobile catalytic converters pass an emissions test before they can be sold for reuse on vehicles. This regulation was expected to have a positive effect on the supply of catalyst metals recoverable from scrapped catalytic converters.[2]

In a separate action, EPA issued rules under the Resource Conservation and Recovery Act, effective November 8, to restrict the export of hazardous wastes, some of which contain precious metals.[3] The rules require the company exporting wastes to receive prior approval from the receiving country and to notify EPA at least 60 days prior to shipping wastes. The International Precious Metals Institute held a seminar in December in Washington, DC, to discuss methods for solving environmental problems affecting the precious metals industry.

DOMESTIC PRODUCTION

ASARCO Incorporated produced platinum and palladium as byproducts of copper refining. Secondary metal was refined by about 17 firms, mostly on the east and west coasts. Most PGM scrap was refined on a toll basis. The largest scrap processor in the United States was Johnson Matthey Inc.

Manville International Corp. received permission from bankruptcy court to invest money in its Stillwater palladium-platinum deposit in Montana, being developed by Manville along with Chevron Resources Inc. and Lac Minerals Ltd. Production from the deposit in Montana was expected to begin by mid-1987 at an initial rate of 500 metric tons of ore per day, yielding 25,000 ounces of platinum and 75,000 ounces of palladium per year.

A number of mineral exploration companies submitted bids to the Minnesota Department of Natural Resources for leases on State-owned mineral rights in northern Minnesota.[4] The companies were interested in exploring for platinum, as well as copper, gold, and nickel. Traces of platinum reportedly have been found in bedrock about 10 miles southeast of Ely. The high bidder on leases available in that area was Overseas Platinum Corp. of Vancouver, Canada, which was awarded a lease.

Handy & Harman Inc. recovered PGM from electronic scrap at its plant in South Windsor, CT, and announced plans in May to open another PGM refinery by the end of the year. The new PGM plant was to work closely with Platina Laboratories Inc., a Handy & Harman subsidiary in South Plainfield, NJ, that produces high-purity PGM compounds used in pharmaceutical and nonautomotive catalysts.

Catalytic Converter Refining Co. was formed in December to recycle used automobile catalytic converters and recover platinum, palladium, and rhodium. The company, in Northlake, IL, a suburb of Chicago, also planned to recover platinum and palladium from used petrochemical catalysts.

Table 2.—Platinum-group metals refined in the United States

(Troy ounces)

	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total
PRIMARY METAL							
Nontoll-refined:							
1982	947	6,131	--	--	--	--	7,078
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
Toll-refined:							
1982	434	1,421	--	--	--	--	1,855
1983	1,150	2,026	--	--	--	--	3,176
1984	1,153	4,895	1,000	250	--	2,000	9,298
1985	1,100	--	--	--	--	2,200	[r]3,300
1986	8,200	6,600	--	1,350	--	13,500	29,650
SECONDARY METAL							
Nontoll-refined:							
1982	190,249	139,286	2,896	--	11,302	427	344,160
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	[r]52,383	[r]201,362	252	--	3,126	1,474	[r]258,597
1986	57,504	168,918	297	--	2,999	1,313	231,031
Toll-refined:							
1982	393,832	430,564	10,108	885	26,693	6,301	868,383
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	[r]490,595	[r]490,948	7,007	3	36,336	13,356	[r]1,038,245
1986	485,548	369,491	3,584	65	38,041	6,146	902,875
1985 TOTALS							
Total primary	1,624	3,463	--	--	--	[r]2,200	[r]7,287
Total secondary	[r]542,978	[r]692,310	7,259	3	39,462	14,830	[r]1,296,842
Total refined metal[r]	544,602	695,773	7,259	3	39,462	17,030	1,304,129
1986 TOTALS							
Total primary	8,813	10,342	--	1,350	--	13,500	34,005
Total secondary	543,052	538,409	3,881	65	41,040	7,459	1,133,906
Total refined metal	551,865	548,751	3,881	1,415	41,040	20,959	1,167,911

[r]Revised.

CONSUMPTION AND USES

Domestic industrial consumption of PGM in 1986 remained essentially the same as that of 1985. 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; in catalysts used to produce acids, organic chemicals, and pharmaceuticals; 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 outfitted on light trucks (trucks weighing 14,000 pounds or less) and automobiles. A typical emission catalyst contained approximately 0.057 ounce of platinum, 0.015 ounce of palladium, and 0.006 ounce of rhodium. For comparison, a typical emission catalyst in 1985 contained approximately 0.055 ounce of platinum, 0.016 ounce of palladium, and 0.006 ounce of rhodium. There was some variation in the quantities of the metals contained in each catalyst, depending 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 electronic applications, ruthenium was the principal PGM used in thick film resistors, and 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 the production of textile or continuous filament glass fiber.

In other applications, platinum and iridium were used in crucibles suitable for growing oxide single crystals such as gadolinium gallium garnet (GGG) and yttrium aluminum garnet (YAG). GGG and YAG are used for computer memory devices and solid-state lasers. Platinum in conjunction with titanium and columbium was used for cathodic protection of steel reinforcing bars in bridge and highway concrete to prevent their corrosion, brought on principally by deicing salts used on roadways.

The Bureau of Mines does not publish data on domestic investor demand for platinum, which reportedly continued to soar, reaching perhaps 220,000 ounces, growing from virtually zero in 1981. The estimate was from Johnson Matthey PLC, using their low end of the range for platinum investment demand in North America.[5]

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
1982	780,146	926,304	10,600	1,358	49,915	104,930	1,873,253
1983	796,716	921,829	5,023	1,389	44,225	144,777	1,913,959
1984:							
Automotive[2]	[r]569,000	[r]179,000	217	--	[r]52,000	[r]1,035	[r]801,252
Chemical	73,496	78,600	735	10	4,631	24,743	182,215
Dental and medical	18,644	347,043	381	1,062	427	62	367,619
Electrical	99,155	389,695	1,514	--	7,461	54,155	551,980
Glass	12,184	10	106	--	2,941	--	15,241
Jewelry and decorative	9,549	6,884	1,173	--	2,116	813	20,535
Petroleum	28,045	92,134	--	--	11	600	120,790
Miscellaneous	66,154	57,134	2,991	--	6,666	7,211	140,156
Total	[r]876,227	[r]1,150,500	7,117	1,072	[r]76,253	88,619	[r]2,199,788
1985:							
Automotive[2]	[r]619,000	[r]181,000	287	--	[r]68,000	1,035	[r]869,322
Chemical	85,227	63,236	966	17	4,096	19,090	172,632
Dental and medical	[r]24,514	[r]338,098	645	868	352	96	[r]364,573
Electrical	115,840	300,677	1,843	--	5,665	50,956	474,981
Glass	20,651	416	177	--	2,467	14	23,725
Jewelry and decorative	16,040	[r]7,982	1,889	--	2,222	661	[r]28,794
Petroleum	28,771	80,940	--	--	31	--	109,742
Miscellaneous	115,722	87,970	4,857	--	5,419	13,722	227,690
Total	[r]1,025,765	[r]1,060,319	10,664	885	[r]88,252	85,574	[r]2,271,459
1986:							
Automotive[2]	625,000	165,000	193	--	67,000	1,000	858,193
Chemical	77,696	44,485	929	17	5,083	24,910	153,120
Dental and medical	22,619	401,760	372	672	611	98	426,132
Electrical	103,506	316,390	1,630	--	6,813	61,489	489,828
Glass	15,973	--	93	--	2,952	20	19,038
Jewelry and decorative	11,908	6,521	1,089	--	3,194	737	23,449
Petroleum	30,566	60,959	--	--	--	--	91,525
Miscellaneous	96,143	61,182	8,132	--	7,775	15,202	188,434
Total	983,411	1,056,297	12,438	689	93,428	103,456	2,249,719

[r]Revised.
[1]Comprises primary and nontoll-refined secondary metals.
[2]1984-86 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 reported stocks held by refiners, importers, and dealers, end users of PGM held sizable quantities of PGM that were not reported to the Bureau of Mines. Stocks of PGM increased by 55%, while consumption (reported sales to industry) and total refined output declined slightly, which probably indicates increased stockpiling by consumers.

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
1982	604,632	384,184	13,348	138	40,562	63,764	1,106,628
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[r]	571,725	454,999	16,930	274	47,133	37,618	1,128,679
1986	948,468	638,746	22,147	438	68,294	76,360	1,754,453

[r]Revised.
[1]Includes metal in depositories of the New York Mercantile Exchange (NYMEX); on Jan. 2, 1987, this comprised 277,800 troy ounces of platinum and 107,300 troy ounces of palladium.

PRICES

For the year, the average dealer price for platinum increased nearly 60%, while the average dealer price for palladium increased by less than 10%. Between September of 1985 and September of 1986, the dealer price for platinum nearly doubled, owing to speculative activity fueled by concern that supplies of platinum from the Republic of South Africa, the world's largest supplier, could be interrupted by political events and mine labor unrest in that country, and by impending antiapartheid legislation in the United States. On October 2, the U.S. Congress passed the comprehensive Anti-Apartheid Act of 1986 (Public Law 99-440), which banned the importation of certain items from the Republic of South Africa; however, the PGM were among several "strategic and critical" minerals that were exempted from the sanctions.

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
1982	475	327	110	67	600	323	600	359	45	26	137	130
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:												
January	475	274	150	121	766	948	600	458	(2)	158	(3)	935
February	475	269	150	124	1,000	1,086	600	546	(2)	160	(3)	950
March	475	260	143	113	1,000	1,018	600	496	(2)	151	(3)	956
April	475	282	120	112	1,000	1,003	600	471	(2)	143	(3)	1,000
May	475	269	120	124	1,000	828	600	435	(2)	101	(3)	1,000
June	475	264	120	93	880	658	600	404	(2)	80	(3)	1,000
July	475	268	120	94	800	643	600	378	(2)	68	(3)	1,000
August	475	308	120	103	1,000	812	600	409	(2)	73	(3)	861
September	475	309	120	99	880	933	600	416	(2)	70	(3)	807
October	475	323	120	101	851	1,016	600	414	(2)	69	(3)	818
November	475	334	120	100	800	1,078	600	410	(2)	70	(3)	825
December	475	334	120	95	1,003	1,119	600	414	(2)	70	(3)	830
Average	475	291	127	107	915	929	600	438	(2)	101	(3)	915

See footnotes at end of table.

Table 5.—Average producer and dealer prices[1] of platinum-group metals —Continued

(Dollars per troy ounce)

	Platinum		Palladium		Rhodium		Iridium		Ruthenium		Osmium	
	Producer	Dealer	Producer	Dealer	Producer	Dealer	Producer	Dealer	Producer	Dealer	Producer	Dealer
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

[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.

Trading volume for platinum on the NYMEX more than doubled from the level of 1985, owing in part to the volatility in prices. Volumes on the NYMEX in futures contracts for platinum and palladium for 1984-86 are shown in the following tabulation:

	Platinum[1]	Palladium[2]
1984	571,127	159,019
1985	693,256	133,223
1986	1,624,635	145,562

[1]50 troy ounces per contract.
[2]100 troy ounces per contract.

FOREIGN TRADE

Some of the imports from the United Kingdom were refined there from ore mined in the Republic of South Africa and Canada, and some of the imports from the Netherlands and other Western European countries may have originated in the U.S.S.R. Imports of PGM scrap continued to grow, amounting to 16% of all PGM imports in 1986. The United States exported sizable quantities of PGM-bearing scrap, some of which was prepared from catalyst that was recovered from used automobile catalytic converters.

Table 6.—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)
1982	8,870	388,437	125,581	167,397	84,832	50,224	10,535	835,876	$182,460
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:									
Australia	--	--	--	1,392	382	117	66	1,957	328
Belgium-Luxembourg	--	72,378	4,985	1,635	665	--	--	79,663	23,249
Canada	3,125	27,459	5,998	28,768	11,082	662	3,183	80,277	24,101
China	4,464	--	1,702	--	7,258	--	--	13,424	1,385
France	3,113	9,154	1,500	950	718	--	626	16,061	3,831
Germany, Federal Republic of	--	6,510	1,732	13,262	5,771	8,214	150	35,639	6,850
Hong Kong	--	--	7	--	1,655	310	22	1,994	470
Israel	--	--	73	47	2,151	--	697	2,968	529
Italy	--	--	436	81	2,063	763	1,991	5,334	1,652
Japan	217	14,986	28,000	58,081	20,998	331	902	123,515	34,895
Netherlands	554	44	5,131	5,044	433	12	3,598	14,816	3,847
Norway	--	--	--	1,396	651	--	--	2,047	572
Singapore	--	--	--	1,964	661	--	--	2,625	679
Spain	--	674	1,354	493	198	--	--	2,719	865
Sweden	--	11,510	--	--	4,728	160	--	16,398	4,015
Switzerland	17,704	133	23,152	7,513	12,512	--	--	61,014	16,765
Taiwan	108	--	67	9,099	83	--	--	9,357	1,384
U.S.S.R	--	--	--	--	2,500	--	--	2,500	1,038
United Kingdom	90	196,288	18,837	41,304	9,055	331	3,953	269,858	73,551
Uruguay	--	--	--	1,299	41	--	--	1,340	154
Other	--	237	138	3,277	2,869	143	505	7,169	1,647
Total	29,375	339,373	93,112	175,605	86,474	11,043	15,693	750,675	201,807

Source: Bureau of the Census.

Table 7.—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
1982	3,298	689,647	1,039,210	19,402	1,600	5,576	68,968	133,798	14,880	1,373	339,095
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:											
Australia	300	--	5,767	--	--	--	71	--	--	--	3,612
Belgium-Luxembourg	1,193	72,363	131,338	115	--	--	1,909	--	--	--	42,196
Canada	18	10,656	52,644	--	--	--	1,124	--	1,429	1,337	374,351
China	--	1,329	126	1,005	--	--	--	--	--	--	1,064
Colombia	4,002	--	--	--	--	--	--	--	--	--	22,274
Czechoslovakia	--	3,918	5,680	--	--	--	--	--	--	--	--
Denmark	--	--	8,886	--	--	--	--	--	--	--	--
Finland	1,061	--	--	--	--	--	354	--	--	--	4,130
Germany, Federal Republic of	368	31,536	15,070	3,383	1,249	--	2,583	3,822	14	--	1,048
Hong Kong	--	965	144	193	--	--	133	--	128	--	5,839
Ireland	--	--	--	--	--	--	--	--	--	--	20,950
Italy	--	6,812	2,010	--	--	--	503	--	--	--	84
Japan	--	2,835	6,496	--	--	--	132	7,040	--	--	152
Mexico	--	--	--	--	--	--	--	--	--	--	94,162
Netherlands	--	91,515	129,008	100	--	--	12,490	1,900	--	--	43,700
Norway	--	--	1,000	--	--	--	--	--	--	--	6,316
South Africa, Republic of	964	1,163,669	527,955	15,469	1,987	--	97,722	93,797	1,200	251	3,216
Sweden	--	--	--	--	--	--	--	--	--	--	12,547
Switzerland	--	13,302	25,638	196	--	--	--	1,300	--	--	--
Taiwan	--	--	1,647	--	--	--	--	--	--	--	23,925
U.S.S.R	--	16,284	194,139	372	--	--	25,437	1,000	320	--	--
United Kingdom	2,456	291,986	276,514	9,535	2,540	4,500	35,833	66,252	13,463	--	67,075
Other	103	6,801	3,069	--	--	--	777	1,469	3,310	282	11,172
Total	10,465	1,713,971	1,387,131	30,368	5,776	4,500	179,068	176,580	19,864	1,870	737,813

	Semimanufactured (troy ounces)					Platinum-group metals in materials not elsewhere specified (troy ounces)	Total	
	Platinum	Palladium	Iridium	Rhodium	Unspecified combinations		Troy ounces	Value (thousands)
1982	114,028	60,760	907	1,005	159	--	2,493,706	$553,935
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:								
Australia	--	--	--	--	--	--	9,750	3,112
Belgium-Luxembourg	3	--	--	--	--	--	249,117	72,340
Canada	23,790	14,687	--	--	--	513	480,549	40,697
China	--	--	--	--	--	--	3,524	1,673
Colombia	1,800	--	--	--	--	--	28,076	10,471
Czechoslovakia	--	--	--	--	--	--	9,598	3,160
Denmark	--	--	--	--	--	--	8,886	1,678
Finland	--	--	--	--	--	--	5,545	3,671
Germany, Federal Republic of	--	7,243	--	--	--	--	66,316	20,971
Hong Kong	2,079	--	--	--	--	--	9,481	3,684
Ireland	--	--	--	--	--	--	20,950	140
Italy	--	--	--	--	--	--	9,409	4,366
Japan	--	--	--	--	--	--	16,655	3,008
Mexico	--	--	--	--	--	--	94,162	1,451
Netherlands	2,167	7,886	--	--	--	--	288,766	69,058
Norway	--	--	--	--	--	--	7,316	3,849
South Africa, Republic of	11,568	1,487	--	--	--	--	1,919,285	738,430
Sweden	--	--	--	--	--	--	12,547	7,794
Switzerland	--	300	--	--	--	--	40,736	8,488
Taiwan	--	--	--	--	--	--	25,572	1,291
U.S.S.R.	28,705	52,946	--	--	--	--	319,203	81,426
United Kingdom	24,461	28,985	4	1	2	--	823,607	256,306
Other	82	1,062	--	--	--	--	28,127	9,651
Total	94,655	114,596	4	1	2	513	4,477,177	1,346,715

Source: Bureau of the Census.

Table 8.—Estimated U.S. imports of platinum, palladium, and rhodium, by country[1]

(Thousand troy ounces)

Country	Platinum		Palladium		Rhodium	
	1985	1986	1985	1986	1985	1986
South Africa, Republic of	1,029	1,178	584	531	116	98
U.S.S.R	23	45	273	247	13	25
United Kingdom	288	366	216	337	51	38
Other	395	483	759	857	32	33
Total[2]	1,735	2,073	1,833	1,972	213	195

[1]This table is based on the figures shown in table 7. 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

As in past years, the Republic of South Africa and the U.S.S.R. together accounted for 95% of world mine production. 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. Production of platinum and palladium, the principal metals of the group, was 3.3 million ounces and 3.7 million ounces, respectively, of which the U.S.S.R. produced an estimated 960,000 ounces of platinum and 2.6 million ounces of palladium.

Demand (industrial demand plus investment demand) in market economy countries for platinum, palladium, and rhodium, according to estimates from several sources, were somewhat higher than total supply. By 1991, a new South African producer, Northam Platinum Ltd., was expected to add 300,000 to 400,000 ounces of PGM to annual supply. In addition, existing producers were expected to increase their capacity.

Table 9.—Supply and demand for platinum, palladium, and rhodium in 1986

(Thousand troy ounces)

	Platinum	Palladium	Rhodium
SUPPLY			
Mine production (market economy countries):			
South Africa, Republic of[e]	2,200	940	110
Canada	121	126	11
Other	37	65	--
Total	2,358	1,131	121
Secondary from old scrap:			
United States	57	169	3
Japan	48	193	6
Other	10	150	2
Total	115	512	11
Soviet sales to market economy countries	270	1,540	80
Total	2,743	3,183	212
DEMAND			
Industrial:			
Japan	1,014	1,546	106
United States	983	1,056	93
Western Europe	410	520	15
Other	140	200	5
Total	[1]2,547	3,322	219

[e]Estimated.
[1]Excludes approximately 400,000 troy ounces of investment demand.

Sources: Sumitomo Corp., Johnson Matthey PLC, Goldman, Sachs & Co., and Bureau of Mines estimates.

Investors continued, as in the last few years, to purchase large quantities of platinum in the form of bars, ingots, and coins. Interest was high because of platinum's price premium over that of gold, because of rising worldwide industrial demand, and because of uncertainty about the stability of supplies from the Republic of South Africa. Several countries, including Canada, China, and Mexico, were considering issuing platinum coins. The Isle of Man, near the United Kingdom, minted a 1-ounce platinum coin called the "Noble."[6]

The U.S. Geological Survey, in a cooperative effort with mineral resource agencies in Australia, Canada, the Federal Republic of Germany, and the Republic of South Africa, published an International Strategic Minerals Inventory (ISMI) report that described the major world resources of PGM.[7] The report uses the United Nations resource classification and covers only known deposits, extensions of known deposits, and newly discovered deposits, but excludes undiscovered deposits.

The Bureau of Mines published an open file report on the availability of PGM and the role of the Republic of South Africa.[8] The report compared the cost of production per troy ounce of platinum for underground mines in the Republic of South Africa with dredging operations in Colombia and the United States, and concluded that the South African mines have significantly lower costs.

Another Bureau of Mines open file report covered the Republic of South Africa and critical materials, including PGM.[9] The report focused on the importance of the Republic of South Africa and its neighboring countries as suppliers of six key materials and examined the available options for mitigating the impact from a supply disruption.

The Gerald Metals Group, owner of PGP Industries Inc. in Santa Fe Springs, CA, reportedly planned to build two PGM recycling plants, one in the Middle East and one in Asia, by yearend 1987. The two plants were to concentrate on recycling petroleum catalysts.

Australia.—Among companies exploring and/or developing PGM deposits were Hunter Resources Ltd., at Munni Munni, in Western Australia, and BHP Minerals Ltd., Noranda Australia Ltd., and EZ Industries Ltd. at Coronation Hill in the South Alligator River area of the Northern Territory.

Canada.—The Ministry of Northern Development and Mines, Ontario, reviewed and classified geologically PGM deposits in Canada and the rest of the world.[10] Its report stated that after the Stillwater deposit in Montana, the PGM deposits in the most advanced state of development in North America were the Lac des Iles and Marathon deposits, both in northern Ontario. The Lac des Iles deposit is owned by the Platinum Group Ltd. and under option to Madeleine Mines Ltd.; the Marathon deposit is owned by Fleck Resources Ltd. Both are copper-nickel deposits containing some palladium and a lesser amount of platinum.

Madeleine Mines, of Toronto, in conjunction with the Canada Centre for Mineral and Energy Technology reportedly planned to test various methods for concentrating PGM from Madeleine's Lac des Iles deposit.[11] If successful, these tests were to be used as the basis for the design of a concentrator and refinery.

Germany, Federal Republic of.—A joint venture between Engelhard Corp. of Edison, NJ, and Kali Chemie AG of Hanover, Federal Republic of Germany, reportedly began production of automobile catalysts at its new plant in Nienburg. The company expected to begin supplying the Western European automobile industry with catalysts before yearend.[12]

Japan.—Imports totaled about 1,000,000 ounces of platinum, primarily from the Republic of South Africa, about 1,400,000 ounces of palladium, primarily from the U.S.S.R., and 100,000 ounces of rhodium, primarily from the U.S.S.R. Imports of platinum decreased, while imports of palladium and rhodium increased from the amounts reported in 1985.

Consumption of platinum in jewelry increased, as did consumption of palladium in electrical and dental uses.

Table 10.—Japanese demand for platinum, palladium, and rhodium

(Thousand troy ounces)

	Platinum	Palladium	Rhodium
Automotive	177	129	64
Chemical	16	395	11
Dental	--	309	--
Electrical	42	604	15
Glass	58	--	4
Jewelry	691	61	--
Miscellaneous	31	48	13
Total[1]	1,014	1,546	106

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

Source: Sumitomo Corp.

South Africa, Republic of.—In early January 1986, Impala Platinum Holding (Pty.) Ltd., the Republic of South Africa's second largest producer of PGM, dismissed 23,000 mine workers, or roughly 70% of its work force, for striking illegally. Impala's four mines are in the tribal homeland of Bophuthatswana, which does not formally recognize the strikers' union. The company reportedly was back to near full production by the end of the first quarter.

Gold Fields of South Africa Ltd. revealed plans in June to develop a new platinum mine in the western Transvaal near the town of Northam. The mine reportedly will cost $214 million, have a lifespan of about 25 years, and produce about 250,000 ounces of PGM per year.

In June, Rustenburg Platinum Mines Ltd. decided to proceed with construction of a new solvent-extraction PGM refinery near the town of Rustenburg. The $123 million Rustenburg refinery, which was expected to be completed by about 1988, will replace primary refining operations at the old Wadeville refinery and Rustenburg's Royston refinery in London, the United Kingdom. When this plant comes on-stream the Republic of South Africa will be refining all or most of its mine output domestically.

Table 11.—Platinum-group metals: World production, by country[1]

(Troy ounces)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Australia, metal content, from domestic nickel ore:[3]					
Palladium	[4]13,379	12,000	12,000	13,600	13,600
Platinum	[4]2,388	1,900	1,900	2,400	2,400
Canada: Platinum-group metals from nickel ore	228,425	223,925	348,216	337,088	281,000
Colombia: Placer platinum	11,886	10,303	10,106	11,650	12,000
Ethiopia: Placer platinum[e]	125	125	125	125	125
Finland:					
Palladium	4,662	2,283	1,093	[e]1,100	1,000
Platinum	4,147	2,186	1,061	[e]1,100	1,000
Japan, metal recovered from nickel-copper ores:[5]					
Palladium	27,862	37,122	33,802	43,703	[4]46,699
Platinum	15,411	21,460	19,523	22,216	[4]21,312
South Africa, Republic of: Platinum-group metals from platinum ore[e 6]	2,600,000	2,600,000	3,500,000	3,700,000	3,600,000
U.S.S.R.: Placer platinum and platinum-group metals recovered from nickel-copper ores[e]	3,500,000	3,600,000	3,700,000	3,800,000	3,850,000
United States: Placer platinum and platinum-group metals from gold-copper ores	8,033	6,257	14,635	W	W
Yugoslavia:					
Palladium	2,893	2,926	[e]3,100	[e]3,300	3,000
Platinum	418	193	[e]200	[e]250	200
Zimbabwe:					
Palladium	2,765	2,395	1,222	965	900
Platinum	1,704	1,695	772	611	600
Total	6,424,098	6,524,770	7,647,755	7,938,108	7,833,836

[e]Estimated. [p]Preliminary. W Withheld to avoid disclosing company proprietary data; excluded from "Total."

[1]Table includes data available through May 5, 1987. 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

A device that injects miniscule quantities of platinum dust into the fuel mixture of internal combustion engines was reported to have the ability to increase engine burning efficiency and fuel economy. Called the platinum gasaver, the device contains sufficient platinum for 12,000 miles of driving before needing a refill.[13]

Scientists at the Sandia National Laboratories, Livermore, CA, facility, reportedly developed a new process to eliminate nitrogen oxides from the exhaust of internal combustion engines. The process, which was in the early stages of development, uses an inexpensive, nontoxic chemical, called cyanuric acid, to convert nitrogen oxides into water, nitrogen, and other gases.[14]

Johnson Matthey reportedly developed a new nickel-based superalloy containing 4.5% platinum, with outstanding resistance to hot corrosion and oxidation and good castability. This alloy is under evaluation by the U.S. Navy and several major U.S. gas turbine manufacturers. Alloys used in gas turbines must withstand temperatures above 1,000° C and retain strength within corrosive environments.[15]

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[1]Physical scientist, Division of Nonferrous Metals.

[2]Federal Register. Environmental Protection Agency. The Sale and Use of Aftermarket Catalytic Converters. V. 51, No. 150, Aug. 5, 1986, pp. 28114-28133.

[3]———. Environmental Protection Agency. Hazardous Waste Management System; Exports of Hazardous Waste; Final Rule. V. 51, No. 153, Aug. 8, 1986, pp. 28664-28686.

[4]News-Tribune & Herald (Duluth, MN). Platinum Rekindles Bidding for Minnesota Mineral Leases. Dec. 19, 1986.

[5]Robson, G. G. Platinum, 1986 Interim Review. Johnson Matthey PLC. P. 9.

[6]Siconolfi, M. With Platinum's Popularity Growing, Several Nations May Soon Issue Coins. Wall St. J., v. 208, No. 4, July 7, 1986, p. 22.

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[9]———. South Africa and Critical Materials. BuMines OFR 76-86, July 1986, 71 pp.; NTIS PB 86-236601.

[10]Roscoe Postle Associates Inc. Review of Platinum Group Element Deposits in Ontario. Mineral Policy Background Paper No. 24, Ministry of Northern Development and Mines, Ontario, Canada, Nov. 1986, 89 pp.

[11]The Northern Miner (Toronto, Ontario, Canada). Platinum Refinery Madeleine's Aim. V. 72, No. 40, Dec. 15, 1986, p. 3.

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[13]Metal Bulletin Monthly. Platinum Dust Gives a Better Burn. No. 187, July 1986, p. 83.

[14]Miller, J. P. Scientists Discover Possible Smog Cure in Pool Chemical. Wall St. J., v. 108, No. 120, Dec. 18, 1986, p. 47.

[15]Corti, C. Platinum Brings Benefits to Superalloys. Met. Bull. Mon., No. 185, May 1986, pp. 47-50.

Potash

By James P. Searls[1]

U.S. potash production and apparent consumption in terms of potassium oxide (K_2O) equivalent decreased significantly in 1986. Spring production was 14% less than fall production. Sales by U.S. producers fell 9% for the year, and average prices decreased 6%. Yearend stocks increased 13%. 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 81% of the domestic apparent consumption. U.S. exports rose, with increased exports to India and Japan, but decreased exports to Brazil and Mexico.

One of the Carlsbad, NM, mines and plants that had been closed and sold at yearend 1985 reopened in April 1986. Another plant that was closed at yearend 1985 reopened in May. The plant in Carlsbad that had been closed since 1983 remained closed through 1986 pending higher market prices for potash. A Utah plant remained closed throughout the year to repair flood damage.

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 10 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)

	1982	1983	1984	1985	1986
United States:					
Production	3,366	2,770	3,039	2,569	2,381
K_2O equivalent	1,784	1,429	1,564	1,296	1,202
Sales by producers	3,387	2,950	3,184	2,505	2,291
K_2O equivalent	1,784	1,513	1,639	1,266	1,147
Value[2]	$265,600	$220,800	$241,800	$178,400	$152,000
Average value per ton of product dollars	$78.42	$74.85	$75.95	$71.22	$66.35
Average value per ton of K_2O equivalent do	$148.87	$145.97	$147.55	$140.89	$132.53
Exports[3]	952	564	836	973	1,025
K_2O equivalent	519	300	446	513	547
Value[4]	$93,200	$55,760	$85,660	NA	NA
Imports for consumption[3 5]	6,338	7,322	7,948	7,571	6,934
K_2O equivalent	3,858	4,440	4,829	4,593	4,212
Customs value	$575,400	$600,600	$658,100	$499,100	$385,100
Apparent consumption[6]	8,773	9,708	10,296	9,103	8,200
K_2O equivalent	5,123	5,653	6,022	5,346	4,843
Yearend producers' stocks, K_2O equivalent	520	[7]391	[8]312	[9]336	[10]378
World: Production, marketable K_2O equivalent	[r]24,510	27,418	29,334	[p]29,051	[e]28,248

[e]Estimated. [p]Preliminary. [r]Revised. 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 industry 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 fell 7% in 1986. Of the total production for the year, 80% was standard, coarse, and granular muriate of potash, also known as potassium chloride, and 7% 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 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.

The New Mexico producers accounted for 87% of the total marketable salts production. New Mexico crude salt mine production was 9.8 million metric tons with an average K_2O content of 14.4%. The producers were AMAX Chemical Corp., which became AMAX Potash Corp. in November, of AMAX Inc.; International Minerals & Chemical Corp. (IMC); Lundberg Industries Ltd.; New Mexico Potash Corp., which was sold by Vertac Chemical Corp. to Cedar Chemical Co., which is owned by Fermenta AB of Sweden; and Western Ag-Minerals Co., which is controlled by the Rayrock Resources Ltd. of Canada.

All of the Carlsbad producers operated at reduced levels during the year. AMAX Potash was closed for 3 months and thereafter operated through yearend on a 10-day-on, 4-day-off schedule. IMC was closed for 2 weeks and thereafter worked at normal shifts through yearend. Lundberg Industries was closed for 2-3/4 months and subsequently worked at normal shifts but reduced capacity. New Mexico Potash was closed for 2 weeks and thereafter operated on a 10-day-on, 4-day-off schedule through yearend. Western Ag-Minerals was closed for 1 month and thereafter operated through yearend on a schedule of 5 days per week with two 8-hour shifts per day. 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 Lundberg Industries plant produced sulfate of potash from Hargreaves furnaces using muriate of potash and sulfur dioxide; that production was included in Bureau of Mines statistics because Lundberg Industries had mined the potash feed in New Mexico. The Permian Chemical Corp. plant in Texas and the Climax Chemical Co. in Utah together produced about 29,900 tons,[2] which is not included in Bureau of Mines statistics because they are not mining firms. Permian Chemical produced from Mannheim furnaces using muriate of potash and sulfuric acid. Climax Chemical produced from a proprietary furnace using muriate of potash and sulfuric acid. The company alternated potassium sulfate and sodium sulfate production from the plant in Utah. Both firms sold byproduct hydrochloric acid.

In Utah, Texasgulf Chemicals Co. of Texasgulf Inc., which is owned by Elf Aquitaine Inc. of the Paris-based Société Nationale Elf Aquitaine, which is owned by Entreprise de Recherches et d'Activitiés Pétrolières, a holding company, which is owned 67% by the Government of France, 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 halite. 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. Great Salt Lake Minerals & Chemicals Corp., a subsidiary of Gulf Resources & Chemical Corp., remained closed throughout the year while repairing flood damage. Construction funded by the State of Utah began during the summer on solar evaporation ponds in the western Great Salt Lake Desert. The solar ponds will provide a means for lowering the lake level.

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	
	1985	1986	1985	1986	1985	1986	1985	1986	1985	1986	1985	1986	1985	1986
January-June:														
Muriate of potash, 60% K_2O minimum:														
Standard	434	342	266	209	431	373	264	228	27,000	19,500	143	199	88	121
Coarse	95	75	58	46	96	101	59	62	6,100	6,000	60	21	37	13
Granular	369	263	223	159	417	274	252	166	25,600	14,100	111	83	68	50
Chemical	21	1	14	(2)	20	8	13	5	W	W	5	3	3	2
Potassium sulfate	99	89	51	45	98	90	50	46	18,500	15,200	61	65	32	33
Other potassium salts[3]	342	334	92	79	393	368	104	89	W	W	200	197	46	47
Total[4]	1,360	1,104	704	539	1,455	1,214	742	595	106,000	83,000	580	568	274	267
July-December:														
Muriate of potash, 60% K_2O minimum:														
Standard	396	392	242	239	307	345	188	211	18,400	16,100	232	246	141	150
Coarse	58	86	35	53	67	74	41	45	3,600	3,700	48	33	30	20
Granular	254	417	154	253	264	284	160	172	12,600	13,400	95	215	58	130
Chemical	21	16	14	10	17	12	11	8	W	W	10	7	6	4
Potassium sulfate	108	84	55	43	103	101	53	52	18,000	15,300	66	48	34	25
Other potassium salts[3]	372	282	92	65	292	261	71	64	W	W	279	219	67	49
Total	1,209	1,277	592	663	1,050	1,077	524	552	72,400	69,100	730	768	336	378
Grand total[4]	2,569	2,381	1,296	1,202	2,505	2,291	1,266	1,147	178,400	152,000	XX	XX	XX	XX

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]
1985:							
January-June	6,160	827	1,221	623	1,322	666	93,900
July-December	5,152	683	1,014	479	927	454	62,100
Total	11,312	1,510	2,235	1,102	2,249	1,120	156,000
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	9,779	1,413	2,118	1,051	[3]2,013	987	132,900

[1]Sylvinite and langbeinite.
[2]F.o.b. mine.
[3]Data do not add to total 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)

	1982	1983	1984	1985	1986
Production	166	168	109	106	88
Sales by producers	176	156	126	103	97
Value[2]	$61,934	$55,453	$47,197	$36,465	$19,858
Exports[3]	71	44	34	46	79
Value[4]	$27,648	$16,390	$13,940	NA	NA
Imports[3]	6	29	29	25	27
Value[5]	$2,409	$12,300	$12,600	$10,400	$9,900
Apparent consumption[6]	111	141	121	82	45
Yearend producers' stocks	36	44	31	34	25

NA Not available.
[1]Excludes potassium magnesium sulfate.
[2]F.o.b. mine.
[3]Bureau of the Census.
[4]F.a.s. U.S. port.
[5]C.i.f. to U.S. port.
[6]Calculated from production plus imports minus exports plus industry stock changes.

CONSUMPTION AND USES

Apparent domestic consumption of all forms of potash decreased 10% from that of 1985. However, the calculation of 1986 apparent consumption may be distorted by errors in reported export data. Downward pressure on demand for fertilizers in the United States continued to come from the decline in demand for U.S.-produced crops and the stockpile of crops remaining from previous crop-years. Foreign buyers of U.S. crops considered prices to be relatively high but decreasing. The U.S. farmers' continuing loss of earning power caused land values to drop, a fact that continued to affect the farmers' borrowing power at the banks.

Table 5.—Sales of North American potash, by State of destination

(Metric tons of K_2O equivalent)

State	Agricultural potash		Nonagricultural potash	
	1985	1986	1985	1986
Alabama	65,558	52,968	63,576	87,005
Alaska	217	825	--	7,592
Arizona	390	943	112	79
Arkansas	54,803	45,055	620	188
California	51,059	51,786	8,848	8,392
Colorado	8,323	7,035	7,044	3,454
Connecticut	5,625	4,238	119	91
Delaware	16,394	23,125	33,500	37,215
Florida	114,560	134,077	3,891	2,131
Georgia	155,822	103,479	1,990	580
Hawaii	13,561	12,219	--	44
Idaho	24,223	24,525	51	22
Illinois	663,632	621,147	22,347	1,457
Indiana	399,639	335,011	357	220
Iowa	400,412	408,702	454	641
Kansas	30,199	28,613	1,984	1,177
Kentucky	132,288	116,581	341	166
Louisiana	54,181	64,416	1,444	946
Maine	7,711	7,284	416	630
Maryland	27,875	33,456	175	112
Massachusetts	3,382	5,270	586	461
Michigan	185,586	185,381	1,501	1,060
Minnesota	350,467	316,132	335	352
Mississippi	32,010	23,342	28,382	35,895
Missouri	232,460	222,751	3,281	2,967
Montana	10,185	10,869	71	14
Nebraska	32,252	30,148	462	132
Nevada	--	363	59	209
New Hampshire	767	461	24	25
New Jersey	7,907	7,819	13,250	864
New Mexico	11,373	7,786	34,673	16,273
New York	82,410	61,211	1,261	6,739
North Carolina	117,822	88,380	158	201
North Dakota	20,092	23,599	384	61
Ohio	399,025	398,569	58,922	64,833
Oklahoma	22,729	18,508	9,105	6,544
Oregon	24,612	25,596	1,437	1,350
Pennsylvania	63,018	53,717	2,427	2,278
Rhode Island	2,207	1,126	92	29
South Carolina	66,496	99,854	167	106
South Dakota	10,894	12,719	--	--
Tennessee	140,373	108,475	591	585
Texas	135,722	119,236	42,998	19,634
Utah	14,491	5,615	11,880	10,639
Vermont	5,029	3,070	14	295
Virginia	63,037	120,248	200	56
Washington	38,735	36,408	2,546	2,169
West Virginia	4,911	2,855	601	480
Wisconsin	292,508	277,501	487	611
Wyoming	2,188	1,497	643	260
Total	4,599,160	4,343,991	363,806	327,264

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	1983	1984	1985	1986
Agricultural:				
Standard	399	446	346	319
Coarse	2,402	2,219	2,065	1,882
Granular	1,533	1,511	1,666	1,683
Soluble	451	471	392	336
Total	4,785	4,647	4,469	4,220
Nonagricultural:				
Soluble	114	120	138	98
Other	195	227	227	225
Total	309	347	365	323
Grand total	5,094	4,994	4,834	4,543

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, and Wisconsin. These six States consumed 54% of the total from Canadian and U.S. producers. However, domestic producers provided only 2% of Illinois' potash consumption, 2% of Iowa's consumption, 1% of Ohio's consumption, less than 0.5% of Indiana's consumption, 2% of Minnesota's consumption, and 1% of Wisconsin's consumption. Potash from other countries was consumed in these States, but quantities are unknown. The major agricultural consumers of domestically produced potash, in decreasing order, were Texas, Missouri, California, Florida, Kansas, and Oklahoma. 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, North Carolina, and Nebraska. These six States accounted for 59% of the total.

STOCKS

Yearend producers' stocks of potash increased nearly 13% over that of 1985. Yearend stocks were 31% of annual production or 16.4 weeks of production. Several producers reported inventory adjustments between December 1985 and January 1986, the sum of which was minus 12,900 tons.

TRANSPORTATION

Quoted as representative rates of ocean potash freight because of their frequent occurrence, the rates from Hamburg or Rostock, northern Europe, to India, and Vancouver, British Columbia, Canada, to India, fell below $20 by the summer and stayed there for the rest of the year. Low freight rates allowed the Canadian potash producers to compete with domestic producers in more areas in both the Atlantic and Pacific Basins because the Canadian price at Vancouver was usually less than the domestic prices at Houston or Long Beach. Markets of natural advantage for domestic producers have been the Caribbean Basin, Central America, and the northern portions of South America because the distance is much shorter from Houston than from Vancouver. In the Western European trade, specifically designed, bulk lake-and-ocean freighters have loaded Canadian potash in Thunder Bay, Ontario, Canada, for shipment directly to European ports, thereby displacing most of the Houston-to-Europe traffic that had not been displaced previously by potash shipments from St. John, New Brunswick, to Europe. In the Pacific Basin trade, any domestic exports to that region have been made possible by domestic cost cutting efforts and low returns to the producers.

Published U.S. rail tariffs for potash were unchanged from those of 1985, but were becoming largely unrepresentative of the freight charges in use. Unpublished, i.e., Staggers Act, contract rates declined toward meeting the costs of trucks backhauling potash from New Mexico plants.

About 640,000 tons of Canadian muriate of potash was shipped by rail to Thunder Bay for lake freightage to U.S. Great Lakes ports. About 780,000 tons of Canadian muriate of potash was shipped by rail to Minneapolis or St. Louis for transfer to barges with U.S. destinations. In addition, more than 20,000 tons of Canadian muriate was shipped by rail to Minneapolis or St. Louis for transfer to barges and shipment down the Mississippi River to New Orleans where the potash was loaded onto ocean bulk carriers for shipment to foreign ports. This potash competed strongly in the remaining export markets of natural advantage to the Carlsbad, NM, producers.

PRICES

The domestic potash market remained oversupplied, and prices continued to fall. The average price, f.o.b. mine, of U.S. potash sales of all types and grades decreased by 6% to $132.53 per ton. The average price was $139.42 in the first half of the year and $125.11 in the second half. The average annual price for the three grades of muriate fell to $81.88 per ton. Standard-grade muriate of potash muriate averaged $80.99 per ton, coarse-grade muriate averaged $87.78 per ton, and granular-grade averaged $81.17 per ton. The average annual price for sulfate of potash declined 13% to $312.82 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	1984 January-June	1984 July-December	1985 January-June	1985 July-December	1986 January-June	1986 July-December
Muriate, 60% K_2O minimum:						
Standard	106.44	106.20	101.99	97.37	85.17	76.46
Coarse	115.23	103.33	102.42	87.35	92.63	81.16
Granular	115.68	103.97	101.30	78.85	84.75	77.73
All muriate[2]	111.98	104.86	101.73	88.71	87.85	80.11
Sulfate, 50% K_2O minimum	374.22	377.21	367.24	339.98	332.24	295.58

[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 rose 5%, by ton product and included a dubious increase of 16% in exports of sulfates of potash. However, export data verification procedures used in the past have not been available since Census discontinued reporting export values in 1985. Other sources of export data are of only limited use for data verification because of their different reporting categories for potash products.

The major destinations of potash exports in Latin America, which received 43% of the total, by ton product, were, in decreasing order, Brazil, Mexico, Colombia, Chile, the Dominican Republic, and Costa Rica. These countries represented 85% of the exports to Latin America. Exports to India rose 93% and exports to Japan rose 14%. These two countries plus Belgium, China, Canada, and Taiwan, in decreasing order, represented 79% of exports to non-Latin American countries.

An 8% decrease in total U.S. imports of potash was represented primarily by reduced imports of muriate of potash from Canada. Canada supplied 94% of all muriate imports and 93%, by K_2O equivalent, of all potash imports. Israel was the second largest source of imports, with 5% of muriate of potash imports and 5%, by K_2O equivalent, of total potash imports.

Table 8.—U.S. exports of potash

	Approximate average K_2O content (percent)	Quantity (metric tons) Product	Quantity (metric tons) K_2O equivalent	Value (thousands)
1985				
Potassium chloride, all grades	61	699,770	426,860	NA
Potassium sulfate	51	91,000	46,410	NA
Potassium magnesium sulfate	22	182,290	40,100	NA
Total	XX	973,060	513,370	NA
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

NA Not available. XX Not applicable.

Sources: Bureau of the Census, Potash & Phosphate Institute, as adjusted by the Bureau of Mines.

Table 9.—U.S. exports of potash, by country

Country	Metric tons of product						Total value (thousands)	
	Potassium chloride		Potassium sulfates, all grades[1]		Total[2]			
	1985	1986	1985	1986	1985	1986	1985	1986
Argentina	3,150	4,990	1,490	5,880	4,640	10,870		
Australia	11,810	6,000	10,000	12,000	21,810	18,090		
Bahamas	--	14	2,650	2,880	2,650	2,890		
Belgium	--	80,290	43	52	43	80,340		
Belize	1,350	620	--	320	1,350	940		
Brazil	272,070	175,510	5,500	11,210	277,570	186,740		
Canada	3,430	730	58,430	43,920	61,860	44,650		
Chile	--	5,150	20,910	28,260	20,910	33,410		
China	--	54,080	--	9,470	--	63,550		
Colombia	48,860	22,060	8,840	19,020	57,700	41,080		
Costa Rica	8,520	4,400	15,620	17,010	24,140	21,410		
Denmark	--	--	--	10,250	--	10,250		
Dominican Republic	20,840	21,690	5,710	2,260	26,550	23,950		
Ecuador	12,100	13,430	3,350	1,040	15,450	14,470		
French West Indies	5,250	3,890	4,580	--	9,830	3,890		
Guatemala	14	--	3,040	3,170	3,050	3,170		
Haiti	74	980	27	74	100	1,050		
Honduras	--	1,540	240	2,090	240	3,630		
India	43,780	84,400	--	--	43,780	84,400	NA	NA
Ireland	--	10,010	--	--	--	10,010		
Italy	110	300	250	1,740	360	2,040		
Japan	76,650	70,470	65,150	90,950	141,800	161,420		
Korea, Republic of	--	--	6,950	400	6,950	400		
Malaysia	14,250	--	12,100	10,910	26,350	10,910		
Mexico	77,820	50,340	30,100	14,950	107,920	65,290		
Netherlands	--	16,270	--	--	--	16,270		
New Zealand	81,820	25,160	--	360	81,280	25,520		
Panama	1,450	4,250	290	2,230	1,740	6,480		
Peru	14,420	8,550	1,260	8,730	15,680	17,280		
Philippines	--	67	11,600	11,760	11,600	11,830		
Salvador	--	2,970	550	460	550	3,430		
Sweden	500	800	--	--	500	800		
Switzerland	--	12,370	--	--	--	12,370		
Taiwan	--	26,230	490	40	490	26,270		
Thailand	--	--	--	3,510	--	3,510		
Uruguay	1,270	--	--	--	1,270	--		
Zambia	--	--	3,280	--	3,280	--		
Other	r770	700	r840	1,790	r1,610	2,490		
Total[2]	699,770	708,360	273,290	316,670	973,060	1,025,030	NA	NA

rRevised. NA Not available.
[1]Includes potassium magnesium sulfate.
[2]Data may not add to totals shown because of independent rounding.

Sources: Bureau of the Census, Potash & Phosphate Institute, as adjusted by the Bureau of Mines.

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.	
	1985	1986	1985	1986	1985	1986	1985	1986	1985	1986	1985	1986	1985	1986
Belgium-Luxembourg	18	4,000	--	6,000	--	--	--	--	18	10,000	$11	$1,400	$11	$1,600
Canada	7,005,200	6,394,100	--	40	58	97	--	4,400	7,005,300	6,398,600	438,500	340,000	471,200	370,400
Chile	--	--	--	--	--	--	33,600	10,700	33,600	10,700	4,300	1,500	4,900	1,000
German Democratic Republic	24,200	93,000	--	--	--	--	--	--	24,200	93,000	1,700	4,700	2,100	5,500
Germany, Federal Republic of	4,400	5,900	49,800	45,800	--	--	--	--	54,200	51,700	10,100	8,300	11,000	9,400
Israel	420,400	310,000	--	--	30,400	30,000	--	--	450,800	340,000	43,700	27,000	49,800	31,800
Japan	--	500	--	6	2	--	200	200	200	700	100	100	100	100
Netherlands	2,000	2,500	--	--	--	--	--	--	2,000	2,500	300	200	300	300
Spain	--	1,600	--	6	--	--	--	--	--	1,600	--	200	--	200
U.S.S.R	--	24,500	--	--	--	--	--	--	--	24,500	--	1,500	--	1,700
United Kingdom	600	400	--	2	--	--	--	--	600	400	400	300	400	300
Total[1]	7,456,800	6,836,500	49,800	51,900	30,500	30,100	33,800	15,300	7,570,900	6,933,800	499,100	385,100	539,900	422,900

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

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.
1985					
Potassium chloride	61	7,456,800	4,548,700	$476,000	$514,600
Potassium sulfate	[r]51	49,800	25,400	9,600	10,400
Potassium nitrate	45	30,500	13,700	9,100	9,900
Potassium sodium nitrate mixtures	14	33,800	4,700	4,400	5,000
Total	XX	7,570,900	4,592,500	499,100	539,900
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

[e]Estimated. [r]Revised. 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 was essentially unchanged from that of 1985. Several market economy producers reduced production to maintain stock levels and limit further price declines, or to cut their losses from unprofitable production. The U.S.S.R. production was estimated to have decreased owing to its misfortunes with mine floods. World prices, as exemplified by the per ton price of standard muriate of potash, f.o.b. Vancouver, Canada, reported by British Sulphur Corp. Ltd., were in the middle $70's, but dropped precipitously during the year to the high $50's. Potash was generally in oversupply, with prices less than many producers' total costs. However, plans for additional potash operations were contemplated or under way in Argentina, Bolivia, Brazil, Canada, Chile, China, Ethiopia, Thailand, Tunisia, the U.S.S.R., and the United States. Several of these operations will have the coproduct of lithium carbonate, which can easily go into oversupply, and one may have the additional coproduct of boric acid.

Argentina.—Duval Corp. joined Texasgulf and Cía. Minera Tea in exploration activities in the Provinces of Mendoza and Neuquén. Thicknesses of 2 to 10 meters of 12% to 18% K_2O sylvinite with an aerial extent of 40 by 70 kilometers have been reported.[3] Party Sasimagi reportedly started constructing an $8 million pilot plant, Campo Quijano in the Salar del Rincón, Puna, with plans for a solar evaporation operation producing muriate of potash, sulfate of potash, and lithium carbonate.[4] In the Catamarcan Province, the state-owned Fabricaciones Militares was designated the Government's director of development for the Salar de Hombre Muerto, which was also planned to be a muriate of potash, sulfate of potash, and lithium carbonate operation.[5]

Canada.—Canadian Development Corp. (CDC) sold part of Kidd Creek Mines Ltd., the former Texasgulf properties, to Falconbridge Ltd., excluding CDC's 40% interest in the Allan Potash Mine, which it shares with Potash Corp. of Saskatchewan (PCS). Rio Algom Ltd. actually purchased Potash Co. of America Inc. (PCA) on February 3. Cominco Ltd. was taken over by Teck Corp. of Vancouver. In October, Canadian Pacific Enterprises Ltd. sold its 52.5% controlling interest, 34.2 million shares, in Cominco, and a consortium of the Vancouver-based Teck Group (50%), Metallgesellschaft AG (25%) of Frankfurt, the Federal Republic of Germany, and M.I.M. Holdings Ltd. (25%) of Brisbane, Australia, bought 31% controlling interest, 20 million shares. The remaining 21.5% of stock was for sale on the open stock market.

Flooding throughout the year of International Minerals & Chemical Corp. (Canada) Ltd.'s (IMCC) Esterhazy K-2 Mine brought into question the long-term viability of K-2 as well as the adjacent K-1 Mine. The Patience Lake Mine owned by Rio Algom also experienced leakage problems. By yearend, the lifetime of the mine was under question because of the increase in flowrate.

The PCS mines were closed for 6 weeks and operated on 10-day-on, 4-day-off schedules thereafter, except for the Lanigan Mine, which experienced a strike from March 10 to yearend, and Rocanville, which operated at full capacity upon reopening. The Noranda Mine was closed for 3-3/4 months. The Cominco Mine was closed for 3-1/4 months. IMCC's K-1 Mine was closed for 2 months, and K-2 produced at about one-half capacity for several months owing to the flooding problem. Kalium Chemicals was closed for about 2 months. The Patience Lake Mine was closed for 1 month, and production was limited because of the mine leak.

Canpotex, the Canadian potash export organization, estimated that 4 to 5 million product tons of potash was available from stockpiles around the world.

The Canamax Resources Inc. potash resource in Manitoba was delineated between Binscarth and Russell, east of Esterhazy. India signed a letter of intent to join the project.

The Denison-Potacan operation at Cloverhill, New Brunswick, which had started production in July 1985, increased exports of potash in 1986.

Table 12.—Salient Canadian potash statistics

(Thousand metric tons of K_2O equivalent)

	1983	1984	1985	1986
Production[1]	5,928	7,749	6,637	6,697
Domestic sales by domestic producers[1]	385	436	434	327
Exports:				
United States[1]	3,965	3,892	4,163	4,091
Overseas[1]	2,026	2,544	1,928	2,612
Imports for consumption[2]	17	20	14	10
Domestic consumption[3]	402	456	448	337
Yearend producers' stocks[1]	862	1,543	1,766	1,537

[1]Data supplied by the Potash & Phosphate Institute.
[2]From Bureau of the Census export data. Muriate and nitrate of potash were landed on the Canadian east coast from European and Middle Eastern sources.
[3]Domestic sales by domestic producers plus imports.

Chile.—Sociedad Chilena de Litio Ltda. was authorized to investigate the potential for muriate of potash production from the solar evaporation brines of the existing lithium carbonate operation. Potential production was estimated at 20,000 tons of K_2O equivalent per year. Production of fertilizer-grade potassium nitrate began at Coya Sur in the nitrate areas northwest of the Salar de Atacama and west of Calama. Initial annual production was estimated to be 9,000 tons of K_2O equivalent, and some muriate of potash was purchased from Canada. The muriate production of the Sociedad Chilena de Litio appeared destined solely for potassium nitrate production. The AMAX project in the Salar de Atacama was seeking additional funding at yearend. Plans for this project included boric acid production from the brine.

China.—Reports reveal that potash has been produced since 1959 from Lake Qarhan (Chaerhan) at a rate of about 12,000 tons of K_2O equivalent per year.[6] Construction of a 120,000-ton-per-year plant has commenced. A 600,000-ton-per-year plant was planned pending the success of the existing large pilot plant.

France.—In October, the Government agreed to on-site, aboveground storage of potash mine tailings to alleviate the environmental problem caused by dumping Alsatian potash mine tailings into the Rhine River. The cost was projected at more than $50 million, to be shared unequally by the Netherlands, France, the Federal Republic of Germany, and Switzerland, in descending order of contribution.

German Democratic Republic.—Kombinat Kali maintained production of muriate of potash at capacity, despite falling prices, and increased production of sulfate of potash at the Ernst Thällmann (Merkers) plant in the Kalibetrieb Werra in the East German portion of the Southern Werra potash district. Production of sulfate of potash in 1985 was estimated to be 50,000 tons.

Germany, Federal Republic of.—Kali und Salz AG closed its mines for 13 to 15 weeks during the year owing to falling prices.

Israel.—Funds for expansions, which had been reduced to $500 million in 1985, were reduced again in 1986 to $425 million. Revised plans included the expansion of the muriate of potash capacity, development of sulfate of potash capacity, and expansion of nitrate of potash capacity. The parent company, Dead Sea Works Ltd., withdrew from the European marketing arrangement, Kali-Export, to form its own sales force in Western Europe.

Jordan.—The Arab Potash Co. awarded a $12 million contract to expand the capacity of the Ghor al-Safi potash operation by means of streamlining and removing bottlenecks. The total increase was expected to be 120,000 tons per year of muriate of potash.

Korea, North.—References to the "Sariwon Potassium Fertilizer Factory" mention plans to mine from an underground potassium resource for a multiproduct plant in conjunction with an electric power dam.[7]

Thailand.—The potash resource in Thailand was estimated to be 270 billion tons of mostly carnallite, averaging 5% K_2O.[8]

[1]Physical scientist, Division of Industrial Minerals.
[2]All tonnages reported in metric tons, K_2O equivalent, unless otherwise specified.
[3]Mining Magazine (London). V. 155, No. 3, Sept. 1985, p. 165.
[4]Industrial Minerals (London). No. 225, June 1986, p. 8.
[5]Mining Journal (London). No. 306, No. 7852, Feb. 14, 1986, p. 116.
[6]Page 9 of work cited in footnote 4.
[7]Foreign Broadcast Information Service. JPRS-KAR-86-041, Sept. 29, 1986, pp. 79-82.
[8]Industrial Minerals (London). No. 221, Feb. 1986, p. 40.

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

(Thousand metric tons of K_2O equivalent)

Country	1982	1983	1984	1985[p]	1986[e]
Brazil	--	--	--	--	10
Canada[2]	5,309	6,938	7,527	6,661	[3]6,969
Chile[4]	[r]22	21	18	[r e]21	20
China[5]	26	29	40	[e]40	40
France	1,704	1,536	1,739	1,750	[3]1,617
German Democratic Republic	3,434	3,431	3,465	3,465	3,450
Germany, Federal Republic of	2,056	2,419	2,645	2,583	2,165
Israel	1,004	[e]1,000	[e]1,100	[e]1,100	[3]1,255
Italy[6]	146	184	163	205	[3]158
Jordan	9	172	295	561	660
Spain	692	657	677	659	[3]702
U.S.S.R	8,079	9,294	9,776	10,367	9,600
United Kingdom	245	308	325	343	400
United States	1,784	1,429	1,564	1,296	[3]1,202
Total	[r]24,510	27,418	29,334	29,051	28,248

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through Apr. 28, 1987.
[2]Official Government figures. Potash & Phosphate Institute production data are given in table 12.
[3]Reported figure.
[4]Data represent officially reported output of potassium nitrate product (gross weight basis) converted assuming 14% K_2O equivalent.
[5]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.
[6]Crude salt.

Pumice and Pumicite

By A. C. Meisinger[1]

Production of pumice and pumicite by 19 domestic producers in 1986 was 554,000 short tons valued at $5.8 million compared with 508,000 tons valued at $4.6 million in 1985. U.S. apparent consumption increased 25% to 938,000 tons owing to increased demand for pumice aggregate used in concrete and masonry block products. Greece continued to be the major source of pumice imports with 92%. World production declined 5% to an estimated 11.5 million tons.

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, 18, or 75%, responded, representing 96% of total production data shown in table 1. Production for the six nonrespondents was estimated using reported prior year production levels adjusted by trends in employment and other guidelines.

Table 1.—Salient pumice and pumicite statistics

(Thousand short tons and thousand dollars unless otherwise specified)

	1982	1983	1984	1985	1986
United States: Sold and used by producers:					
Pumice and pumicite	416	449	502	508	554
Value (f.o.b. mine and/or mill)	$3,750	$4,486	$4,929	$4,553	$5,756
Average value per ton	$9.01	$9.99	$9.82	$8.96	$10.39
Exports[e]	1	1	1	1	1
Imports for consumption	121	184	293	242	385
Apparent consumption[1]	536	632	794	749	938
World: Production, pumice and related volcanic materials	[r]12,884	[r]13,121	12,432	[p]12,085	[e]11,520

[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 increased 9% in quantity to 554,000 tons and 26% in value to $5.8 million compared with 1985 output. Twenty-one mines and/or plants were operated by 19 companies in 8 States, with California, Idaho, New Mexico, and Oregon accounting for 96% of U.S. production.

Principal domestic producers were Tionesta Aggregates Co., Tulelake, CA; Hess Pumice Products, Malad City, ID; Producers Pumice, 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 93% of the tonnage and 69% 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	1985		1986	
	Quantity	Value	Quantity	Value
Arizona	W	2	2	30
California	78	1,491	46	1,263
New Mexico	152	1,114	255	2,370
Other[1]	279	1,947	251	2,094
Total[2]	508	4,553	554	5,756

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Includes Hawaii, Idaho, Kansas, Oklahoma, Oregon, and data indicated by symbol W.
[2]Data may not add to totals shown because of independent rounding.

CONSUMPTION AND USES

U.S. apparent consumption increased 25% compared with that of 1985, to 938,000 tons. A greater demand for pumice construction aggregates was reflected in a 58% increase in pumice imported for concrete masonry products and a 100% increase in domestic sales of concrete admixture and aggregate. Pumice used for landscaping increased slightly; however, that used for decorative building block decreased 35%, and abrasive and other uses, combined, declined 33% compared with that of 1985.

Table 3.—Pumice and pumicite sold and used by producers in the United States, by use

(Thousand short tons and thousand dollars)

Use	1985		1986	
	Quantity	Value	Quantity	Value
Abrasives (includes cleaning and scouring compounds)	28	497	17	517
Concrete admixture and aggregate	158	818	316	2,258
Decorative building block	260	2,400	168	1,893
Landscaping	18	133	22	196
Other[1]	44	705	31	892
Total	508	4,553	554	5,756

[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 $10.39 per ton, a 16% increase compared with the 1985 value.

Prices quoted in Chemical Marketing Reporter remained unchanged from that of 1985 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 from $6.47 to $6.87 per ton.

FOREIGN TRADE

Pumice imported for consumption increased 59%, compared with that of 1985. Of the 385,000 tons imported, Greece supplied nearly 354,700 tons and most of that was used for concrete masonry products. Imports of pumice from Italy increased from about 1,500 tons in 1985 to nearly 22,600 tons. The 21,000-ton difference was used to produce concrete masonry products.

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		Manu-factured, n.s.p.f.
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Value (thousands)
1985:							
Greece	24	$10	41	$15	237,535	$1,537	$30
Iceland	498	92	--	--	--	--	--
India	--	--	--	--	2,176	2	--
Italy	120	42	294	79	1,051	7	44
Mexico	90	32	--	--	--	--	--
Other[1]	49	22	22	9	1	1	144
Total	781	198	357	103	240,763	1,547	218
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[2]	28	21	21	31	3	9	329
Total	3,488	297	509	204	381,091	2,776	512

[1]Includes Austria, Canada, Denmark, Ecuador, France, the Federal Republic of Germany, Japan, Spain, Switzerland, Taiwan, and the United Kingdom.
[2]Includes Austria, Canada, Denmark, France, the Federal Republic of Germany, Hong Kong, Iran, Ireland, Japan, the Netherlands, Niger, Spain, Taiwan, and the United Kingdom.

Source: Bureau of the Census.

WORLD REVIEW

World production of pumice and related volcanic materials declined 5% to an estimated 11.5 million tons. Greece, Italy, and Spain, together, accounted for 8.5 million tons, or 74% of total world output. France, the United States, and Yugoslavia each produced over 500,000 tons during the year.

[1]Industry economist, Division of Industrial Minerals.

Table 5.—Pumice and related volcanic materials: World production, by country[1]

(Thousand short tons)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Argentina[3]	59	76	60	62	60
Austria: Trass	12	3	11	8	8
Cameroon: Pozzolan	89	NA	NA	[e]105	105
Cape Verde Islands: Pozzolan[e]	11	11	11	11	11
Chile: Pozzolan	190	192	190	227	220
Costa Rica[e]	2	2	2	2	2
Dominica: Pumice and volcanic ash[e]	120	120	120	120	120
France: Pozzolan and lapilli	790	669	551	610	550
Germany, Federal Republic of:					
Pumice (marketable)	441	[r]243	220	391	350
Pozzolan[e]	220	NA	NA	NA	NA
Greece:					
Pumice	707	552	691	684	690
Pozzolan	1,297	1,004	1,001	1,034	1,050
Guadeloupe: Pozzolan[e]	265	265	[r]275	[r]240	230
Guatemala:					
Pumice	[e]13	17	[e]15	13	13
Volcanic ash	[e]4	([4])	([4])	([5])	--
Iceland	21	50	61	62	60
Italy:					
Pumice and pumiceous lapilli[e]	[r]855	[r]1,025	[r]990	[r]825	770
Pozzolan	[r]5,508	[r]6,603	[e]6,100	[e]5,500	5,000
Martinique: Pumice[e]	170	[r]160	[r]150	165	155
New Zealand	55	19	17	[e]22	22
Spain[6]	1,070	1,105	915	936	990
United States (sold and used by producers)	416	449	502	508	[7]554
Yugoslavia: Volcanic tuff	569	556	[e]550	[e]560	560
Total	[r]12,884	[r]13,121	12,432	12,085	11,520

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.
[1]Table includes data available through May 19, 1987.
[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]Revised to zero.
[6]Includes Canary Islands.
[7]Reported figure.

Rare-Earth Minerals and Metals

By James B. Hedrick[1]

Domestic production of rare earths in 1986 dropped to its lowest level in 10 years as a result of continued decreased demand in certain market sectors, especially catalysts. Foreign sources of rare earths obtained a smaller share of the U.S. market, while domestic exports decreased from 1985 levels. Molycorp Inc. and Australian-owned Associated Minerals (USA) Ltd. Inc. were the only domestic mine producers of commercial quantities of rare-earth minerals. The P. W. Gillibrand Co. began test production of a mixed heavy minerals concentrate containing rare-earth-bearing apatite; however, additional separation was needed to produce salable rare-earth products. Molycorp, Rhône-Poulenc Inc., W. R. Grace & Co.'s Davison Chemical Div., and the Research Chemicals Div. of NUCOR Corp. were the principal processors of rare earths in the United States. Major end uses were in petroleum fluid cracking catalysts, metallurgical applications, glass and ceramics, and permanent magnets. Rare earths were used in high-technology applications to produce synthetic crystals used in medical, industrial, and weapon laser systems, permanent magnets with the highest magnetic strengths yet attained, ultralow-loss optical fibers that can transmit data thousands of miles without repeaters, and high-temperature superconductors.

Table 1.—Salient U.S. rare earth statistics

(Metric tons of rare-earth oxides (REO) unless otherwise specified)

	1982	1983	1984	1985	1986
Production of rare-earth concentrates[1]	17,501	17,083	25,311	13,428	11,094
Exports:[e]					
Ore and concentrate	2,565	2,684	4,304	4,419	3,433
Ferrocerium and pyrophoric alloys	22	59	27	23	29
Imports for consumption:[e]					
Monazite	3,962	2,215	3,114	3,132	1,628
Metals, alloys, oxides, compounds	1,695	1,857	2,926	1,124	1,155
Shipments from Government stockpile	364	--	--	--	--
Stocks, producers and processors, yearend	W	W	W	W	W
Consumption, apparent[e]	17,100	19,600	21,400	12,100	11,800
Prices, yearend, dollars per kilogram:					
Bastnasite concentrate, REO basis	\$2.31	\$2.14	\$2.14	\$2.14	\$2.14
Monazite concentrate, REO basis	\$0.75	\$0.71	\$0.64	\$1.09	\$1.06
Mischmetal, metal basis	\$12.35	\$12.35	\$12.35	\$12.35	\$12.35
Employment, mine and mill[e 2]	303	266	321	330	283
Net import reliance[e 3] as a percent of apparent consumption	([4])	12	([4])	([4])	5.94

[e]Estimated. W Withheld to avoid disclosing company proprietary data.

[1]Comprises only the rare earths derived from bastnasite, as reported in Unocal Corp. (previously Union Oil Co. of California) annual reports.

[2]Employment at a rare-earth mine in California and at minerals 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.

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.

Legislation and Government Programs.—Sales of materials held in the National Defense Stockpile (NDS), including rare earths, continued to be suspended during 1986 because the $250 million limit imposed on the NDS Transaction Fund was exceeded during 1985. Two laws governed the disposal of materials from the NDS in 1986. Under both laws, the Department of Defense Authorization Act, 1986 (Public Law 99-145), which was signed November 8, 1985, and effective during fiscal year 1986, and the Department of Defense Authorization Act, 1987 (Public Law 99-661), which was signed November 14, 1986, and effective during fiscal year 1987, no rare earths were authorized for disposal. Yttrium oxide, which was held in a non-NDS Government stockpile, was not affected by these laws and was declared excess and available for disposal.

DOMESTIC PRODUCTION

A new plant to recover heavy minerals, including rare-earth-bearing apatite, as byproducts of industrial sand and gravel, began operation in September 1985. The mine, in Soledad Canyon, CA, is operated by Gillibrand. Materials processed at the mine contain from 5% to 20% heavy minerals containing 50% ilmenite, 20% apatite, 15% magnetite, and from 1% to 4% zircon. Pilot plant recoveries reached 85% of the heavy minerals in the feed. The company planned to install additional gravity separation equipment and to purchase electrostatic and magnetic separation equipment to process the heavy minerals concentrate into salable products. Planned capacity of the new plant was 100,000 metric tons of heavy minerals per year.[2] In addition to its mine, Gillibrand had 8,000 acres of mining claims in the area, most of which contain alluvial and lode deposits of heavy minerals.

Associated Minerals was the only commercial minerals sands operation in the United States to produce monazite in 1986. The monazite was obtained as a byproduct of processing heavy minerals sands for titanium and zirconium minerals at Green Cove Springs, FL. Associated Minerals installed an underwater bucketwheel excavator on its dredge, resulting in improved mining recoveries and higher production from compacted areas of the ore body.[3]

REMACOR, the parent company of Reactive Metals and Alloys Corp. and the domestic mischmetal and rare-earth silicide producer, and Mitsubishi Metal Corp. formed a joint-venture company, Neomet Corp., to produce neodymium alloys for use in high-strength permanent magnets. The new company, in West Pittsburg, PA, started development in August 1986 with commercial quantities scheduled to be available in the first quarter of 1987.

Neomag Inc., a subsidiary of Polymag Inc., announced plans to open a plant in New Castle, PA, to produce neodymium-iron-boron permanent magnets using material provided by nearby Neomet. The plant was expected to be in production by February 1987. The plant produces flexible and rigid polymer bonded neodymium-iron-boron magnets in various sizes.

According to Unocal Corp.'s annual report, Molycorp's 1986 sales declined for the second consecutive year. Demand reportedly held steady for rare earths used in petroleum fluid cracking catalysts after a major decline in demand in 1985. However, revenues from Molycorp's rare-earth products were the third highest in the company's history. Molycorp began marketing several new rare-earth products during the year, including a pipe thread additive, cerium fluoride dopant, that can withstand high temperatures and pressures and an extended line of neodymium products, including alloys, for use in neodymium-iron-boron permanent magnets.

Startup production of yttrium concentrate, feed material for Molycorp's processing plant at Louviers, CO, began in October at Unocal Canada Ltd.'s joint venture at Elliot Lake, Ontario, Canada. The joint-venture company, formed by Unocal's Canadian subsidiary, Unocal Canada, and two other Canadian companies, Denison Mines Ltd. and SM Yttrium Ltd., a joint venture of the Japanese companies Shin-Etsu Chemical Co. Ltd. and Mitsui & Co. Ltd., recovered yttrium and rare earths as a byproduct of processing uranium leach solutions from Denison's Elliot Lake Mine.

General Motors Corp.'s (GM) Delco Remy Div. started production of its Magnequench line of neodymium-iron-boron permanent magnets at its Anderson, IN, plant. Pilot facilities, which were completed in 1984 and became operational in 1985, were scaled up to a $70 million commercial operation that went into production in July 1986. The Anderson plant was slated to supply magnetic materials to the new facility in Meridian, MI, that was to produce permanent magnet gear-reduced cranking motors beginning in March 1987. GM planned to install the cranking motor in its 1987 model full-size pickup truck during the second half of 1987. GM also began worldwide marketing of its Magnequench magnets in 1986 to compete in the ferrite magnet market.

M&M Minerals Inc. of Concord, NC, installed separation equipment to produce monazite and other heavy minerals sands as a byproduct of processing industrial sand and gravel. Preliminary tests with the new processing equipment began in 1986; however, monazite grades were not as high as expected with only localized high-grade areas. Further testing was under way to determine the feasibility of recovering monazite as a byproduct with the other heavy minerals.

Rhône-Poulenc Inc. purchased an iron ore tailings deposit from Williams Metals Industries Inc. in July, which contains rare earths and yttrium in apatite. Rhône-Poulenc Inc. began ore separation studies at the Mineville, NY, tailings deposit, but has not set a date for production. The deposit was purchased to supply rare-earth feed to Rhône-Poulenc Inc.'s existing separation plants in Freeport, TX, and La Rochelle, France.

W. R. Grace, Shin-Etsu Chemical, and Mitsui announced a joint project to produce separated rare earths in the United States. The Davison Chemical Div. of W. R. Grace, which currently processes the rare-earth ore and concentrate to produce petroleum fluid cracking catalysts and polishing compounds, was scheduled to expand its facilities in Chattanooga, TN, for the separation plant. The new plant will reportedly employ separation technology licensed from Shin-Etsu Chemical.[4]

CONSUMPTION AND USES

Domestic rare-earth processors consumed an estimated 11,800 tons of equivalent rare-earth oxides (REO) in various forms in 1986, a slight decrease from that of 1985. Compared with that of 1985, bastnasite consumption was 14% lower, and monazite consumption, 48% lower. The decreased consumption of monazite was attributed to decreased demand in the rare-earth petroleum catalyst market.

Shipments of rare-earth products from domestic processors of ore, concentrates, and intermediate concentrates amounted to 13,200 tons of equivalent REO, a decrease of 6% from the 1985 shipments of 14,000 tons.

Consumption of mixed rare-earth compounds increased 46% while consumption of purified compounds increased 9%. Higher consumption of purified compounds was the result of continued strong demand for samarium, neodymium, dysprosium, 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 8% less rare earths in 1986 than in 1985, while shipments of these goods fell 24%. Shipments of high-purity rare-earth metals increased 59% during the year, primarily because of increased demand for neodymium metal for use in permanent magnets.

The approximate distribution of rare earths by use, based on information supplied by primary processors and some consumers, was as follows: metallurgical uses (including iron and steel additives, alloys, and mischmetal), 37%; petroleum catalysts (including chemical processing), 31%; ceramics and glass (including polishing compounds and glass additives), 29%; and miscellaneous uses (including phosphors, electronics, permanent magnets, lighting, and research), 3%.

The glass industry's principal use of rare earths, mainly cerium concentrate or cerium oxide, was as polishing compounds for lenses, mirrors, cut crystal, television and other cathode-ray tube (CRT) faceplates, gem stones, and plate glass. Purified rare-earth compounds were also used as additives to glass used in containers, television and CRT faceplates, radiation shielding windows, opthalmic lenses, lasers, incandescent and fluorescent lights, and optical, photochromic, filter, and photographic lenses. The rare-earth additives acted as colorants, color correctors, and decolorizers; as stabilizers against discoloration from ultraviolet light and against browning caused by high-energy radiation; as dopants in laser glass; as modifiers to increase the refractive indices and decrease dispersion; and as absorbers of ultraviolet and visible light.

Phosphors containing rare earths were used in color television tubes, radar screens, avionic and data displays, X-ray intensifying screens, low- and high-pressure mercury vapor lights, electronic thermometers, and trichromatic fluorescent lamps.

The ceramics industry used purified rare earths in pigments, heating elements, dielectric and conductive ceramics, thermal and/or flash protective devices, stereoviewing systems, data printers, image storage devices, and as principal constituents and stabilizers in high-temperature refractories such as yttria-stabilized zirconia and in glasses and paints.

Purified rare-earth compounds also had applications in petroleum fluid cracking catalysts, noncracking catalysts, oxygen-sensing electrolytes, computer bubble domain memories, dyes and softeners for textiles, electronic components, nuclear fuel reprocessing, microwave applications, incandescent gas mantles, laser crystals, fiber optics, carbon arc lighting, synthetic gem stones, and superconductors.

Rare-earth permanent magnets were used in electric motors, alternators, generators, line printers, computer disk-drive actuators, proton linear accelerators, synchronous torque couples, eddy current brakes, microwave focusing, magnetrons, klystrons, medical and dental applications including nuclear magnetic resonance imaging, traveling wave tubes, metallic separators, aerospace applications including electric actuators for ailerons and rudders, and in speakers, headphones, microphones, and tape drives.

Metallurgical applications of rare earths included alloys and additives in high-strength, low-alloy steels; gray and ductile iron; stainless and carbon steels; high-temperature and corrosion-resistant metals; hydrogen storage alloys used in heat exchangers and fuel cells; lighter flints; armaments; permanent magnets; neutron converter foils; special lead fuses; target materials for sealed-tube neutron generators; and high-voltage transmission cable.

STOCKS

U.S. Government stocks of rare earths in the NDS, all classified as excess to goal, remained at 457 tons throughout 1986. Rare-earth stocks held in the NDS were contained in sodium sulfate and were inventoried on a contained-REO basis. Authority to dispose of these excess rare earths was suspended effective October 1, 1984, by section 902 of the Department of Defense Authorization Act, 1985. All remaining stocks of yttrium oxide, 108 kilograms, held in non-NDS Government inventories, were sold during the year.

Industry stocks of rare earths held by 23 producing, processing, and consuming companies decreased 16%. Bastnasite stocks held by the principal producer and four other processors decreased 47% from the yearend 1985 level. Yearend stocks of monazite increased 20%, while stocks of other concentrates, including yttrium, decreased 52%.

Stocks of mixed rare-earth compounds decreased 10%, while stocks of purified compounds, mostly separated REO, decreased 35% during the year. Yearend stocks of mischmetal, rare-earth silicide, and other alloys containing rare earths were down 42%, while inventories of high-purity rare-earth metals were 53% higher.

PRICES

The price of Australian monazite (minimum 55% REO including thoria, f.o.b.-f.i.d.),[5] as quoted in Metal Bulletin (London), was $A850-$A900 per ton at yearend 1986, unchanged from the yearend 1985 price. Changes in the U.S.-Australian foreign exchange rate in 1986, resulting from the continued economic strength of the U.S. dollar against Australian currency, caused the corresponding U.S. price to decrease slightly from US$580-US$614 in 1985 to US$565-US$598 in 1986.[6] The average declared value of imported monazite was increased to $374 per ton, up $25 from the 1985 value.

The yearend price quoted in Industrial Minerals (London) for yttrium concentrate (60% Y_2O_3, f.o.b. Malaysia) was $46 per kilogram. Domestic prices quoted for yttrium concentrate during 1986, 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 $0.92, $0.97, and $1.17 per pound of contained REO, respectively, at yearend 1986, unchanged since 1983.

The price of cerium concentrate quoted by American Metal Market was $1.40 per pound of contained cerium oxide at yearend 1986, a slight increase over the yearend 1984 price. The price of lanthanum concentrate was unchanged at $1.40 per pound of contained REO. The mischmetal (99.8%, lots over 100 pounds, f.o.b. shipping point) price, quoted in American Metal Market, expanded from the yearend 1985 price range of $5.00-$5.60 per pound to $4.90-$5.60 per pound at yearend 1986.

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, 1986, 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	65.00
Lanthanum	99.99	300	7.00
Neodymium	96.0	300	5.00
Do	99.9	50	40.00
Praseodymium	96.0	300	16.80
Samarium	96.0	55	50.00
Terbium	99.9	55	375.00
Yttrium	99.99	50	55.50

[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, 1986, 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	.84
Lanthanum carbonate	99.9	300	4.60
Lanthanum chloride	46.0	525	.95
Lanthanum-lanthanide carbonate	60.0	200	2.45
Lanthanum-lanthanide nitrate	39.0	250	1.75
Neodymium carbonate	96.0	300	3.35

[1]Priced on a contained REO basis.

Rhône-Poulenc Inc. 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, 1986, as follows:

Product[1] (oxide)	Percent purity	Quantity (kilograms)	Price per kilogram
Cerium	99.5	20	$20.35
Erbium	96.0	50	210.00
Europium	99.99	40	1,865.00
Gadolinium	99.99	50	136.50
Lanthanum	99.99	25	18.10
Praseodymium	96.0	20	38.85
Samarium	96.0	25	88.20
Terbium	99.9	20	875.00
Yttrium	99.99	50	110.00

[1]Dysprosium, holmium, lutetium, thulium, and ytterbium oxide prices on request from Rhône-Poulenc Inc.

Rhône-Poulenc Inc. also quoted prices for rare earths produced at its Freeport, TX, plant, net 30 days, f.o.b. Freeport, TX, effective January 1, 1986, as follows:

Product (compound)	Percent[1] purity	Quantity (kilograms)	Price[2] per kilogram
Cerium carbonate	95.0	20	$8.60
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	7.20
Lanthanum nitrate	99.5	200	11.90
Lanthanum oxide	99.5	20	13.25
Neodymium carbonate	95.0	20	7.75
Neodymium nitrate	95.0	200	8.40
Neodymium oxide	95.0	20	9.25

[1]Purity expressed as percent of total REO.
[2]Priced on a contained REO basis.

Nominal prices for various rare-earth products were quoted by Research Chemicals, net 30 days, f.o.b. Phoenix, AZ, effective November 1, 1986, 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, produced primarily from bastnasite, 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 7.7 million kilograms in 1985 to 6.0 million kilograms in 1986. Exports of rare-earth metal ores, excluding monazite, were valued at $11.8 million in 1986. Major destinations were Japan, 61%; Austria, 17%; and the United Kingdom, 8%.

Exports of ferrocerium and other pyrophoric alloys containing rare earths totaled 33,132 kilograms, 28% higher than those of 1985. Major destinations for these exports were Canada, 32%; Mexico, 30%; and Japan, 21%.

Exports of thorium ore, including monazite, decreased 22% from the 1985 level. France was the destination of all of the reported total of 581,854 kilograms valued at $326,846, approximately $561.73 per ton.

Lower U.S. import duties on rare-earth materials, resulting from the 1979 Tokyo Round of tariff negotiations, continued for nations having most-favored-nation status. The import duties for these countries were scheduled to decline annually at staged rates through January 1, 1987.

The import tariff for yttrium-bearing ores, materials, and compounds, which excludes high-purity yttrium oxide, was suspended in 1984 for nations having most-favored-nation status. Yttrium ores and concentrates are currently imported under Tariff Schedule of the United States (TSUS) No. 907.51, which was scheduled to remain in effect until July 1, 1988.

Table 2.—U.S. import duties on rare earths

Item	TSUS No.	Most favored nation (MFN)		Non-MFN
		Jan. 1, 1986	Jan. 1, 1987	Jan. 1, 1986
Ore and concentrate[1]	601.12, 601.45	Free	Free	Free.
Cerium chloride, oxide, compounds	418.40, 418.42, 418.44	8.2% ad valorem.	7.2% ad valorem.	35% ad valorem.
Rare-earth oxides except cerium oxide	423.0030	3.9% ad valorem.	3.7% ad valorem.	25% ad valorem.
Rare-earth metals (including scandium and yttrium).	632.38	do	do	Do.
Alloys wholly or almost wholly of rare-earth metals (mischmetal).	632.78	34 cents per pound.	32 cents per pound.	$2 per pound.
Other alloys wholly or almost wholly of rare-earth metals.	632.79	23 cents per pound plus 2.9% ad valorem.	20 cents per pound plus 2.4% ad valorem.	$2 per pound plus 25% ad valorem.
Ferrocerium and other pyrophoric alloys	755.35	25 cents per pound plus 3.0% ad valorem.	22 cents per pound plus 2.6% ad valorem.	Do.
Yttrium-bearing materials and compounds (includes yttrium concentrates).	907.51	Free	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	1982		1983		1984		1985		1986	
	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	6,600	$2,830	3,726	$1,395	5,610	$2,156	5,694	$1,984	2,660	$978
India	--	--	--	--	--	--	--	--	300	128
Malaysia	603	240	302	122	--	--	--	--	--	--
South Africa, Republic of	--	--	--	--	51	46	--	--	--	--
Total	7,203	3,070	4,028	1,517	5,661	2,202	5,694	1,984	2,960	1,106
REO content[e]	3,962	XX	2,215	XX	3,114	XX	3,132	XX	1,628	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	1984		1985		1986	
	Quantity (kilograms)	Value	Quantity (kilograms)	Value	Quantity (kilograms)	Value
Cerium chloride:						
Malaysia	701,092	$754,588	--	--	--	--
Singapore	--	--	--	--	34,500	$39,871
Total	701,092	754,588	--	--	34,500	39,871
Cerium compounds:						
Canada	--	--	--	--	11,987	8,328
France	1,000	4,778	1,770	$8,981	247,420	354,290
Germany, Federal Republic of	42	10,373	206	34,469	188	32,141
Japan	207	9,226	--	--	--	--
Switzerland	1	266	--	--	--	--
United Kingdom	5	783	10	2,306	--	--
Total	1,255	25,426	1,986	45,756	259,595	394,759
Cerium oxide:						
Austria	68	738	--	--	91	1,195
Canada	--	--	--	--	117	7,561
China	--	--	--	--	100	1,083
France	3,790	53,891	5,327	81,670	4,595	76,014
Germany, Federal Republic of	12	1,457	94	2,283	--	--
Japan	3,357	30,522	--	--	561	18,844
Switzerland	6	1,207	--	--	--	--
United Kingdom	40	287	27	1,707	--	--
Total	7,273	88,102	5,448	85,660	5,464	104,697
Cerium salts:						
Japan	--	--	--	--	11	4,099
Netherlands	--	--	--	--	5,296	11,647
Total	--	--	--	--	5,307	15,746
Rare-earth oxide excluding cerium oxide:						
Austria	50	2,646	--	--	--	--
Belgium-Luxembourg	16,803	42,856	110	46,342	963	31,269
Brazil	--	--	--	--	500	15,383
Canada	83,815	23,264	--	--	22	3,270
China	4,058	263,084	3,830	348,923	41,943	2,082,324
France	271,555	13,880,011	170,556	11,132,432	200,601	12,535,724
Germany, Federal Republic of	1,078	284,165	811	266,213	1,839	486,350
Hong Kong	--	--	--	--	981	63,551
India	199,998	192,500	--	--	--	--
Italy	--	--	--	--	3	3,750
Ivory Coast	--	--	--	--	514	90,074
Japan	14,311	1,034,997	7,814	872,783	10,130	1,094,614
Korea, Republic of	68	5,087	--	--	--	--
Malaysia	274,592	295,907	6,210	186,534	--	--
Mexico	50,499	2,222	--	--	--	--
Netherlands	54	23,459	513	36,372	--	--
Norway	6,168	659,184	5,996	655,382	2,478	402,216
Switzerland	--	--	318	111,800	35	13,050

Table 4.—U.S. imports for consumption of rare earths, by country —Continued

Country	1984 Quantity (kilograms)	1984 Value	1985 Quantity (kilograms)	1985 Value	1986 Quantity (kilograms)	1986 Value
Rare-earth oxide excluding cerium oxide —Continued						
U.S.S.R.	11,984	$747,572	6,506	$691,201	22,776	$1,809,588
United Kingdom	225	28,541	197	38,133	5,468	311,050
Total	935,258	17,485,495	202,861	14,386,115	288,253	18,942,213
Rare-earth alloys:[1]						
Austria	52,463	444,685	--	--	--	--
Brazil	79,993	526,031	162,998	817,875	47,359	239,274
France	--	--	1,062	9,946	--	--
Germany, Federal Republic of	11,276	100,653	17,211	167,343	3,665	49,148
Japan	--	--	--	--	11	1,130
United Kingdom	5	485	5,057	35,535	15,100	119,729
Total	143,737	1,071,854	186,328	1,030,699	66,135	409,281
Rare-earth metals including scandium and yttrium:						
Austria	--	--	100	2,968	786	24,395
China	1,573	59,526	--	--	5,655	299,929
Ivory Coast	--	--	--	--	97	15,611
Japan	--	--	1,000	76,099	1,000	76,099
Malaysia	40	644	--	--	--	--
U.S.S.R.	700	164,735	2,061	183,044	9,666	805,497
United Kingdom	2,003	394,484	24	22,642	2,354	615,271
Total	4,316	619,389	3,185	284,753	19,558	1,836,802
Other rare-earth metals:						
China	1,000	1,181	--	--	--	--
France	135	3,979	329	9,870	7,066	149,562
Germany, Federal Republic of	77	7,514	655	15,275	2	1,207
Japan	--	--	--	--	80	4,695
United Kingdom	--	--	209	9,225	60	2,842
Total	1,212	12,674	1,193	34,370	7,208	158,306
Ferrocerium and other pyrophoric alloys:						
Austria	937	12,875	1,000	13,240	655	10,032
Brazil	47,388	685,088	45,349	632,014	32,799	434,340
France	72,470	695,395	66,771	641,505	50,123	640,986
German Democratic Republic	170	1,589	--	--	--	--
Germany, Federal Republic of	459	5,340	--	--	765	15,092
Hong Kong	--	--	--	--	892	2,943
Japan	15,537	204,308	20	1,699	796	14,953
Korea, Republic of	--	--	--	--	8,778	21,276
Netherlands	--	--	--	--	58	1,153
United Kingdom	1,167	45,965	245	13,080	396	13,526
Total	138,128	1,650,560	113,385	1,301,538	95,262	1,154,301

[1]Essentially all mischmetal.

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 minerals sands mined for titanium and zirconium minerals or tin in Australia, Brazil, China, India, and Malaysia. Smaller quantities of rare earths, especially yttrium, were obtained from the yttrium-rich minerals sands 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 amounts of rare earths were also produced from ion adsorption ore in China and from spent uranium leach solutions in Canada.

World reserves of rare earths were estimated by the Bureau of Mines at 45 million tons of contained REO, of which 19% is in market economy countries.[7] China, with 80%, had the largest share of world reserves.

Australia.—Renison Goldfields Consolidated Ltd. (RGC) was successful in its bid to acquire Allied Eneabba Ltd. In purchasing Allied, RGC issued 2.4 million shares and paid US$5.3 million[8] to obtain additional reserves of minerals sands including the rare-earth ore monazite, mining leases adjacent to RGC's properties in Eneabba, a heavy minerals sands mine at Eneabba, and a processing plant at Narngulu, all in Western Australia. The acquisition made RGC the world's principal minerals sands producer and largest producer of rare earths from monazite. RGC's share of the world's monazite capacity was estimated at 40%. RGC's monazite production increased substantially to 8,527 tons as a result of including production from Allied's operations for the second half of the year.[9]

Prior to the RGC acquisition, Allied and Asahi Chemical Industry Co. Ltd. were studying the feasibility of building a rare-earth separation plant at Geraldton, Western Australia, to process monazite. RGC reported that it was continuing study of the proposed project, but acknowledged that both Allied and RGC still had long-term contracts to supply monazite to Rhône-Poulenc S.A. of France.[10]

West Coast Holdings Ltd. agreed to purchase the share of its partner, Union Oil Corp., of the Brockman deposit in Western Australia. The multimineral deposit contains yttrium, rare earths, columbium (niobium), tantalum, gallium, zirconium, and hafnium in 4.29 million tons of ore. Union Oil reportedly sold its stake to West Coast Holdings for US$265,700, retaining a 2.55% net profits interest in the project.[11] Initial hydrometallurgical tests of the Brockman ore indicated processing at a proposed rate of 340,000 tons per year would recover 1,496 tons of columbium, 37 tons of gallium metal, 119 tons of hafnium oxide, 340 tons of heavy lanthanide oxides, 92 tons of tantalum oxide, 422 tons of yttrium oxide, and 3,536 tons of zirconium oxide. Development of the deposit could take place as early as 1988, depending on the outcome of additional feasibility studies.[12]

Westralian Sands Ltd. reported record-high earnings in 1985. However, production of rare-earth-bearing monazite decreased during the year from 3,100 tons to 2,100 tons. Both the Yoganup Extended Mine and North Capel Mine operated at full capacity in 1985. Westralian Sands planned to open a new heavy minerals sands mine, the Yoganup North Mine, at Boyanup, Western Australia, in early 1987.[13]

Brazil.—The Brazilian state-owned Companhia Vale do Rio Doce announced plans to commercially produce rare earths as a byproduct of processing the mineral anatase for its titanium content. At the planned capacity of 500,000 tons of 90% titanium dioxide per year, an estimated 8,000 tons of REO could be produced. Pilot plant studies showed high contents of europium and yttrium in the byproduct concentrate. At full capacity, the new mine could produce about four times Brazil's current rare-earth production in terms of contained REO.

Canada.—Highwood Resources Ltd. and Hecla Mining Co. of Canada Ltd., a wholly owned subsidiary of Hecla Mining Co. (United States), announced a joint venture to develop Highwood's Thor Lake beryllium-rare-earth property near Yellowknife, Northwest Territories. Hecla reportedly agreed to reimburse Highwood for 50% of its prior expenditures and provide financing to bring the deposit into production. Reserves of the deposit were estimated at 1.6 million tons grading 0.85% beryllium oxide and 431,000 tons grading 0.2% yttrium oxide.[14]

China.—Rare-earth resources are primarily in the Baiyun-Ebo deposit in the Nei Monggol Autonomous Region, followed by deposits in Jiangxi Province and in Guangdong Province. Resources in Jiangxi Province are rich in the heavy-group rare-earth elements, especially yttrium, samarium, europium, terbium, and ytterbium. Except for xenotime, recovered in small amounts in Australia, Malaysia, and Thailand, most rare earths recovered in the world have high contents of the light rare-earth elements.[15]

Production capacities, by rare-earth ore type, in terms of REO content, were as follows: bastnasite, 14,000 tons; monazite, 4,500 tons; ion adsorption ore, 1,200 tons; and xenotime, 400 tons. Total capacity of the country's rare-earth industry was 20,100 tons of REO. Rare-earth production in 1985, from various ores, was reported as 12,200 tons of REO.[16]

Japan.—Imports of rare earths in 1986 were reported in the Japan Metal Journal, as follows:

Product	Quantity (kilograms)
Cerium fluoride	19
Cerium oxide	411,080
Ferrocerium and other pyrophoric alloys	28,914
Lanthanum oxide	202,902
Rare-earth chloride	4,553,648
Rare-earth metals including yttrium and scandium	131,867
Yttrium oxide	448,414

Principal sources of imported compounds, in decreasing order of weight, were China, India, France, the United States, and Brazil.

Data on Japanese demand for rare earths in 1985 were reported as follows:[17] catalysts, 300 tons; cerium oxide, 2,250 tons; europium oxide, 10 tons; lanthanum oxide, 340 tons; mischmetal, 300 tons; rare-earth fluoride, 60 tons; samarium oxide, 300 tons; yttrium oxide, 250 tons; and other REO's, 200 tons.

Rhône-Poulenc S.A. of France announced the formation of a joint-venture company between its Japanese subsidiary Rhône-Poulenc Japan Ltd. and Sumitomo Metal Mining Co. Ltd. of Japan, called Nippon Rare Earths Co. Ltd. (NRE). Beginning in July, NRE planned to import and market a full range of Rhône-Poulenc S.A.'s rare-earth products, except polishing compounds. Rhône-Poulenc S.A.'s polishing compounds are presently imported by Showa Denko K.K. NRE's future plans were to develop Sumitomo's rare-earth separation technology.[18]

Madagascar.—QIT-Fer et Titane Inc., of Montreal, Canada, and the Government of Madagascar entered into a joint venture to recover heavy minerals sands, including monazite, on the east coast of Madagascar. Under the agreement, QIT will operate the mine and hold a 49% stake in the operation with the Madagasy Government controlling the remaining 51%. The primary product of the proposed mine is ilmenite, which will reportedly be sent to QIT's ilmenite smelter in Sorel, Quebec, Canada, for processing into high-grade titanium slags for pigments.[19]

Malaysia.—Production of xenotime increased substantially in 1985 to 1,124 tons, an increase of 741 tons over the 1984 level. Although firm data were not available for 1986, it was estimated that xenotime production would be lower because of decreased tin production in Malaysia.[20]

Thailand.—In a cooperative effort, the Metal Mining Agency of Japan agreed to build a pilot plant in Thailand to recover rare metals, including rare earths, columbium, and tantalum, from tin milling wastes. Planned capacity of the test plant was 1 ton of milling wastes per day and was scheduled for completion in the first half of 1987. If development of processing technology is successful, a joint-venture commercial plant was planned for 1989.[21]

Table 5.—Monazite concentrate: World production, by country[1]

(Metric tons)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Australia	9,562	15,141	16,260	18,735	10,500
Brazil	1,814	5,256	3,622	1,213	2,000
India[e 3]	4,000	4,000	4,000	4,000	4,000
Malaysia[4]	[r]582	1,051	4,451	5,808	1,000
Mozambique	3	4	[e]4	[e]4	4
Sri Lanka	304	[e]300	147	[e]200	200
Thailand	162	277	298	245	200
United States	W	W	W	W	W
Zaire	32	15	2	--	--
Total	[r]16,459	26,044	28,784	30,205	17,904

[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. 28, 1987.

[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]Data are for years beginning Apr. 1 of that stated.

[4]The 1982-83 figures are exports and the 1984-86 figures are production.

TECHNOLOGY

Experiments at IBM Corp.'s research laboratory in Zurich, Switzerland, led to the discovery of superconductivity at a record-high temperature of 30° K (-243° C) in a new material, an oxide compound containing lanthanum, barium, and copper. The discovery, in January 1986, was the first finding of high-temperature superconductivity in a ceramic material.[22] The work done by researchers at IBM's Zurich laboratory led to unprecedented research activity throughout the world on high-temperature superconductors, leading to continual advances in the temperature at which the ceramic materials superconduct (Tc). By yearend, other scientists reported superconductivity up to 39° K (-234° C). Researchers were confident that further progress in the increase of Tc's was possible in this new class of materials. Applications projected for high-temperature superconductors were in fusion confinement, nuclear magnetic resonance imaging, energy storage and transmission, magnetic separation, levitated transportation, electronic components and connectors, magnets for supercolliders, and new devices not yet envisioned.

Scientists at Lawrence Livermore National Laboratory, using the "Nova" Nd glass system of lasers, successfully produced a "little star" by fusion, as part of the Inertial Confinement Fusion Program. The laser system reportedly poured 100 trillion watts (1 terawatt) of energy into a small sphere of deuterium and tritium, creating temperatures of approximately 30 million degrees Celsius in 50 trillionths of a second (50 picoseconds). The fusion produced helium and energy, estimated at twice that of the entire electric generating capacity of the United States, on an equivalent picosecond basis. Advancements in laser-induced fusion could eventually result in low-cost nonradioactive electrical power generation.[23]

Researchers at the Harbor-UCLA Medical Center in Torrance, CA, used a neodymium doped yttrium-aluminum garnet (Nd:YAG) laser to experimentally weld animal skin, in place of conventional suturing (stitches or staples). Compared with other lasers, the procedure reportedly worked best with a 1-watt Nd:YAG laser operating at 1.32 nanometers. In experiments with animals, the laser-welded tissue displayed strength comparable to stitched tissue, displayed less inflammation, healed faster, and had fewer adhesions. However, researchers claimed improvements in the procedure were needed before laser welding replaces suturing to close wounds and incisions on humans.[24]

An ultralow-loss optical fiber system was developed by researchers at the Naval Research Center in Washington, DC, using a mixture of various fluoride compounds, including lanthanum fluoride. The fluoride glass fiber system reportedly transmits data with a loss rate of 0.001 decibels per kilometer, more than 100 times better than the best available silica glass fibers. In addition to data transmission, lanthanum-containing optical fiber has potential applications in laser surgery and cauterization, acoustic and magnetic fiber sensor systems, infrared power delivery, and remote temperature and chemical sensing.[25]

A new method was developed to process the rare-earth ore monazite in the solid state. Using sodium carbonate and a minor amount of sodium fluoride, monazite was sintered at 700° C to produce cerium and thorium as the oxide and the remaining rare earths as a mixed double phosphate. The remaining rare earths were extracted from the intermediate sodium-rare-earth, double-phosphate compound with diluted hydrochloric acid recovering nearly 95% of the equivalent REO in monazite.[26]

Researchers at Ergenics Inc. developed a 300-watt thermal engine that requires no external electric power. Containing lanthanum-nickel hydride as a hydrogen storage-energy system, the pump can reportedly deliver 38 liters (10 gallons) of water per minute from a depth of 50 feet. The pump was designed to benefit arid areas, especially where no power distribution grid is available. The same lanthanum-nickel hydride system has been used to purify water by reverse osmosis, to produce refrigeration, and to generate electric power.[27]

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[1]Physical scientist, Division of Nonferrous Metals.

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[3]Renison Goldfields Consolidated Ltd. Annual Report 1986. 43 pp.

[4]Rare-Earth Information Center News. Grace To Separate Rare Earths. V. 21, No. 3, Sept. 1, 1986, p. 2.

[5]Free on board-free into container depot.

[6]Values have been converted from Australian dollars (A$) to U.S. dollars at yearend exchange rates of A$1.4652=US$1.00 for 1985 and A$1.5053=US$1.00 for 1986.

[7]Hedrick, J. B. Rare Earth Elements and Yttrium. Ch. in Mineral Facts and Problems, 1985 Edition. BuMines B 675, 1986, pp. 647-664.

[8]Values have been converted from Australian dollars (A$) to U.S. dollars at yearend exchange rates of A$1.4652=US$1.00 for 1985 and A$1.5053=US$1.00 for

1986.

[9]Work cited in footnote 3.

[10]Work cited in footnote 3.

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[21]Japan Metal Journal. Agency Will Build Test Plant for Recovering Rare Metals in Thailand. Mar. 24, 1986, p. 7.

[22]Bednorz, J. G., and K. A. Müller. Possible High Tc Superconductivity in the Ba-La-Cu-O System. Zeitschrift für Physik B-Condensed Matter, v. 64, 1986, pp. 189-193.

[23]Rare-Earth Information Center News. Tiny Laboratory "Star." V. 21, No. 1, Mar. 1, 1986, p. 3.

[24]Laser & Applications. Pigskin and Rats Get Laser Welded. June 1986, p. 34.

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[26]Kizilyalli, M., and A. J. E. Welch. A New Method for Processing of Monazite and Examination of the Products by X-Ray Analysis. A poster presented at the Seventeenth Rare-Earth Research Conference, Hamilton, Ontario, Canada.

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Salt

By Dennis S. Kostick[1]

Production and sales of all types of salt decreased because of reduced demand for salt for highway deicing and chloralkali manufacture. Production and sales of rock salt decreased in 1986, primarily because of consumer stock buildups during 1985. Reported production and use of salt brine decreased because of the closures of the last domestic synthetic soda ash plant and a few chlorine-caustic soda operations.

Apparent consumption of salt decreased in response to a sharp decrease in domestic demand. Exports of salt increased 29% and imports for consumption of salt increased 7%.

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 70 operations to which a survey request was sent, 68 responded, representing 96% of the total production shown in table 1. Production for one nonrespondent was estimated on the basis of its prior response to the 1986 production estimate survey. The other nonrespondent apparently terminated its production activities. One producer reported no production.

Legislation and Government Programs.—On May 28, 1986, the U.S. Department of Energy announced its final selection of three candidate sites, in Nevada, Texas, and Washington, for the first nuclear waste repository in the Western United States. The Deaf Smith County site in Texas was the only site that is in bedded salt. Site characterization studies were begun, and the final choice of location was scheduled to be made by 1994. About 77,000 short tons of high-level nuclear waste was planned to be stored in the selected repository, with disposal commencing by 1998.[2]

Table 1.—Salient salt statistics

(Thousand short tons and thousand dollars)

	1982	1983	1984	1985	1986
United States:					
Production[1]	37,665	32,973	39,181	[r]39,217	37,282
Sold or used by producers[1]	37,894	34,573	39,225	[r]40,067	36,663
Value	$671,424	$597,081	$675,099	[r]$739,609	$665,400
Exports	1,001	517	820	904	1,165
Value	$16,647	$12,368	$15,299	$15,988	$16,928
Imports for consumption	5,451	5,997	7,545	6,207	6,665
Value	$56,184	$60,194	$74,100	$65,593	$79,709
Consumption, apparent[2]	42,344	40,053	45,950	[r]45,370	42,163
World: Production	[r]181,071	[r]175,401	190,196	[p]191,565	[e]192,222

[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 5%. The amount sold or used captively decreased 9%. Production and sold or used data for 1985 were revised to include additional information obtained from newly disclosed solar and brine operations that operated in 1985, and to correct unintentional double reporting by two producers. In 1986, 34 companies operated 69 salt-producing plants in 15 States. Nine of the companies and 10 of the plants produced more than 1 million tons each and accounted for 84% and 62%, respectively, of the U.S. total. Many individual companies and plants produced more than one type of salt. In 1986, 12 companies (18 operations) produced solar-evaporated salt; 7 companies (18 operations), vacuum pan and open pan salt; 10 companies (15 operations), rock salt; and 18 companies (29 operations), salt brine.

The five leading States in quantity of salt sold or used were Louisiana, 32%; Texas, 23%; New York, 14%; Ohio, 11%; and Kansas, 5%. A significant quantity of the salt produced in Alabama, Louisiana, New York, Texas, 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:

	1985[r]	1986
Salt in brine	48	49
Mined rock	37	34
Vacuum pan salt and grainer or open pan salt	9	10
Solar-evaporated salt	6	7
Total	100	100

[r]Revised.

Because of economic, environmental, and market conditions, several chloralkali manufacturers shut down permanently, which contributed to a decrease in brine production and use statistics. Among the closures were Allied Chemical Corp. in New York, Pennwalt Corp. in Michigan, and FMC Corp. in West Virginia. A few chlorine and caustic soda producers that had operated their own salt brine wells to supply feedstock turned to independent brine suppliers to operate the fields for them. The number of brine supply companies increased as chloralkali companies relinquished their dual role of salt producer and salt consumer.

On March 31, Diamond Crystal Salt Co., based in St. Clair, MI, permanently closed its Jefferson Island, LA, salt processing operation. The company had been purchasing rock and evaporated salt for its salt processing facility since its own rock salt mine was flooded in November 1980 following a drilling accident. Although prices for processed salt had remained firm, prices for purchased salt had increased, a fact which led to the decision for closure that eliminated 70 jobs.[3]

In May, Diamond Crystal celebrated its 100th anniversary. The company had begun in April 1886 as the St. Clair Rock Salt Co. and was renamed Diamond Crystal 1 month later.

At midyear, Diamond Crystal signed a letter of intent to form a joint venture with AMAX Inc.'s Sol-Aire Salt and Chemical Co. to produce solar salt on the Great Salt Lake in Utah. However, in July, a storm breached a dike surrounding AMAX's brine concentration ponds, which became flooded. By yearend, Diamond Crystal had agreed to purchase all the solar salt facilities of AMAX for $800,000 and future royalties. Diamond Crystal intended to spend an additional $12 million for evaporation pond renovation and construction, commencing in early 1987. Because of the time cycle for solar salt concentration, evaporation, and harvest, the first recoverable salt would be available for market in 1990-91.[4]

Crystal Mines Inc., a subsidiary of Wayne Disposal Co., had purchased International Salt Co. Inc.'s Michigan rock salt mine for $2.5 million in May 1985. Wayne Disposal, which already operated the State's only licensed commercial hazardous waste landfill facility, applied for a permit in 1986 to store 20 million cubic yards of solid hazardous waste in the abandoned salt mine, which is under Detroit and its suburbs. If the permit is obtained, the solid hazardous wastes would be labeled and separated for future recycling. Radioactive, gaseous, and ignitable wastes would not be stored underground in the mine.[5]

Table 2.—Salt production in the United States

(Thousand short tons)

Year	Vacuum pans and open pans	Solar	Rock	Brine	Total
1982	3,721	2,845	13,264	17,835	37,665
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	r2,549	r13,990	r19,065	r39,217
1986	3,637	2,679	13,333	17,633	37,282

rRevised.
[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
1985					
Bulk	666	r1,794	r13,397	r19,065	r34,922
Compressed pellets	818	r83	XX	XX	r901
Packaged	1,829	r590	524	XX	r2,943
Pressed blocks	299	r82	69	XX	r450
Total[1]	3,613	r2,549	r13,990	r19,065	r39,217
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

rRevised. 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 type and product form

(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
1985[r]										
Bulk	647	27,810	1,912	30,280	14,000	189,421	19,107	117,434	35,666	364,945
Compressed pellets	817	81,895	83	5,383	XX	XX	XX	XX	900	87,278
Packaged:										
Less-than-5-pound units	180	NA	--	NA	53	NA	XX	XX	233	NA
More-than-5-pound units	1,658	NA	588	NA	567	NA	XX	XX	2,813	NA
Total	1,838	196,308	588	25,188	620	32,197	XX	XX	3,046	253,693
Pressed blocks:										
For livestock	214	NA	57	NA	69	NA	XX	XX	340	NA
For water treatment	88	NA	26	NA	1	NA	XX	XX	115	NA
Total	302	22,772	83	5,341	70	5,580	XX	XX	455	33,693
Grand total	3,604	328,785	2,666	66,192	14,690	227,198	19,107	117,434	40,067	739,609
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

[r]Revised. NA Not available. XX Not applicable.
[1]As reported at salt production locations. Data does not include salt imported, purchased, or sold from inventory.

Table 5.—Salt sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1985[r] Quantity	1985[r] Value	1986 Quantity	1986 Value
Kansas[1]	1,790	71,970	1,656	68,887
Louisiana	12,271	137,273	11,608	103,611
Michigan	927	71,224	W	W
New York	7,044	142,318	5,071	122,601
Ohio	4,329	130,964	4,115	126,757
Texas	8,390	84,249	8,520	62,996
Utah	1,057	30,013	1,112	31,830
West Virginia	895	W	W	W
Other[2]	3,364	71,598	4,581	148,718
Total	40,067	739,609	36,663	665,400
Puerto Rico[e]	35	735	40	880

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Quantity and value of brine included with "Other."
[2]Includes Alabama, Arizona (1986), California, Kansas (brine only), Nevada, New Mexico, North Dakota, Oklahoma, and data indicated by symbol W.

Table 6.—Evaporated salt sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1985[r] Quantity	1985[r] Value	1986 Quantity	1986 Value
Kansas	876	61,986	856	60,221
Louisiana	205	18,612	193	18,747
Michigan	980	76,258	W	W
New York	723	63,821	739	62,884
Utah	997	28,859	1,068	30,901
Other[1]	2,489	145,441	3,289	213,109
Total	6,270	394,977	6,145	385,862
Puerto Rico[e]	35	735	40	880

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Includes Arizona (1986), California, New Mexico, North Dakota, Ohio, Oklahoma, and Texas.

CONSUMPTION AND USES

Reported consumption in 1986 decreased 6% from revised reported consumption in 1985. The revisions in 1985 data reported previously in Bureau of Mines publications significantly affected certain types of salt, by end use. As shown in table 7, imported solar salt for chemical use changed because two chemical companies, which had previously produced and imported salt, ceased domestic production activities, thereby changing their status from that of salt producer to salt purchaser and consumer. The miscellaneous use of brine was revised because of more accurate data disclosure.

In 1986, apparent consumption of all types of salt decreased 7%. Salt sales declined for highway deicing, 6%, and chloralkali manufacture, 7%. The chlorine and caustic soda industry, which traditionally has been the largest end-use market, required about 18.8 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 coproduct caustic soda. Production of chlorine gas and sodium hydroxide, as reported by the Bureau of the Census, was as follows, in thousand short tons:

	1985[r]	1986
Chlorine gas (100%)	10,402	10,426
Sodium hydroxide, liquid (100%)	10,811	11,055

[r]Revised.

The reported percent distribution of salt by major end use in 1986 was chemicals, 49%; ice control, 26%; distributers, 10%; food and agricultural, 7%; industrial, 5%; water treatment, 1%; and other, 2%. In table 7, specific sectors of distribution, such as agricultural and water-treatment condi-

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: Domestic	Vacuum pans and open pans: Imported	Solar: Domestic	Solar: Imported	Rock: Domestic	Rock: Imported	Salt in brine	Total[1]: Domestic	Total[1]: Imported	Total[1]: Grand
1985[r]											
Chemical:											
Chloralkali producers	2812	36	W	399	W	1,539	W	18,185	20,159	277	20,436
Other chemical	28 (excludes 2812, 2899)	313	W	124	W	243	W	50	730	38	768
Total		349	17	523	163	1,782	136	18,235	20,889	315	21,204
Food-processing industry:											
Meat packers	201	164	W	34	W	202	W	--	400	15	415
Dairy	202	95	W	3	W	4	(2)	--	102	2	105
Canning	2091, 203	126	W	32	W	83	W	1	242	21	263
Baking	205	115	W	3	W	7	W	--	125	1	126
Grain mill products	204 (excludes 2047)	55	--	(2)	W	25	W	--	80	1	81
Other food processing	206-208, 2047, 2099	139	W	23	W	41	W	--	203	14	217
Total[1]		694	6	94	34	362	15	1	1,152	55	1,208
General industrial:											
Textiles and dyeing	22	70	W	7	W	47	(2)	2	126	60	186
Metal processing	33, 34, 35, 37	27	W	11	W	335	1	W	373	8	382
Rubber	2822, 30 (excludes 3079)	4	--	(2)	W	4	W	28	36	(2)	36
Oil	13, 29	65	--	385	W	73	W	439	962	3	965
Pulp and paper	26	16	W	187	W	77	W	6	286	25	311
Tanning and/or leather	311	10	W	52	W	71	W	--	133	4	137
Other industrial	9621	74	W	79	W	57	5	W	210	34	244
Total[1]		265	33	723	90	664	13	475	2,126	136	2,261
Agricultural:											
Feed retailers and/or dealers-mixers		353	W	135	W	339	W	1	828	35	863
Feed manufacturers	2048	86	W	78	W	226	W	--	390	22	412
Direct-buying end users	02	19	--	18	W	19	W	--	56	(2)	56
Total[1]		458	7	231	43	583	7	1	1,274	57	1,331

Water treatment:											
Government (Federal, State, local)	2899	9	W	32	W	215	W	2	258	15	273
Commercial or other	2899	83	--	122	W	53	W	16	274	6	280
Total[1]		92	W	155	15	268	W	17	532	21	553
Ice control and/or stabilization:											
Government (Federal, State, local)	9621	5	W	88	W	8,951	1,520	1	9,045	1,706	10,751
Commercial or other	5159	12	W	17	W	329	66	--	358	71	429
Total[1]		17	W	105	190	9,280	1,586	1	9,403	1,777	11,180
Distributors:											
Agricultural distribution	5159	134	W	70	W	123	W	--	327	60	387
Grocery wholesalers and/or retailers	514, 54	600	W	110	W	157	W	--	867	34	901
Institutional wholesalers and end users.	58, 70	30	W	13	W	135	25	--	178	30	208
Water-conditioning distribution	7399	259	W	175	W	253	W	([2])	687	201	888
U.S. Government resale	9199	7	--	1	([2])	5	--	--	13	([2])	14
Other wholesalers and/or retailers	5251	612	W	45	W	676	11	--	1,333	138	1,471
Total		1,641	18	416	343	1,349	101	([2])	3,405	463	3,869
Other n.e.s.[3]		132	W	340	38	374	11	372	1,218	54	1,272
Grand total[1]		3,648	86	2,588	917	14,662	1,869	19,102	40,002	[4]2,878	42,880

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											
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.

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

[r]Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."

[1]Data may not add to totals shown because of independent rounding. Data may differ from totals shown in tables 1, 4, 5, 6, and 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 tables 12, 13, and 14.

Table 8.—Distribution of domestic and imported evaporated and rock salt[1] in the United States, by destination

(Thousand short tons)

Destination	1985[r]			1986		
	Evaporated			Evaporated		
	Vacuum pans and open pans	Solar	Rock	Vacuum pans and open pans	Solar	Rock
Alabama	47	(2)	511	48	(2)	330
Alaska	(2)	7	--	3	W	--
Arizona	6	16	6	6	58	3
Arkansas	29	(2)	97	31	1	56
California	145	1,027	1	150	842	1
Colorado	18	111	44	19	125	51
Connecticut	15	7	212	11	11	223
Delaware	2	W	10	2	32	7
District of Columbia	1	W	W	1	(2)	W
Florida	82	W	34	90	W	30
Georgia	58	4	85	67	W	81
Hawaii	W	W	(2)	W	W	--
Idaho	5	76	W	5	78	W
Illinois	362	54	1,199	358	79	1,134
Indiana	153	26	872	149	32	650
Iowa	164	48	291	151	43	250
Kansas	98	W	331	93	17	259
Kentucky	37	1	489	39	W	388
Louisiana	72	W	308	44	W	320
Maine	7	W	175	6	W	223
Maryland	50	W	104	46	W	163
Massachusetts	32	W	537	33	46	531
Michigan	228	25	1,225	W	W	1,527
Minnesota	142	107	343	145	127	369
Mississippi	23	--	123	23	(2)	W
Missouri	112	17	460	112	17	302
Montana	5	30	W	2	34	W
Nebraska	81	33	144	86	32	172
Nevada	W	W	W	W	W	W
New Hampshire	W	(2)	W	2	W	W
New Jersey	125	46	212	126	153	295
New Mexico	8	127	2	6	W	2
New York	243	W	2,415	248	W	W
North Carolina	138	W	46	152	85	W
North Dakota	46	15	2	37	10	5
Ohio	305	20	2,368	W	19	1,596
Oklahoma	47	W	89	38	W	67
Oregon	11	108	--	W	55	--
Pennsylvania	165	W	1,211	162	104	1,015
Rhode Island	5	1	77	6	4	W
South Carolina	38	W	13	38	W	12
South Dakota	40	25	38	39	26	39
Tennessee	61	(2)	778	67	(2)	625
Texas	162	89	204	153	82	197
Utah	W	196	W	4	169	W
Vermont	5	W	164	6	W	189
Virginia	66	W	79	75	120	106
Washington	W	W	--	W	406	(2)
West Virginia	15	W	208	16	W	172
Wisconsin	221	46	795	223	48	927
Wyoming	(2)	29	(2)	W	24	1
Other[3]	36	1,675	198	598	835	2,720
Total[4]	3,711	3,966	16,502	3,716	3,713	15,040

[r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Each salt type includes domestic and imported quantities.
[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. Data may differ from totals shown in tables 1, 4, 5, 6, and 7 because of imports, changes in inventory, and/or incomplete data reporting.

tioning, can be combined with the primary agricultural and water categories for a complete end-use analysis.

The largest end-use market for dry salt was highway deicing, which represented about 47% of domestic consumption of dry salt. The environmental effects and corrosive action on automobiles, roads, and bridges owing to salting are counterbalanced by the pressure to maintain open and safe public roads in winter. Eight cities, including Tulsa and Oklahoma City, OK, and Ithaca, NY, experimented with banning deicing salt altogether. After numerous accidents, citizen complaints, and legal claims for damage, the no-salt policies were rescinded.[6] Severe snow and ice storms in late 1985 and early 1986 throughout most of the Northern United States caused problems for several municipalities. In Lansing, MI, it was reported that during the first one-third of winter, two-thirds of the money allocated for snow removal had already been spent.[7]

In an experiment to reduce salt usage on some of Michigan's icy secondary roads, flyash from Detroit Edison's Monroe powerplant was used as a salt substitute to provide road traction rather than deicing. The fine grit is not corrosive to automobiles as is salt and can remain on the roads throughout the winter.[8]

STOCKS AND PURCHASES

Total yearend stocks reported by producers increased from 2.5 million tons in 1985 to 2.7 million tons in 1986. Most of these stocks were rock salt and solar salt. Many States, municipalities, distributers, and road deicing contractors stockpiled additional quantities of salt in anticipation of adverse weather conditions.

Intraindustry purchases of salt amounted to 2.2 million tons, of which 47% was salt brine; rock salt, 41%; solar salt, 12%; and vacuum pan and open pan salt, less than 0.5%.

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 salt prices were quoted in Chemical Marketing Reporter.[9]

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
1985[r]				
Bulk	42.95	15.84	13.53	6.14
Compressed pellets	100.82	64.64	XX	XX
Packaged	106.78	42.81	51.92	XX
Average[2]	92.66	23.10	15.15	6.14
Pressed blocks	96.37	64.00	79.54	XX
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

[r]Revised. 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

The United States imported nearly six times the quantity of salt that it exported. Exports to Canada represented about 94% of the total U.S. export market; the balance was distributed to 45 other countries.

Approximately 99% of total salt imports was bulk rock salt and solar salt. The Bahamas, Canada, Chile, and Mexico supplied 88% of total imports. Imports of salt in bags, sacks, barrels, and brine, primarily from Canada, Chile, France, and the Federal Republic of Germany, represented the remainder.

Table 10.—Salt shipped to the Commonwealth of Puerto Rico and the Virgin Islands

Area	1985		1986	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Puerto Rico	22,990	$5,196	24,400	$6,725
Virgin Islands	--	--	--	--

Source: Annual FT800 U.S. Trade with Puerto Rico and U.S. Possessions, Bureau of the Census.

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

(Thousand short tons and thousand dollars)

Country	1985		1986	
	Quantity	Value	Quantity	Value
Argentina	(1)	8	(1)	20
Australia	(1)	3	(1)	14
Bahamas	1	86	(1)	45
Brazil	--	--	42	704
Canada	883	12,313	1,091	13,265
Costa Rica	(1)	4	(1)	99
Denmark	1	35	2	17
Dominican Republic	(1)	8	(1)	31
Ecuador	1	47	1	234
Honduras	(1)	21	(1)	10
Iraq	1	190	--	--
Kenya	--	--	(1)	171
Mexico	5	302	10	334
Netherlands Antilles	(1)	105	1	82
Saudi Arabia	9	1,930	6	1,170
South Africa, Republic of	(1)	16	(1)	4
Trinidad and Tobago	(1)	17	--	--
United Arab Emirates	(1)	54	(1)	10
United Kingdom	1	216	6	195
Venezuela	(1)	2	(1)	22
Other	2	631	6	501
Total	904	15,988	1,165	16,928

[1]Less than 1/2 unit.

Source: Bureau of the Census as adjusted by the Bureau of Mines.

Table 12.—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
1983	30	1,826	[1]5,967	[1]58,368
1984	71	2,386	[2]7,474	[2]71,714
1985	66	3,794	[3]6,141	[3]61,799
1986	70	3,170	[4]6,595	[4]76,539

[1]Includes salt brine from Canada through Buffalo, NY, customs district, 400 pounds ($610); from Mexico through Laredo, TX, customs district, 18 short tons ($1,126); from Denmark through Cleveland, OH, customs district, 100 pounds ($269); from the United Kingdom through Baltimore, MD, customs district, 100 pounds ($1,209); from Ireland through New York, NY, customs district, 15 short tons ($300); and from Japan through Seattle, WA, customs district, 1,300 pounds ($392).

[2]Includes salt brine from Iceland, the United Kingdom, and Hong Kong 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).

[3]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.

[4]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).

Source: Bureau of the Census as adjusted by the Bureau of Mines.

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

(Thousand short tons and thousand dollars)

Country	1985		1986	
	Quantity	Value	Quantity	Value
Bahamas	952	10,301	915	9,798
Brazil	70	642	--	--
Canada[1]	2,670	21,916	2,944	26,932
Chile	280	2,828	312	3,153
France[2]	199	1,967	101	1,974
Germany, Federal Republic of[3]	2	135	6	315
Italy[4]	55	430	135	2,289
Mexico[5]	1,230	18,657	1,711	26,339
Netherlands	90	2,149	213	4,047
Netherlands Antilles	191	2,440	61	1,100
Spain[6]	402	3,188	124	1,351
Other	67	941	143	2,411
Total[7]	6,207	65,593	6,665	79,709

[1]Includes salt in bags, sacks, and barrels through 11 customs districts, 40,691 short tons ($2,769,497) in 1985; and 7 customs districts, 34,241 short tons ($2,187,191) in 1986.

[2]Includes salt in bags, sacks, and barrels through 4 customs districts, 128 short tons ($38,356) in 1985; and 5 customs districts, 3,041 short tons ($69,401) in 1986.

[3]Includes salt in bags, sacks, and barrels through 4 customs districts, 2,084 short tons ($120,114) in 1985; and 8 customs districts, 6,152 short tons ($287,031) in 1986.

[4]Includes salt in bags, sacks, and barrels through 2 customs districts, 1 short ton ($5,160) in 1985; and 3 customs districts, 10 short tons ($156,204) in 1986.

[5]Includes salt in bags, sacks, and barrels through 3 customs districts, 14,762 short tons ($148,417) in 1985; and 2 customs districts, 67 short tons ($12,295) in 1986.

[6]Includes salt in bags, sacks, and barrels through 1 customs district, 22 short tons, ($145,725) in 1985; and 1 customs district, 1 short ton ($1,038) in 1986.

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

Source: Bureau of the Census as adjusted by the Bureau of Mines.

Table 14.—U.S. imports for consumption of salt, by customs district

(Thousand short tons and thousand dollars)

Customs district	1985		1986	
	Quantity	Value	Quantity	Value
Anchorage, AK	17	272	([1])	90
Baltimore, MD	413	3,686	311	3,241
Boston, MA	73	1,325	43	989
Buffalo, NY	1	67	1	61
Chicago, IL	590	4,070	355	4,137
Cleveland, OH	92	721	23	240
Detroit, MI	991	9,766	1,256	11,543
Duluth, MN	114	887	59	554
Los Angeles, CA	127	1,082	132	2,306
Milwaukee, WI	706	3,343	859	5,546
New Orleans, LA	148	1,593	194	2,424
New York, NY	404	6,234	345	6,696
Norfolk, VA	114	951	73	877
Ogdensburg, NY	5	92	11	130
Philadelphia, PA	216	2,505	189	2,552
Portland, ME	461	3,787	510	4,265
Portland, OR	505	7,049	595	8,884
Providence, RI	13	629	259	2,754
St. Albans, VT	6	142	6	174
San Juan, PR	10	269	21	381
Savannah, GA	400	3,398	361	3,797
Seattle, WA	503	9,580	639	11,680
Tampa, FL	89	760	129	1,401
Wilmington, NC	207	3,207	287	4,838
Other	2	176	7	149
Total	6,207	[2]65,593	6,665	79,709

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

Pakistan.—The Pakistan Mineral Development Corp. set up an iodized-salt plant in Khewra. The plant had a production capacity of 57,600 tons per year.[10]

Thailand.—The Government, in a coventure with Asahi Glass Co. of Japan, granted approval of a rock salt project in northeastern Thailand. The project was planned to augment the Thai-Asahi Glass solar evaporation facility in that region.[11]

Table 15.—Salt: World production, by country[1]

(Thousand short tons)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Afghanistan[e]	11	11	11	11	11
Albania[e]	75	80	80	80	82
Algeria	154	[e]165	193	185	[3]209
Angola[e]	65	60	55	11	11
Argentina:					
Rock salt	1	1	1	[e]1	1
Other salt	655	746	1,033	[e]880	940
Australia (marine salt and brine salt)	5,303	5,699	6,278	[r] [e]6,800	6,800
Austria:					
Rock salt	1	1	1	1	1
Evaporated salt	478	396	462	483	480
Salt in brine	236	155	263	254	230
Bahamas	899	950	[e]960	[e]940	940
Bangladesh[4]	634	268	741	539	550
Benin[e]	([3] [5])	([5])	([5])	([5])	([5])
Brazil:					
Rock salt	922	[6]1,023	1,046	1,097	1,100
Marine salt	3,183	[6]3,592	3,944	1,911	2,800
Bulgaria	97	95	98	98	100
Burma[7]	297	317	309	353	[3]354
Cambodia[e]	[3]42	45	45	45	45
Canada	8,752	9,482	11,282	11,117	[3]12,222
Chile	743	788	690	831	1,100

See footnotes at end of table.

Table 15.—Salt: World production, by country[1] —Continued

(Thousand short tons)

Country[2]	1982	1983	1984	1985[p]	1986[e]
China	18,060	[e]17,780	[e]17,950	15,924	19,070
Colombia:					
Rock salt	331	293	[e]300	258	280
Marine salt	223	321	517	369	440
Costa Rica (marine salt)	121	[e]120	[e]120	33	33
Cuba	218	198	204	244	250
Cyprus	11	--	--	8	[3]7
Czechoslovakia	360	265	268	[e]270	270
Denmark	[r]493	[r]449	577	586	550
Dominican Republic[e]	70	70	70	[3]52	60
Egypt	913	1,012	953	1,170	1,400
El Salvador[e]	2	2	[r]3	3	3
Ethiopia:[e, 4]					
Rock salt	17	17	17	17	17
Marine salt	121	121	130	130	130
France:					
Rock salt	421	311	249	407	[3]425
Brine salt	1,181	1,184	1,240	1,272	[3]1,240
Marine salt	1,696	[r]1,493	1,522	1,569	[3]1,775
Salt in solution	4,091	4,673	4,869	4,593	[3]4,368
German Democratic Republic:					
Rock salt	[r]3,373	[r]3,384	3,390	3,395	[3]3,390
Marine salt	61	62	64	64	63
Germany, Federal Republic of: Marketable:					
Rock salt	7,754	6,906	7,837	10,642	7,900
Marine salt and other salt	[r]5,197	[r]5,074	5,624	3,765	4,400
Ghana[e]	55	55	55	55	55
Greece	128	176	146	165	165
Guatemala	[e]15	17	[e]18	19	20
Honduras[e]	35	35	35	35	35
Iceland	([5])	1	1	1	2
India:					
Rock salt	5	5	[e]6	[r, e]4	4
Marine salt	7,758	7,725	8,514	10,885	11,000
Indonesia	1,387	681	408	[e]660	660
Iran[e, 8]	770	830	830	830	830
Iraq[e]	90	90	90	80	80
Israel[e]	[3]163	160	160	170	170
Italy:					
Rock salt and brine salt	3,974	3,807	3,588	3,501	[3]3,784
Marine salt[9]	[r]946	[r]811	797	628	660
Japan[10]	1,065	1,015	1,053	[e]1,300	[3]1,510
Jordan	[e]55	37	24	35	35
Kenya:					
Rock salt	[e]50	[e]70	80	73	77
Other salt	27	[e]26	31	28	28
Korea, North[e]	630	630	630	630	630
Korea, Republic of	952	530	571	709	720
Kuwait	21	[e]22	23	23	23
Laos[e]	[3]10	11	[r]9	11	33
Lebanon[e]	11	6	6	6	6
Leeward and Windward Islands[e]	55	55	55	55	55
Libya[e]	11	13	13	[r]13	13
Madagascar[e]	33	33	33	33	33
Mali[e]	5	5	5	5	5
Malta	([5])	([5])	([5])	([5])	([5])
Mauritania[e]	[3]8	6	6	6	6
Mauritius[e]	[3]7	7	7	7	7
Mexico	6,130	6,287	6,798	7,129	7,200
Mongolia[e]	17	18	18	18	18
Morocco	62	77	69	102	[3]106
Mozambique[e]	30	30	30	30	30
Namibia (marine salt)	203	151	97	168	150
Netherlands	3,517	3,444	4,050	4,579	[3]4,148
Netherlands Antilles[e]	300	[3]312	390	390	390
New Zealand	77	89	63	[e]70	70
Nicaragua[e]	20	20	17	17	17
Niger[e]	[3]3	3	3	3	3
Pakistan:[4]					
Rock salt	594	629	659	643	630
Other salt	246	[e]210	[e]200	297	[3]381
Panama (crude)	[11]27	[11]94	20	18	[3]11
Peru[e]	[3]535	540	550	550	550
Philippines	402	421	442	464	440

See footnotes at end of table.

Table 15.—Salt: World production, by country[1] —Continued

(Thousand short tons)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Poland:					
Rock salt	1,475	[r]1,246	1,306	1,323	1,300
Other salt	2,776	[e]2,750	3,887	4,040	4,100
Portugal:					
Rock salt	448	467	502	510	[3]506
Marine salt[e]	110	120	120	130	120
Romania	5,243	5,066	5,373	5,532	5,500
Senegal	176	190	182	[e]180	180
Sierra Leone[e]	220	220	220	220	220
Somalia[e]	33	33	33	33	33
South Africa, Republic of	646	820	679	796	[3]829
Spain:					
Rock salt	2,439	2,214	2,376	2,381	2,300
Marine salt and other evaporated salt	1,187	1,267	1,359	1,190	1,100
Sri Lanka	194	142	118	85	83
Sudan	31	[e]80	[e]80	42	44
Switzerland	399	349	410	412	400
Syria	112	96	96	[e]100	100
Taiwan	289	87	241	206	[3]244
Tanzania	[e]41	31	24	[e]20	28
Thailand:					
Rock salt	12	6	11	14	13
Other salt[e]	180	180	180	180	180
Togo[e]	([5])	--	--	--	--
Tunisia	464	413	364	446	440
Turkey	1,448	1,390	1,422	1,175	1,300
Uganda[e]	6	6	6	6	6
U.S.S.R	17,416	17,857	18,200	17,747	17,700
United Kingdom:					
Rock salt	2,435	1,451	1,730	2,238	2,200
Brine salt[12]	1,713	1,537	1,569	1,711	1,700
Other salt[12]	4,270	3,969	4,557	3,928	3,900
United States including Puerto Rico (sold or used by producers):					
Rock salt	13,503	9,941	13,355	14,690	12,598
Other salt:					
United States	24,391	24,632	25,871	25,377	24,065
Puerto Rico[e]	16	32	30	35	40
Venezuela	375	342	[e]360	[e]390	400
Vietnam[e]	720	980	880	880	880
Yemen (Aden)[e]	80	80	80	80	80
Yemen (Sanaa)[e]	60	155	160	[3]165	[3]331
Yugoslavia:					
Rock salt	219	212			
Marine salt	42	32	419	450	465
Salt from brine	211	215			
Total	[r]181,071	[r]175,401	190,196	191,565	192,222

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through July 7, 1987.
[2]Salt is produced in many other countries, but quantities are relatively insignificant and reliable production data are not available.
[3]Reported figure.
[4]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: 1982—81,462; 1983—221,502; 1984—89,470; 1985—49,061; and 1986—49,600 (estimated).
[8]Year beginning Mar. 21 of that stated.
[9]Does not include production from Sardinia and Sicily, estimated at 220,000 short tons annually.
[10]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

For the benefit of people who must avoid or restrict salt in their diet, Provesta Co. has developed a fermentation process to eliminate the use of salt to isolate flavor proteins in food flavoring manufacture. Traditional flavorings are made with hydrolyzed vegetable proteins and autolyzed yeast extracts, both of which contain salt. Wide adoption of this new process by food processors holds promise for many people to enjoy eating certain foods without the risk of ingesting sodium-based ingredients.[12]

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[1]Physical scientist, Division of Industrial Minerals.

[2]Environmental Science and Technology. V. 20, No. 7, 1986, p. 645.

[3]Chemical Marketing Reporter. Diamond Crystal Shuts Salt Processing Facility. V. 229, No. 6, Feb. 10, 1986, p. 4.

[4]Industrial Minerals (London). Sol-Aire to Diamond Crystal. No. 232, 1987, p. 13.

[5]Flint Journal. Storing Wastes in Old Salt Mine Would Be a First for U.S. Apr. 20, 1986.

[6]Salt Institute Highway Digest. Ithaca Reverses No-Salt Policy. V. 21, No. 1. Spring-Summer 1986, pp. 1, 4.

[7]Mining Journal (London). DOT Blames Costs on Early Winter. Jan. 24, 1986, p. 6B.

[8]Evening News (Monroe, MI). Power Plant "Bottom Ash" Being Used on Icy Roads Here. Jan. 16, 1986.

[9]Chemical Marketing Reporter. Prices of Chemicals and Related Materials. V. 230, No. 26, Dec. 29, 1986, p. 31.

[10]Industrial Minerals (London). Mineral Notes. No. 224, 1986, p. 72.

[11]Mining Annual Review. Salt. 1986, p. 117.

[12]Chemical Week. Low-Salt Flavors Synthesis. V. 139, No. 7, Aug. 13, 1986, p. 31.

Sand and Gravel

By Valentin V. Tepordei[1]

A total of 883 million short tons of construction sand and gravel valued at $2.7 billion, f.o.b. plant, was produced in the United States in 1986. This tonnage, the highest production reported since 1979, was 8% below the record-high production of 1978, but 14% higher than that of 1984, when the last full annual survey was conducted.

Production of industrial sand and gravel in 1986 totaled 27.4 million tons valued at $359 million, f.o.b. plant, a decrease of 7% from that of 1985. This tonnage is the third lowest production reported since 1979, equal to that of 1982, and 18% below the record-high production of 1979.

Exports of construction sand and gravel in 1986 decreased 23% to 1.2 million tons valued at $7.8 million, while imports for consumption decreased 17% to 205,000 tons valued at $1.4 million. Domestic apparent consumption of construction sand and gravel in 1986 was 882 million tons.

Exports of industrial sand decreased slightly to 849,000 tons valued at $20.4 million, while imports for consumption increased 9% to 88,000 tons valued at $1.0 million. Apparent consumption of industrial sand and gravel was 26.7 million tons.

Table 1.—Salient U.S. sand and gravel statistics[1]

(Thousand short tons and thousand dollars)

	1982	1983	1984	1985	1986
Sold or used:					
Construction sand and gravel:					
Quantity	594,000	[e]655,100	773,900	[e]800,100	883,000
Value	$1,674,000	[e]$1,935,000	$2,244,000	[e]$2,438,000	$2,747,200
Industrial:					
Sand:					
Quantity	26,350	26,080	28,680	29,070	26,940
Value	$316,900	$329,500	$370,370	$370,730	$354,460
Gravel:					
Quantity	1,024	537	705	357	484
Value	$6,846	$5,667	$6,844	$3,340	$4,853
Total industrial:[2]					
Quantity	27,400	26,620	29,380	29,430	27,420
Value	$323,800	$335,200	$377,200	$374,070	$359,300
Exports:					
Quantity	1,946	2,350	3,038	2,379	2,015
Value	$34,397	$32,487	$37,981	$31,515	$28,201
Imports for consumption:					
Quantity	275	181	177	327	293
Value	$4,002	$2,666	$2,529	$3,085	$2,426

[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. To reduce the Federal Government's costs as well as respondents' reporting burden, the Bureau of Mines implemented new canvassing procedures for its construction sand and gravel surveys. Beginning with 1981, 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 that is used to generate only annual preliminary estimates at the State level. Industrial sand and gravel producers are surveyed every year. Of the 6,672 construction sand and gravel operations surveyed, 5,111, or 77%, responded. Their combined production represented 82% of the U.S. total published in table 1. The nonrespondents' production was estimated using mostly employment data. Of the total number of operations surveyed, 5,797, or 87%, were active and 875 were idle. Of the 171 industrial sand and gravel operations surveyed, 139, or 81%, reported to the Bureau of Mines. Their combined production represented 87% of the U.S. total published in table 1. The nonrespondents' production was estimated using mostly employment data. Of the 171 operations surveyed, 162, or 95%, were active and 9 were idle.

CONSTRUCTION SAND AND GRAVEL

DOMESTIC PRODUCTION

U.S. production of construction sand and gravel increased 14% in 1986 compared with that of 1984, when the last full annual survey was conducted. Of the four major geographic regions, the West again led the Nation in production with 315 million tons, or 36% of the U.S. total, followed by the North Central with 240 million tons, or 27% of the total, the South with 217 million tons or 25%, and the Northeast with 111 million tons, or 13%. Production increased 24% in the Northeast, 16% in the North Central, 13% in the West, and 9% in the South.

Of the nine geographic regions, the Pacific again led the Nation with 197 million tons, or 22% of the U.S. total. Next was the East North Central with 152 million tons, or 17% of the total, followed by the Mountain with 118 million tons, or 13% of the total.

Based on the 1980 census data on population, 1986 U.S. per capita construction sand and gravel production was 3.9 tons. At the four major geographic regions level, per capita production was 7.3 tons in the West, followed by the North Central with 4.1 tons, the South with 2.9 tons, and the Northeast with 2.3 tons.

Construction sand and gravel was produced in every State, and the 10 leading States were, in descending order of tonnage, California, Texas, Michigan, Arizona, Ohio, New York, Florida, Illinois, Alaska, and Washington. Their combined production represented 51% of the national total.

Production in 1986, compared with that of 1984, increased in 41 States and decreased in 9 States. Production increased in 8 of the top 10 producing States, by 34% in Florida, 33% in Arizona, 25% in California, 20% in New York, 18% in Michigan, 16% in Ohio, 13% in Washington, and 7% in Illinois. Production decreased 10% in Alaska and 5% in Texas.

A total of 4,323 companies produced construction sand and gravel at 5,797 operations. Operations larger than 200,000 tons per year produced 71% of the total U.S. tonnage while representing only 20% of the total number of operations. The trend toward larger operations with a higher degree of mechanization and automation continued.

The top 10 producers of construction sand and gravel were, in descending order of tonnage, Koppers Co. Inc., CalMat Co., Lone Star Industries Inc., Florida Rock Industries Inc., ARC America Corp., Owl Rock Products Co., Tanner Co., Martin Marietta Corp., Hallett Construction Co., and A. Teichert & Sons Inc. Combined production of the 171 operations owned by the top 10 producers was 12.3% of the national total.

In response to shortages of construction aggregates occurring in some areas, mostly major metropolitan areas, some offshore sand and gravel has been dredged and used on land as fill, construction aggregates, and for beach replenishment. Information on occasional mining of offshore sand and gravel is available from some State agencies.

Martin Marietta of Bethesda, MD, acquired Weaver Construction Co. of Alden, IA, the largest producer of sand and gravel and crushed stone in Iowa.

Redland Aggregates Ltd. of Reigate, United Kingdom, a subsidiary of Redland PLC, acquired Genstar Stone Products Co. of Hunt Valley, MD, from The Flintkote Co. of San Francisco, CA, a subsidiary of Imasco Ltd. of Montreal, Canada. Redland and Koppers of Pittsburgh, PA, announced the formation of a joint venture for the purpose of acquiring and operating aggregate and related plants in the States of Colorado, Kansas, New Mexico, and Wyoming. The newly formed company, Western Mobile Inc., of Denver, CO, is owned equally by Koppers and Redland. Redland is a major aggregate producer in the United Kingdom, Australia, and Western Europe, while Koppers is the largest sand and gravel and the third largest crushed stone producer in the United States.

Lone Star of Greenwich, CT, sold 60% of its southeastern operations to Tarmac PLC of Wolverhampton, United Kingdom. The transaction included Lone Star's sand and gravel, crushed stone, cement, concrete, and concrete products operations in North Carolina, South Carolina, and Virginia.

TXTX Corp. of Port Arthur, TX, started shipping crushed granite produced at the Glensanda quarry in Scotland, United Kingdom, by Foster Yeoman Ltd. of Somerset, United Kingdom. TXTX is the exclusive importer and distributor of the Glensanda aggregates for Alabama, Louisiana, Mississippi, and Texas. The aggregates were produced to meet U.S. and State specifications.

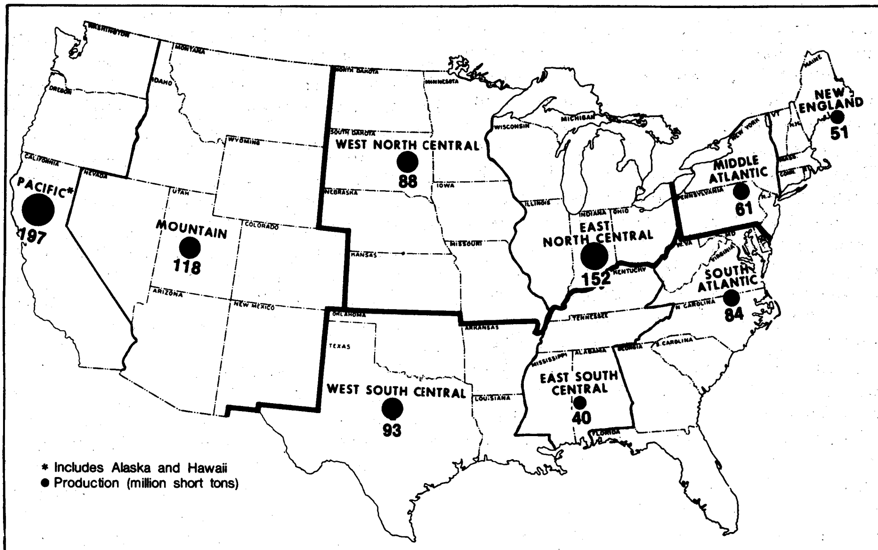

Figure 1.—Production of construction sand and gravel in the United States in 1986, by geographic region.

CONSUMPTION AND USES

Sand and gravel production reported by producers to the Bureau of Mines is actually material that is "sold or used" by the companies and is defined as such. Stockpiled production is not reported until it is sold or consumed. Therefore, the sold or used tonnage represents the amount produced for domestic consumption and export.

Of the 883 million tons produced, 25% was used as concrete aggregate including concrete sand for airports, buildings, dams, and highways; 15% for road base and coverings; 10% as asphaltic concrete aggregates and other bituminous mixtures; 7% as construction fill; 2% for concrete products such as blocks, bricks, pipes, decorative, etc.; 1% in plaster and gunite sands; and the remainder for railroad ballast, snow and ice control, road stabilization, roofing granules, and other miscellaneous and unspecified uses. Because some companies did not report a breakdown by end use, their total production as well as the estimated production for nonrespondents were included in "Other unspecified uses," which represents about 38% of the U.S. total.

Most of the sand and gravel for concrete aggregates and concrete products combined was used in the South, 38%, and the West, 30%, regions with high levels of construction activities. Most of the sand and gravel for road base and coverings and for asphaltic concrete aggregates was used in the West, 47% and 49%, respectively, and the North Central, 32% and 26%.

TRANSPORTATION

Of the construction sand and gravel produced, 52% was transported from the plant to the consumer by truck, 2% by waterway, and 1% by rail. The percentage of sand and gravel shown as transported by truck is significantly lower than that of 1984, mostly because a significant number of companies did not indicate how their production was shipped. Because most producers either did not keep records or did not report shipping distances or cost per ton per mile, no transportation cost data were available.

PRICES

Prices in this chapter are f.o.b. plant, usually the first point of sale or captive use. This value does not include transportation from the plant or yard to the consumer. It does, however, include all costs of mining, processing, and in-plant transportation.

Compared with that of 1984, the 1986 average unit prices increased 7% to $3.11 per ton, with the largest increases in railroad ballast and roofing granules, 20% each; asphaltic concrete aggregates and other bituminous mixtures and snow and ice control, 16% each; concrete aggregates, 8%; and road base and coverings, 7%. Average unit prices for concrete products and construction fill decreased slightly.

FOREIGN TRADE

Exports.—Exports of construction sand decreased 32% to 674,000 tons. Canada was the major destination, receiving 96% of the total, while Mexico received 2%. Exports of construction gravel decreased 5% to 492,000 tons, 80% of which went to Canada, and 10% to Mexico.

Imports.—Imports of construction sand and gravel decreased 17% to 205,000 tons, 77% of which came from Canada, and 17% from Antigua.

TECHNOLOGY

A comprehensive study of sand and gravel deposits near seven major metropolitan areas within the U.S. Exclusive Economic Zone (EEZ) was completed by the Bureau of Mines, with the purpose of selecting offshore deposits for consideration as near-term lease offerings. The seven areas investigated included sites offshore Boston, MA; Honolulu, HI; Houston, TX; Los Angeles, CA; New York, NY; San Francisco, CA; and San Juan, PR. Based upon preliminary market and resource analysis, three of the sites near the cities of Boston, New York, and Los Angeles were found to have favorable economic conditions for offshore mining. The three favorable sites were subjected to engineering, cost, and economic analysis. Financial analysis of the various scenarios for the selected areas indicated that significant potential exists for the near-term development of sand and gravel deposits offshore Boston and New York, but the potential for supplying offshore aggregates to the Los Angeles area is less attractive economically.

The study recommended that the U.S. Department of the Interior's Minerals Management Service, which is responsible for managing hard minerals development within the EEZ, consider the potential for near-term leasings in the Boston and New York offshore areas. More detailed studies were recommended to better characterize the local aggregate markets, the effects of offshore production on them, and to determine the suitability of offshore resources for commercial applications.[2]

Sulfur concrete, a strong, corrosion-resistant material developed by the Bureau of Mines, was named one of the 1986 100 "most significant" technical developments by the publishers of Research and Development magazine that annually presents awards to developers of innovative products. Sulfur concrete is a construction material composed of sulfur cement and sand and gravel. It is stronger and more resistant to corrosion than portland cement concrete, has a longer life, and requires less maintenance than conventional concretes. Sulfur concrete is produced by mixing plasticized sulfur cement with heated aggregate. The mixture is poured at 275° F to 300° F, similar to that of asphalt paving materials, and sets rapidly as it cools. Setting time for sulfur concrete is under 1 hour, and approximately 80% of the material's ultimate strength is achieved within 4 hours. Sulfur concrete is extremely resistant to chemical corrosion by all mineral acids and salts and is impervious to moisture. The cost of sulfur concrete is about $70 per cubic yard, or about 15% more than portland cement concrete, but the higher cost is easily offset by the material's longer life and reduced maintenance. The Bureau's sulfur-asphalt pavement technology is being evaluated on test highways in 30 States, and its sulfur concrete technology was used to construct the floor for the world's largest and newest copper plant built in Morenci, AZ. The Bureau is a world leader in research and development of sulfur uses in construction and holds two patents on sulfur concrete (U.S. Pat. Nos. 4,311,826 and 4,348,313).[3]

The 70th Annual Convention of the National Sand and Gravel Association was held on February 2-6, 1986, in Las Vegas, NV, in conjunction with the biennial International Concrete and Aggregates Show. Major topics covered at the convention were retrofit automation in the aggregate industry, an integrated approach to plant improvement through automation and its impact on productivity, and the Federal Highway Program and its impact on the future of the sand and gravel industry. Over 40 educational seminars covering a range of specialized topics involving production, sales, marketing, and management practices also were held in conjunction with the convention. A sign of improved conditions in the aggregates industries was the significant number of new products displayed at the International Concrete and Aggregates Show including concrete pavement recycling, crushing, and screening equipment.

As quarry planning becomes more complex, substantial savings in time and costs can be achieved by applying microcomputer-aided deposit evaluation. Precise mathematical procedures rather than manual estimates can be performed, various options compared, and even three-dimensional models of the deposits can be generated before a final decision is made.[4]

Table 2.—Construction sand and gravel sold or used in the United States, by geographic region

Geographic region	1985				1986			
	Quantity[e] (thousand short tons)	Percent of total	Value[e] (thousands)	Percent of total	Quantity (thousand short tons)	Percent of total	Value (thousands)	Percent of total
Northeast:								
New England	38,300	5	$117,900	5	50,546	5	$154,857	6
Middle Atlantic	55,600	7	199,200	8	60,544	7	226,374	8
North Central:								
East North Central	132,200	17	370,800	16	151,742	17	421,712	15
West North Central	82,600	10	196,400	8	88,444	10	205,825	8
South:								
South Atlantic	67,900	8	203,400	8	83,992	10	276,964	10
East South Central	39,200	5	115,000	5	40,415	5	115,193	4
West South Central	93,900	12	302,700	12	92,791	11	307,573	11
West:								
Mountain	112,900	14	338,400	14	117,972	13	356,615	13
Pacific	177,500	22	594,200	24	196,556	22	682,060	25
Total[1]	800,100	100	2,438,000	100	883,000	100	2,747,200	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	1985[e] Quantity	1985[e] Value	1986 Quantity	1986 Value
Alabama	11,000	32,000	10,781	30,807
Alaska	29,000	63,000	27,762	61,954
Arizona	37,000	118,000	40,468	140,004
Arkansas	8,500	24,400	8,571	26,999
California	112,800	430,000	128,407	498,456
Colorado	27,500	88,000	23,233	70,095
Connecticut	6,000	21,000	7,254	25,984
Delaware	1,300	4,000	1,547	4,156
Florida	22,500	49,500	28,233	67,898
Georgia	5,000	13,400	8,126	23,222
Hawaii	500	2,100	605	2,666
Idaho	4,000	11,400	5,708	14,830
Illinois	26,600	77,000	27,867	82,523
Indiana	18,600	55,800	19,642	61,232
Iowa	12,000	30,500	14,511	40,418
Kansas	13,200	31,800	15,609	33,721
Kentucky	7,600	19,000	7,194	16,986
Louisiana	15,000	48,000	14,292	46,134
Maine	7,200	18,000	8,572	22,843
Maryland	17,000	58,000	18,173	86,925
Massachusetts	14,900	47,500	19,200	60,464
Michigan	38,000	93,000	42,514	91,886
Minnesota	25,000	55,500	24,055	53,116
Mississippi	13,400	42,000	15,080	42,809
Missouri	7,500	20,000	9,746	24,065
Montana	9,000	26,000	8,066	19,391
Nebraska	11,600	28,800	9,675	23,912
Nevada	9,500	24,800	12,197	35,692
New Hampshire	6,300	19,800	8,418	26,089
New Jersey	10,600	36,700	13,999	53,746
New Mexico	8,400	22,800	8,471	25,862
New York	28,000	88,500	31,172	103,748
North Carolina	6,100	19,500	7,543	23,127
North Dakota	6,900	13,800	5,135	10,741
Ohio	33,000	109,000	36,806	126,747
Oklahoma	12,600	32,300	10,366	24,585
Oregon	12,500	36,800	13,441	42,597
Pennsylvania	17,000	74,000	15,373	68,880
Rhode Island	1,200	4,600	2,269	8,252
South Carolina	4,900	14,000	7,200	19,783
South Dakota	6,400	16,000	9,713	19,853
Tennessee	7,200	22,000	7,360	24,592
Texas	57,800	198,000	59,562	209,855
Utah	14,000	36,400	16,452	39,763
Vermont	2,700	7,000	4,834	11,226
Virginia	10,200	42,000	11,670	46,488
Washington	22,700	62,300	26,342	76,387
West Virginia	900	3,000	1,501	5,365
Wisconsin	16,000	36,000	24,913	59,325
Wyoming	3,500	11,000	3,377	10,977
Total[1]	800,100	2,438,000	883,000	2,747,200

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

Table 4.—Construction sand and gravel production in the United States in 1986, by size of operation

Size range	Number of operations	Percent of total	Quantity (thousand short tons)	Percent of total
Less than 25,000	1,817	31.4	18,778	2.1
25,000 to 49,999	919	15.9	33,444	3.8
50,000 to 99,999	1,027	17.7	73,478	8.3
100,000 to 199,999	891	15.4	126,500	14.3
200,000 to 299,999	383	6.6	92,203	10.5
300,000 to 399,999	243	4.2	82,891	9.4
400,000 to 499,999	124	2.1	55,071	6.2
500,000 to 599,999	100	1.7	53,873	6.1
600,000 to 699,999	58	1.0	37,321	4.2
700,000 to 799,999	53	.9	39,599	4.5
800,000 to 899,999	39	.7	32,871	3.7
900,000 to 999,999	26	.4	24,437	2.8
1,000,000 to 1,499,999	75	1.3	88,674	10.1
1,500,000 to 1,999,999	23	.4	38,268	4.3
2,000,000 and over	19	.3	85,600	9.7
Total	5,797	100.0	[1]883,000	100.0

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

Table 5.—Number of construction sand and gravel operations[1] and processing plants in the United States in 1986, 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	129	262	14	65	3	473
Middle Atlantic	255	209	28	102	23	617
North Central:						
East North Central	295	480	67	133	65	1,040
West North Central	141	639	41	110	191	1,122
South:						
South Atlantic	120	67	8	120	98	413
East South Central	81	82	7	24	53	247
West South Central	167	106	13	163	72	521
West:						
Mountain	228	428	47	86	17	806
Pacific	256	167	29	83	23	558
Total	1,672	2,440	254	886	545	5,797

[1]An undetermined number of operations leased from the Bureau of Land Management in Alaska are counted as one operation.

Table 6.—Construction sand and gravel sold or used in the United States in 1986, by major use

Use	Quantity (thousand short tons)	Value (thousands)	Value per ton
Concrete aggregates (including concrete sand)	219,009	$814,860	$3.72
Plaster and gunite sands	10,049	39,972	3.98
Concrete products (blocks, bricks, pipe, decorative, etc.)	16,274	55,648	3.42
Asphaltic concrete aggregates and other bituminous mixtures	87,410	322,666	3.69
Road base and coverings	128,112	354,740	2.77
Road stabilization (cement)	1,509	3,928	2.60
Road stabilization (lime)	901	3,342	3.71
Fill	66,094	128,780	1.95
Snow and ice control	5,797	17,210	2.97
Railroad ballast	1,512	5,662	3.74
Roofing granules	564	3,102	5.50
Other	13,981	55,706	3.98
Unspecified	331,792	941,558	2.84
Total[1] or average	883,000	2,747,200	3.11

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

Table 7.—Construction sand and gravel sold or used in

(Thousand short tons

Geographic region	Concrete aggregates (including concrete sand)		Plaster and gunite sands		Concrete products, (blocks, bricks, pipe, decorative, etc.)		Asphaltic concrete aggregates and other bituminous mixtures	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Northeast:								
New England	8,937	40,293	254	1,492	918	3,363	2,684	11,109
Middle Atlantic	11,997	54,131	754	3,710	2,008	8,069	6,180	29,456
North Central:								
East North Central	29,352	91,783	940	3,127	2,555	7,715	13,007	39,627
West North Central	17,847	48,601	1,206	3,448	918	2,537	9,878	23,536
South:								
South Atlantic	32,984	134,865	2,228	7,101	3,253	10,939	4,760	18,543
East South Central	13,142	38,355	460	1,491	1,286	5,110	4,383	15,652
West South Central	38,015	141,531	926	3,985	494	1,717	3,892	16,198
West:								
Mountain	18,909	75,638	575	2,318	1,944	6,271	16,717	63,847
Pacific	47,825	189,662	2,706	13,300	2,897	9,926	25,907	104,700
Total[2]	219,009	814,860	10,049	39,972	16,274	55,648	87,410	322,666

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1]Includes road and other stablization (cement and lime).
[2]Data may not add to totals shown because of independent rounding.

the United States in 1986, by geographic region and major use

and thousand dollars)

Road base and coverings[1]		Fill		Snow and ice control		Railroad ballast		Other uses		Total[2]	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
5,641	15,654	4,037	8,597	1,521	4,493	38	130	26,518	69,726	50,546	154,857
9,358	30,709	3,385	7,822	W	W	W	W	25,215	87,459	60,544	226,374
23,010	60,735	13,487	26,996	1,316	3,159	152	405	67,921	188,165	151,742	421,712
19,253	36,281	5,356	8,685	495	1,416	36	104	33,454	81,218	88,444	205,825
2,777	9,352	11,565	16,030	W	W	W	W	26,198	79,302	83,992	276,964
3,967	9,953	1,802	3,016	8	49	27	71	15,340	41,495	40,415	115,193
5,157	13,850	4,243	5,905	W	W	W	W	39,959	124,130	92,791	307,573
30,169	74,520	8,083	17,825	334	1,135	226	338	41,016	114,723	117,972	356,615
31,191	110,956	14,137	33,904	330	1,387	846	4,078	70,716	214,147	196,556	682,060
130,522	362,010	66,094	128,780	5,797	17,210	1,512	5,662	346,337	1,000,365	883,000	2,747,200

Table 8.—Construction sand and gravel sold or used in

(Thousand short tons

State	Concrete aggregates (including concrete sand)		Plaster and gunite sands		Concrete products, (blocks, bricks, pipe, decorative, etc.)		Asphaltic concrete aggregates and other bituminous mixtures	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	4,119	10,158	372	1,156	W	W	1,704	6,279
Alaska	319	2,242	W	W	--	--	180	926
Arizona	6,441	24,893	212	763	1,810	5,845	8,960	39,750
Arkansas	3,687	12,750	121	423	50	147	858	3,800
California	36,994	150,804	2,556	12,511	2,641	8,978	21,136	87,212
Colorado	4,893	19,545	70	275	101	301	2,337	7,985
Connecticut	873	4,259	43	193	104	456	365	788
Delaware	152	543	W	W	--	--	--	--
Florida	10,311	30,858	1,176	3,821	1,048	2,928	1,008	3,381
Georgia	1,469	4,714	W	W	177	529	32	148
Hawaii	76	456	--	--	--	--	13	113
Idaho	612	2,178	10	53	16	77	165	282
Illinois	6,048	18,757	205	603	572	1,646	2,539	9,017
Indiana	4,685	15,158	89	355	911	2,326	1,913	6,328
Iowa	2,739	8,521	62	251	98	381	621	1,933
Kansas	3,340	7,433	788	1,870	29	91	1,764	4,076
Kentucky	3,644	7,681	8	29	W	W	839	2,373
Louisiana	3,034	13,113	W	W	--	--	500	2,249
Maine	702	2,935	W	W	610	1,895	600	2,278
Maryland	9,536	49,491	W	W	621	2,601	588	2,048
Massachusetts	4,730	22,772	119	836	160	831	755	3,392
Michigan	5,114	16,784	106	343	453	1,346	2,550	5,620
Minnesota	4,237	12,163	100	432	410	1,015	4,416	9,027
Mississippi	3,433	13,072	32	82	W	W	1,151	3,580
Missouri	4,417	10,997	137	606	76	175	321	872
Montana	746	2,685	W	W	--	--	1,455	3,903
Nebraska	1,826	4,829	111	251	293	832	748	2,363
Nevada	1,823	7,903	W	W	--	--	1,175	3,511
New Hampshire	1,568	6,144	83	427	5	28	666	3,462
New Jersey	2,927	11,094	368	1,576	433	1,320	1,443	7,407
New Mexico	2,539	10,250	230	995	--	--	605	1,683
New York	4,970	22,359	137	756	1,102	4,202	2,159	10,056
North Carolina	2,719	8,591	194	506	65	113	1,300	5,494
North Dakota	141	452	--	--	--	--	642	2,143
Ohio	7,524	24,767	434	1,502	457	2,011	4,347	15,054
Oklahoma	2,975	7,989	120	245	288	867	427	798
Oregon	3,029	10,996	53	267	--	--	2,472	9,326
Pennsylvania	4,100	20,679	249	1,378	473	2,548	2,579	11,993
Rhode Island	569	2,262	--	--	--	--	W	W
South Carolina	3,199	10,932	370	1,009	668	1,159	849	2,834
South Dakota	1,148	4,205	8	38	W	W	1,366	3,122
Tennessee	1,946	7,445	W	W	224	805	690	3,420
Texas	28,319	107,678	404	2,210	157	704	2,108	9,352
Utah	1,314	6,039	38	190	W	W	1,490	4,135
Vermont	495	1,922	W	W	38	154	154	417
Virginia	5,021	27,409	194	927	674	3,608	969	4,592
Washington	7,407	25,160	88	441	256	948	2,107	7,123
West Virginia	576	2,328	--	--	--	--	15	45
Wisconsin	5,980	16,317	106	323	163	387	1,658	3,607
Wyoming	540	2,144	W	W	13	28	531	2,599
Total[2]	219,009	814,860	9,393	37,643	15,196	51,282	87,270	321,896
Undistributed	--	--	654	2,329	1,079	4,369	144	771
U.S. total[2]	219,009	814,860	10,049	39,972	16,274	55,648	87,410	322,666

W Withheld to avoid disclosing company proprietary data; included by State with "Other and undistributed uses" column, and by use in "Undistributed" line. XX Not applicable.

[1]Includes road and other stabilization (cement and lime).

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

[3]Less than 1/2 unit.

the United States in 1986, by State and major use

and thousand dollars)

Road base and coverings[1]		Fill		Snow and ice control		Railroad ballast		Other and undistributed uses		Total[2]	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
847	1,962	158	199	--	--	27	71	3,554	10,983	10,781	30,807
396	2,040	948	3,264	66	525	--	--	25,853	52,956	27,762	61,954
10,232	27,839	3,213	8,895	1	1	--	--	9,598	32,018	40,468	140,004
649	1,446	109	242	--	--	--	--	3,097	8,191	8,571	26,999
22,270	81,078	8,197	20,857	2	12	609	2,625	34,000	134,381	128,407	498,456
5,663	14,397	2,342	4,059	178	749	23	98	7,626	22,686	23,233	70,095
931	3,524	638	2,103	297	1,364	--	--	4,001	13,299	7,254	25,984
W	W	388	777	--	--	--	--	1,008	2,835	1,547	4,156
W	W	6,234	6,883	--	--	--	--	8,456	20,027	28,233	67,898
W	W	178	215	--	--	--	--	6,269	17,616	8,126	23,222
105	754	114	399	--	--	--	--	297	944	605	2,666
2,448	5,669	145	174	--	--	--	--	2,312	6,397	5,708	14,830
3,254	11,387	2,984	6,717	171	475	W	W	12,095	33,921	27,867	82,523
1,127	3,552	1,581	3,443	234	642	--	--	9,102	29,428	19,642	61,232
1,706	4,182	832	1,617	143	378	12	12	8,299	23,142	14,511	40,418
2,910	5,290	1,581	2,305	120	361	--	--	5,078	12,295	15,609	33,721
194	486	117	236	1	2	--	--	2,393	6,181	7,194	16,986
381	1,244	1,350	1,704	--	--	--	--	9,027	27,824	14,292	46,134
1,297	2,357	790	2,090	549	1,037	--	--	4,023	10,251	8,572	22,843
1,326	4,691	716	2,025	W	W	--	--	5,387	26,068	18,173	86,925
1,273	3,069	1,766	3,108	378	1,369	W	W	10,018	25,088	19,200	60,464
8,013	16,427	2,278	3,298	493	792	56	93	23,451	47,182	42,514	91,886
5,524	9,935	1,891	2,777	119	281	W	W	7,357	17,486	24,055	53,116
1,612	3,845	1,251	1,846	--	--	--	--	7,600	20,385	15,080	42,809
484	1,545	179	619	37	106	--	--	4,095	9,145	9,746	24,065
2,542	4,704	324	845	42	72	W	W	2,958	7,182	8,066	19,391
2,307	5,603	360	525	20	52	--	--	4,009	9,456	9,675	23,912
1,928	4,997	440	1,273	60	179	8	41	6.764	17,788	12,197	35,692
1,166	4,978	545	905	165	476	--	--	4,220	9,669	8,418	26,089
441	1,924	678	2,384	45	218	--	--	7,664	27,823	13,999	53,746
1,587	3,782	331	564	(3)	1	W	W	3,179	8,585	8,471	25,862
5,841	15,409	2,302	4,135	1,322	3,688	W	W	13,338	43,142	31,172	103,748
300	1,035	330	534	3	11	--	--	2,632	6,843	7,543	23,127
1,854	2,982	49	160	10	35	(3)	1	2,438	4,968	5,135	10,741
5,131	18,183	3,925	9,333	161	565	41	140	14,784	55,192	36,806	126,747
803	1,888	1,084	1,497	W	W	W	W	4,669	11,302	10,366	24,585
2,898	9,876	430	920	87	332	192	1,240	4,281	9,641	13,441	42,597
3,075	13,375	405	1,303	278	1,108	--	--	4,215	16,497	15,373	68,880
W	W	52	66	--	--	11	47	1,638	5,876	2,269	8,252
--	--	1,530	2,467	W	W	--	--	584	1,380	7,200	19,783
4,468	6,745	464	681	45	203	W	W	2,214	4,859	9,713	19,853
1,314	3,661	276	736	W	W	--	--	2,910	8,525	7,360	24,592
3,324	9,272	1,700	2,461	W	W	W	W	23,551	78,177	59,562	209,855
4,413	9,554	1,227	1,889	27	33	--	--	7,943	17,923	16,452	39,763
884	1,631	245	326	132	248	7	12	2,878	6,517	4,834	11,226
462	1,944	2,150	3,029	119	415	W	W	2,081	4,564	11,670	46,488
5,522	17,208	4,448	8,464	175	519	45	212	6,294	16,307	26,342	76,387
--	--	40	100	2	4	--	--	868	2,889	1,501	5,365
5,485	11,186	2,719	4,205	258	684	W	W	8,545	22,615	24,913	59,325
1,356	3,575	61	127	26	100	W	W	850	2,404	3,377	10,977
129,743	360,231	66,094	128,780	5,766	17,037	1,031	4,592	349,503	1,010,853	833,000	2,747,200
777	1,776	--	--	31	175	483	1,070	XX	XX	XX	XX
130,522	362,010	66,094	128,780	5,797	17,210	1,512	5,662	XX	XX	883,000	2,747,200

Table 9.—Number of construction sand and gravel active operations[1] and processing plants in the United States in 1986, by State

State	Mining operations on land				Dredging operations	Total active operations
	Stationary	Portable	Stationary and portable	No plants or unspecified		
Alabama	25	10	3	5	22	65
Alaska	5	7	--	7	2	21
Arizona	48	59	13	4	1	125
Arkansas	26	20	1	8	8	63
California	151	64	22	14	12	263
Colorado	36	104	11	21	9	181
Connecticut	17	37	3	8	1	66
Delaware	3	2	--	2	1	8
Florida	5	9	--	6	27	47
Georgia	10	2	1	8	24	45
Hawaii	1	1	--	3	--	5
Idaho	22	32	--	10	2	66
Illinois	28	32	14	49	23	146
Indiana	44	59	6	6	12	127
Iowa	31	85	9	8	36	169
Kansas	17	67	3	12	45	144
Kentucky	9	12	--	--	7	28
Louisiana	13	68	1	6	18	106
Maine	22	92	2	19	1	136
Maryland	25	32	3	18	2	80
Massachusetts	42	75	5	6	1	129
Michigan	53	200	20	17	6	296
Minnesota	50	172	18	21	4	265
Mississippi	25	54	3	7	14	103
Missouri	9	52	--	1	24	86
Montana	26	67	3	5	1	102
Nebraska	10	70	1	11	82	174
Nevada	14	35	7	9	--	65
New Hampshire	15	25	3	5	--	48
New Jersey	25	23	5	7	7	67
New Mexico	37	48	5	9	1	100
New York	162	155	15	85	8	425
North Carolina	34	4	4	54	25	121
North Dakota	7	69	2	2	--	80
Ohio	117	47	15	32	23	234
Oklahoma	43	5	3	52	30	133
Oregon	44	24	2	12	7	89
Pennsylvania	68	31	8	10	8	125
Rhode Island	11	1	--	3	--	15
South Carolina	13	8	--	20	9	50
South Dakota	17	124	8	55	--	204
Tennessee	22	6	1	12	10	51
Texas	85	13	8	97	16	219
Utah	29	57	6	20	--	112
Vermont	22	32	1	24	--	79
Virginia	28	10	--	11	8	57
Washington	55	71	5	47	2	180
West Virginia	2	--	--	1	2	5
Wisconsin	53	142	12	29	1	237
Wyoming	16	26	2	8	3	55
Total	1,672	2,440	254	886	545	5,797

[1]An undetermined number of operations leased from the Bureau of Land Management in Alaska are counted as one operation.

Table 10.—Transportation of construction sand and gravel in the United States in 1986 to site of first sale or use

Method of shipment	Quantity (thousand short tons)	Percent of total
Truck	454,317	52
Rail	9,899	1
Waterway	19,869	2
Not shipped, used at site	335,541	38
Unspecified	63,377	7
Total	[1]883,000	100

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

Table 11.—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]
1985				
Canada	892	3,061	485	1,430
Germany, Federal Republic of	4	657	--	--
Mexico	74	520	11	238
Netherlands Antilles	1	7	8	131
Saudi Arabia	11	64	(2)	7
Trinidad and Tobago	4	244	1	112
Other	11	1,659	11	806
Total	997	6,212	516	[3]2,723
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

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

Table 12.—U.S. imports for consumption of construction sand and gravel, by country

(Thousand short tons and thousand dollars)

Country	1985		1986	
	Quantity	C.i.f. value[1]	Quantity	C.i.f. value[1]
Antigua	9	61	34	103
British Virgin Islands	11	155	5	62
Canada	212	908	157	707
Japan	--	--	4	88
Mexico	2	20	--	--
Spain	11	297	(2)	3
Other	1	131	5	449
Total	246	1,572	205	1,412

[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.

INDUSTRIAL SAND AND GRAVEL

DOMESTIC PRODUCTION

The total output of industrial sand and gravel decreased 7% to 27.4 million tons. The North Central major geographic region continued to lead the Nation with 41% of the U.S. total, followed by the South with 35% and the West and Northeast with 12% each. Of the total U.S. industrial sand output, 76% was produced in two major geographic regions, the North Central and the South. Compared with that of 1985, the output of industrial sand and gravel decreased 13% in the Northeast, 11% in the South, 3% in the North Central, and remained essentially unchanged in the West.

Based on the 1980 census data on population, 1986 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 North Central, followed by the South with 0.13 ton, the Northeast with 0.07 ton, and the West with 0.06 ton.

The five leading States in the production of industrial sand and gravel in 1986 were, in descending order of volume, Illinois, Michigan, California, New Jersey, and Florida. Their combined production represented 50% of the national total. Of the major producing States, significant increases were recorded in Oklahoma and North Carolina, while production decreased significantly in Texas, 34%, Florida 31%, and New Jersey, 17%.

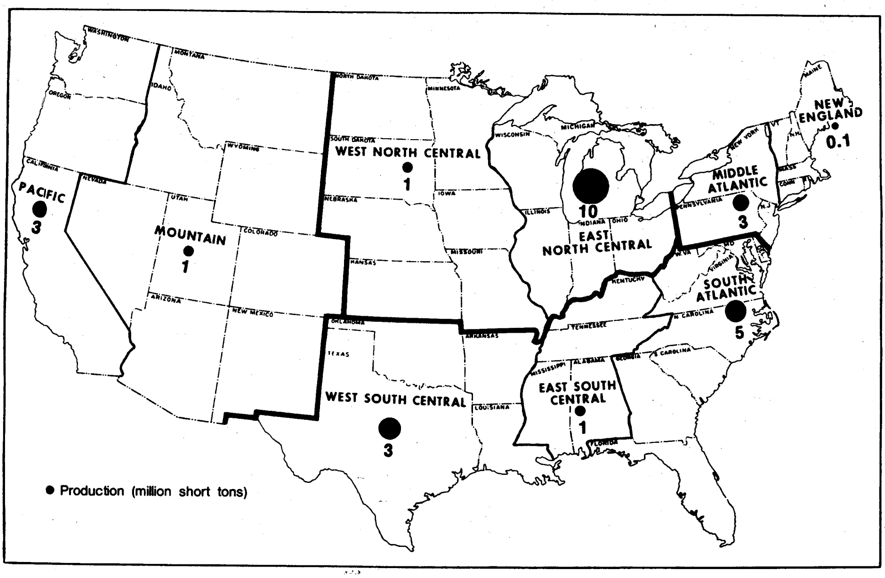

Figure 2.—Production of industrial sand and gravel in the United States in 1986, by geographic region.

The Bureau of Mines canvassed 91 producers of industrial sand and gravel with 162 active operations. About 74% of the industrial sand and gravel produced came from 42 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., Manley Bros. of Indiana Inc., Standard Sand & Silica Co., Wedron Silica Co., Owens-Illinois Inc., Badger Mining Corp., Construction Aggregates Corp., and Oglebay Norton Co. Their combined production, from 58 operations, represented 70% of the U.S. total.

United States Borax & Chemical Corp. of Los Angeles, CA, a subsidiary of The Rio Tinto Zinc Corp. PLC of London, United Kingdom, purchased Ottawa Silica Co. of Ottawa, IL, the fourth largest U.S. producer of industrial sand in 1985. This acquisition followed U.S. Borax's purchase of Pennsylvania Glass Sand Corp. in 1985. The newly formed subsidiary company, U.S. Silica, which owns a total of 16 operations, became one of the largest U.S. producers of industrial sand. The operations previously owned by Ottawa Silica are in California, Connecticut, Illinois, Louisiana, Michigan, and Texas, and Pennsylvania Glass Sand's 10 operations are in Missouri, New Jersey, Ohio, Oklahoma, Pennsylvania, South Carolina, Texas, and West Virginia.

Unimin of New Canaan, CT, a subsidiary of SA SCR Sibelco NV, of Antwerp, Belgium, purchased the quartz-processing operation in Spruce Pine, NC, of International Minerals & Chemical Corp. (IMC) of Northbrook, IL. This operation produces a very high-purity silica also known as Iota Quartz, by means of the Iota process, a froth flotation-based process developed jointly by IMC and the Bureau of Mines.

The Feldspar Corp. of Spruce Pine, NC, announced plans to build a new $7.25 million plant at its Spruce Pine operation to produce high- and ultrahigh-purity grades of silica. The new plant was expected to be completed in 1987. The ultrahigh-purity silica will compete with the Iota Quartz produced by Unimin. Ultrahigh-purity silica is used in the semiconductor industry, for specialty glass, and other high-tech applications.

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 27.4 million tons of industrial sand and gravel sold or used, 40% was consumed as glassmaking sand and 21% as foundry sand. Other important uses were abrasive sand, 7%, and hydraulic fracturing sand, 4%. Because some companies did not report a breakdown by end use, their total production as well as the estimated production for nonrespondents were included in "Other unspecified uses," which represent about 17% of the U.S. total. On a regional level, most of the glassmaking sand was produced in the South, 40%, followed by North Central, 24%, and the West, 21%, and most of the foundry sand was produced in the North Central, 75%, and the South, 12%. Of the smaller by volume but important uses, most of the hydraulic fracturing sand was produced in the North Central, 79%, and most of the abrasive sand was produced in the South, 42%, and the North Central, 28%.

TRANSPORTATION

Of the total industrial sand and gravel produced, 66% was transported by truck from the plant to the site of first point of sale or use, down from 80% in 1985; 31% was transported by rail, up from 18% in 1985; and 3% by waterway. Because most of the producers had no records of and 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 increased 3% to $13.10 per ton. Average unit values for industrial sand and industrial gravel were $13.16 and $10.03 per ton, respectively. Nationally, industrial sand used as fillers for rubber, paint, and putty, etc., had the highest value per ton, $53.14, followed by silica sand used in ceramics, $34.02, fiberglass (ground), $28.70, and scouring cleansers, $26.53.

FOREIGN TRADE

Exports.—Exports of industrial sand decreased slightly to 849,000 tons valued at $20.4 million. Of this, 84% went to Canada and 7% went to Mexico.

Imports.—Imports for consumption of industrial sand increased 9% to 88,000 tons valued at $1.0 million. Of this, 32% came from Antigua, 26% from Japan, and 25% from Australia.

TECHNOLOGY

High-purity glass sands used for manufacturing specialty glass or glass products are produced most often through the beneficiation of lower grade sands. The most common method of beneficiation is a two-stage process consisting of attrition and flotation. This processing usually reduces the iron (Fe_2O_3) content to about 0.020%. To obtain sands with lower iron content, leaching of iron by means of hydrochloric acid is one of the most common methods. However, the reagent is relatively expensive and the processing conditions are difficult, especially from the environmental aspect. A new process that uses heterotrophic acid-producing bacteria and fungi to remove iron from quartz sands has been tested at the Institute of Mining and Geology, Sofia, Bulgaria. The experiments indicated that the biological methods of iron removal from sands would be feasible under large-scale conditions. The biological leaching can be combined with conventional methods such as flotation and magnetic separation and also can be used for the removal of iron from minerals such as kaolins, other clays, and bauxites.[5]

One of the distinct characteristics of the glass industry is that the process of manufacturing materials is continuous. Unlike most manufacturing industries, the glass industry has no intermediate stage where the quality of the product can be checked and adjusted before the product is completed. This particularity requires raw materials of premium quality and leads to a very conservative approach to making any changes, especially with respect to raw material specifications. At the same time, continuous pressure in the glass industry to reduce batch and melting costs inevitably leads to new alternative raw materials with different characteristics. Over the years, many attempts have been made in various countries to produce absolute standards for raw materials. Because of the nature of glass sand deposits in different parts of the world, and the personal preferences of glass manufacturers, usually based on the requirements of their particular manufacturing processes, no agreement has been reached on this subject. Attempts to impose absolute standards like the British Standards proved to be of limited practical value.[6]

A comprehensive review of the synthetic mineral fabric industries that include mineral wool, continuous filament glass fiber, optical fiber, and ceramic fiber has been published by Industrial Minerals magazine. Synthetic mineral fibers are used in a wide range of applications and their uses are expanding at the expense of traditional materials.[7]

[1]Physical scientist, Division of Industrial Minerals.
[2]U.S. Bureau of Mines. An Economic Reconnaissance of Selected Sand and Gravel Deposits in the U.S. Exclusive Economic Zone. BuMines OFR 3-87, 1987, 113 pp.
[3]McBee, W. C., T. A. Sullivan, and H. L. Fike. Sulfur Construction Materials. BuMines B. 678, 1985, 31 pp.
[4]Baumgartner, W. Use of Computer To Evaluate Quarry. Rock Prod., v. 89, No. 5, May 1986, pp. 44-62.
[5]Groudev, S. N., and V. I. Groudeva. Iron From Quartz Sands. Ind. Miner. (London), No. 222, Mar. 1986, pp. 81-84.
[6]Reynolds, A. Seen Through Glass Darkly. Ind. Miner. (London), No. 222, Mar. 1986, pp. 97-102.
[7]Griffiths, J. Synthetic Mineral Fibers. Ind. Miner. (London), No. 228, Sept. 1986, pp. 20-43.

Table 13.—Industrial sand and gravel sold or used in the United States, by geographic region

Geographic region	1985				1986			
	Quantity (thousand short tons)	Percent of total	Value (thousands)	Percent of total	Quantity (thousand short tons)	Percent of total	Value (thousands)	Percent of total
Northeast:								
New England	164	1	$3,879	1	129	1	$3,541	1
Middle Atlantic	3,542	12	41,352	11	3,088	11	41,132	11
North Central:								
East North Central	10,092	34	120,162	32	9,990	36	116,698	32
West North Central	1,578	5	25,523	7	1,340	5	16,011	4
South:								
South Atlantic	5,959	20	67,060	18	5,452	20	71,292	20
East South Central	1,121	4	11,113	3	945	3	9,198	3
West South Central	3,648	12	52,004	14	3,161	11	42,929	12
West:								
Mountain	746	3	9,950	3	694	3	9,251	3
Pacific	2,576	9	43,022	11	2,621	10	49,257	14
Total[1]	29,430	100	374,070	100	27,420	100	359,300	100

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

Table 14.—Industrial sand and gravel sold or used in the United States, by State

(Thousand short tons and thousand dollars)

State	1985 Quantity	1985 Value	1986 Quantity	1986 Value
Alabama	524	4,533	433	3,388
Arizona	W	W	W	W
Arkansas	412	5,414	400	3,975
California	2,255	37,434	2,364	44,813
Colorado	W	W	W	W
Connecticut	W	W	W	W
Florida	2,123	12,642	1,467	14,930
Georgia	571	6,675	W	W
Idaho	W	W	W	W
Illinois	4,056	56,915	4,039	52,133
Indiana	182	1,209	193	1,490
Kansas	134	1,124	132	1,155
Kentucky	W	W	W	W
Louisiana	267	3,838	256	4,225
Maryland	W	W	W	W
Massachusetts	W	W	45	739
Michigan	3,345	25,469	3,343	29,493
Minnesota	884	16,910	W	W
Mississippi	W	W	W	W
Missouri	535	7,330	517	6,230
Montana	W	W	W	W
Nebraska	W	W	W	W
Nevada	479	5,944	518	W
New Jersey	2,820	31,119	2,341	29,878
New York	W	W	59	1,164
North Carolina	1,294	13,086	1,464	16,656
North Dakota	--	--	W	W
Ohio	1,312	21,945	1,221	21,183
Oklahoma	W	W	1,203	16,454
Pennsylvania	693	9,846	688	10,091
Rhode Island	W	W	22	143
South Carolina	794	14,092	800	14,081
Tennessee	569	6,156	488	5,523
Texas	1,968	29,095	1,302	18,274
Utah	8	144	6	123
Virginia	W	W	W	W
Washington	322	5,589	W	W
West Virginia	W	W	W	W
Wisconsin	1,197	14,624	1,194	12,399
Other	2,686	42,934	2,927	50,768
Total[1]	29,430	374,070	27,420	359,300

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Data may not add to totals shown because of independent rounding.

Table 15.—Industrial sand and gravel production in the United States in 1986, by size of operation

Size range	Number of operations	Percent of total	Quantity (thousand short tons)	Percent of total
Less than 25,000	37	22.9	292	1.1
25,000 to 49,999	28	17.3	1,025	3.7
50,000 to 99,999	30	18.5	2,257	8.2
100,000 to 199,999	25	15.4	3,684	13.4
200,000 to 299,999	6	3.7	1,528	5.6
300,000 to 399,999	12	7.4	4,284	15.6
400,000 to 499,999	7	4.3	2,975	10.9
500,000 to 599,999	6	3.7	3,222	11.8
600,000 to 699,999	5	3.1	3,194	11.6
700,000 and over	6	3.7	4,959	18.1
Total	162	100.0	27,420	100.0

Table 16.—Number of industrial sand and gravel operations[1] and processing plants in the United States in 1986, by geographic region

Geographic region	Mining operations on land: Stationary	Mining operations on land: Portable	Mining operations on land: Stationary and portable	Mining operations on land: No plants or unspecified	Dredging operations	Total active operations
Northeast:						
New England	4	--	--	1	--	5
Middle Atlantic	10	--	2	2	4	18
North Central:						
East North Central	35	--	4	--	3	42
West North Central	8	--	--	--	3	11
South:						
South Atlantic	16	--	1	3	6	26
East South Central	9	--	1	1	3	14
West South Central	14	--	--	2	10	26
West:						
Mountain	6	--	--	--	1	7
Pacific	10	--	--	1	2	13
Total	112	--	8	10	32	162

[1]An undetermined number of operations leased from the Bureau of Land Management in Alaska are counted as one operation.

Table 17.—Transportation of industrial sand and gravel in the United States in 1986 to site of first sale or use

Method of shipment	Quantity (thousand short tons)	Percent of total
Truck	18,067	66
Rail	8,388	30
Waterway	829	3
Not transported	137	1
Total	[1]27,420	100

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

Table 18.—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	North Central: Quantity (thousand short tons)	North Central: Value (thousands)	North Central: 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
1985															
Sand:															
Glassmaking:															
Containers	1,369	$17,538	$12.81	1,562	$19,663	$12.59	2,235	$26,996	$12.08	1,656	$27,133	$16.38	6,822	$91,330	$13.39
Flat (plate and window)	W	W	12.41	448	4,319	9.64	1,138	12,860	11.30	W	W	14.48	1,777	19,815	11.15
Specialty	W	W	15.23	369	4,279	11.60	W	W	12.56	--	--	--	768	9,790	12.75
Fiberglass (unground)	W	W	10.00	309	3,857	12.48	W	W	15.28	60	861	14.35	587	7,753	13.21
Fiberglass (ground)	W	W	58.00	W	W	30.68	W	W	27.26	W	W	21.71	339	9,247	27.28
Foundry:															
Molding and core	683	5,954	8.72	2,912	30,304	10.41	865	8,740	10.10	108	1,539	14.25	4,568	46,536	10.19
Molding and core facing (ground)	W	W	18.17	W	W	12.62	--	--	--	--	--	--	352	4,475	12.71
Refractory	W	W	24.71	184	1,677	9.11	W	W	17.88	W	W	17.82	223	2,457	11.02
Metallurgical:															
Silicon carbide	W	W	22.67	W	W	10.12	24	124	5.17	1	W	9	121	1,143	9.45
Flux for metal smelting	--	--	--	W	W	7.57	W	W	13.50	51	619	12.14	67	753	11.24
Abrasives:															
Blasting	117	2,054	17.56	221	3,694	16.71	841	14,052	16.71	252	2,961	11.75	1,431	22,762	15.91
Scouring cleansers (ground)	W	W	28.00	W	W	21.94	W	W	26.12	--	--	--	233	5,358	23.00
Sawing and sanding	W	W	13.00	W	W	20.27	W	W	25.00	--	--	--	17	355	20.88
Chemicals (ground and unground)	W	W	12.42	125	1,355	10.84	176	2,613	14.85	W	W	19	378	4,924	13.03
Fillers (ground):															
Rubber, paint, putty, etc	21	1,341	63.86	W	W	95.33	96	4,768	49.67	W	W	13.38	137	7,360	53.72
Silica flour	W	W	26.63	--	--	--	W	W	25.09	--	--	--	21	542	25.81
Ceramic (ground):															
Pottery, brick, tile, etc	W	W	33.93	W	W	38.91	50	1,479	29.58	--	--	--	150	5,295	35.30
Filtration	122	1,661	13.61	39	921	23.62	166	1,215	7.32	18	184	10.22	345	3,981	11.54
Traction (engine)	14	228	16.29	142	1,325	9.33	100	875	8.75	36	335	9.31	292	2,763	9.46
Coal washing	W	W	12.67	--	--	--	W	W	11.57	--	--	--	18	199	11.06
Roofing granules and fillers	36	619	17.19	40	444	11.10	288	3,415	11.86	39	577	14.79	403	5,056	12.55
Hydraulic fracturing	W	W	17.47	1,396	29,853	21.38	W	W	17.47	47	1,045	22.23	2,102	42,417	20.18
Other uses, specified	1,200	14,059	11.72	3,706	41,794	11.28	2,540	39,609	15.59	820	15,902	19.39	XX	XX	XX
Other uses, unspecified[2]	138	1,727	12.51	158	1,451	9.18	1,968	11,817	6.00	182	890	4.89	2,446	15,885	6.49
Total[1] or average	3,701	45,179	12.21	11,609	144,935	12.48	10,489	128,564	12.26	3,270	52,048	15.92	29,070	370,730	12.75

See footnotes at end of table.

Table 18.—Industrial sand and gravel sold or used by U.S. producers, by major use —Continued

Major use	Northeast: Quantity (thousand short tons)	Northeast: Value (thousands)	Northeast: Value per ton	North Central: Quantity (thousand short tons)	North Central: Value (thousands)	North Central: 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
1985 —Continued															
Gravel: Metallurgical:															
Silicon, ferrosilicon	--	--	--	W	W	$10.00	W	W	$6.44	51	$917	$17.98	315	$2,771	$8.80
Filtration	W	W	$10.40	W	W	18.75	W	W	24.00	W	W	r5.40	23	383	16.65
Grinding	--	--	--	--	--	--	W	W	8.60	W	W	r3.25	5	43	8.60
Other uses	--	--	--	--	--	--	W	W	10.21	W	W	W	15	143	9.53
Total[1] or average	W	W	10.40	61	$750	12.30	W	W	6.75	53	924	17.43	357	3,340	9.36
Grand total[1] or average	W	W	14.90	11,670	145,685	12.48	W	W	12.13	3,323	52,972	15.94	29,430	374,070	12.71
1986															
Sand:															
Glassmaking:															
Containers	1,321	$17,257	13.06	1,587	12,077	7.61	2,516	$28,337	11.26	2,157	36,068	16.72	7,581	93,738	12.36
Flat (plate and window)	W	W	13.03	676	8,080	11.95	1,089	11,906	10.93	W	W	15.42	1,946	22,449	11.54
Specialty	W	W	15.57	138	1,971	14.28	260	3,219	12.38	W	W	19.27	581	8,095	13.93
Fiberglass (unground)	W	W	11.46	211	2,171	10.29	165	1,736	10.52	W	W	15.52	514	5,867	11.41
Fiberglass (ground)	--	--	--	W	W	36.21	336	9,400	27.98	W	W	38.67	371	10,646	28.70
Foundry:															
Molding and core	601	8,405	13.99	4,184	40,490	9.68	W	W	9.85	W	W	14.12	5,483	56,282	10.26
Molding and core facings (ground)	W	W	16.75	W	W	31.18	113	1,284	11.36	W	W	W	151	2,432	16.11
Refractory	W	W	22.25	104	636	6.12	W	W	17.42	W	W	31.20	143	1,422	9.94
Metallurgical:															
Silicon carbide	W	W	35.50	W	W	6.86	W	W	W	--	--	--	W	W	7.39
Flux for metal smelting	--	--	--	46	322	7.00	--	--	--	--	--	--	46	322	7.00
Abrasives:															
Blasting	289	4,158	14.39	487	7,775	15.97	799	14,784	18.50	294	5,356	18.22	1,868	32,073	17.17
Scouring cleansers (ground)	W	W	29.50	W	W	29.50	W	W	23.58	W	W	47.00	40	1,061	26.53
Sawing and sanding	W	W	W	W	W	8.53	W	W	24.00	--	--	--	39	356	9.13
Chemicals (ground and unground)	W	W	13.44	W	W	7.95	155	2,752	17.75	10	333	33.30	317	4,568	14.41
Fillers (ground):															
Rubber, paint, putty, etc	21	768	36.57	47	4,108	87.40	66	4,903	74.29	82	1,699	20.72	216	11,479	53.14
Silica flour	W	W	27.30	W	W	31.14	W	W	20.71	W	W	76.16	51	1,341	26.29

Ceramic (ground):															
Pottery, brick, tile, etc	W	W	31.44	128	4,343	33.93	49	1,667	34.02	W	W	55.75	198	6,736	34.02
Filtration	334	3,678	11.01	21	293	13.95	127	1,266	9.97	11	341	31.00	494	5,577	11.29
Traction (engine)	W	W	15.75	98	874	8.92	57	480	8.42	W	W	13.73	177	1,685	9.52
Coal washing	W	W	W	W	W	3.50	W	W	W	--	--	--	W	W	4.86
Roofing granules and fillers	W	W	22.94	W	W	10.24	156	2,345	15.03	67	1,206	18.00	261	4,133	15.84
Hydraulic fracturing	W	W	W	888	16,241	18.29	W	W	16.86	25	483	19.32	1,130	20,371	18.03
Other uses, specified	522	8,508	16.30	510	6,291	12.34	951	12,018	12.64	528	10,766	20.39	XX	XX	XX
Other uses, unspecified[2]	115	1,433	12.46	2,160	26,386	12.22	2,351	24,276	10.33	82	1,570	19.15	4,708	53,664	11.40
Total[1] or average	3,204	44,207	13.80	11,286	132,056	11.70	9,189	120,371	13.07	3,258	57,822	17.75	26,937	354,457	13.16
Gravel: Metallurgical:															
Silicon, ferrosilicon	--	--	--	W	W	13.50	371	3,047	8.21	W	W	22.25	424	3,916	9.24
Filtration	--	--	--	W	W	23.33	--	--	--	--	--	--	W	W	23.33
Other uses	13	466	35.85	--	--	--	--	--	--	W	W	8.07	W	W	14.74
Total[1] or average	13	466	35.85	44	653	14.84	371	3,047	8.21	56	686	12.25	484	4,853	10.03
Grand total[1] or average	3,217	44,673	13.89	11,330	132,709	11.71	9,559	123,418	12.91	3,315	58,508	17.65	27,420	359,300	13.10

[r]Revised. W Withheld to avoid 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 19.—U.S. exports of industrial sand, by country

(Thousand short tons and thousand dollars)

Country	1985		1986	
	Quantity	F.a.s. value[1]	Quantity	F.a.s. value[1]
North America:				
Bahamas	1	80	(2)	40
Canada	739	10,926	713	9,224
Costa Rica	(2)	68	--	--
Dominican Republic	1	64	4	104
Mexico	50	1,516	63	1,708
Netherlands Antilles	1	11	8	106
Panama	9	239	13	254
Other	r3	r197	3	262
Total[3]	805	13,101	804	11,698
South America:				
Argentina	(2)	12	(2)	29
Chile	(2)	135	(2)	265
Colombia	1	161	(2)	132
Ecuador	6	144	(2)	100
Peru	7	754	1	124
Venezuela	(2)	114	3	159
Other	(2)	34	1	95
Total[3]	15	1,354	5	904
Europe:				
Belgium	6	327	7	778
France	1	203	(2)	182
Germany, Federal Republic of	2	444	1	425
Italy	2	35	3	145
Netherlands	6	2,300	3	1,164
Norway	2	584	(2)	8
United Kingdom	9	484	10	520
Yugoslavia	--	--	2	811
Other	r1	r280	2	776
Total[3]	28	4,656	28	4,809
Asia:				
Indonesia	2	142	1	256
Japan	4	700	2	835
Singapore	4	780	1	286
Other	2	588	2	900
Total[3]	11	2,211	6	2,277
Middle East and Africa:				
Saudi Arabia	1	156	(2)	16
United Arab Emirates	3	585	2	152
Other	1	202	3	287
Total	5	943	5	455
Oceania	2	316	1	220
Grand total[3]	866	22,580	849	20,363

r Revised.
[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.

Table 20.—U.S. imports for consumption of industrial sand, by country

(Thousand short tons and thousand dollars)

Country	1985		1986	
	Quantity	C.i.f. value[1]	Quantity	C.i.f. value[1]
Antigua	14	92	28	173
Australia	42	737	22	387
British Virgin Islands	5	89	--	--
Canada	2	115	3	87
Japan	11	16	23	27
Spain	3	30	--	--
United Kingdom	2	53	12	102
Other	3	382	([2])	238
Total[3]	81	1,513	88	1,014

[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.

Silicon

By Clark R. Neuharth[1]

Demand for silicon ferroalloys and silicon metal declined compared with that of 1985 owing to decreased production in the iron and steel and aluminum industries. Domestic production of silicon ferroalloys overall decreased by about 25%; however, production of silicon metal increased slightly. Imports of silicon-containing ferroalloys were at record-high levels, 44% higher than those of 1985. Silicon metal imports decreased by more than 20%. Exports of ferrosilicon declined, while those of silicon metal more than doubled compared with that of 1985. Published prices for most domestically produced silicon materials did not change throughout 1986 but were generally lower than the average 1985 prices, owing to declining demand and competition from low-priced imports. World demand for silicon materials decreased slightly in 1986 compared with that of 1985.

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 1986

(Short tons, gross weight, unless otherwise specified)

Alloy	Silicon content (percent)		Producers' stocks as of Dec. 31, 1985[r]	Gross production	Net shipments	Producers' stocks as of Dec. 31, 1986
	Range	Typical				
Silvery pig iron	5-24	18	W	W	W	W
Ferrosilicon (including briquets)	25-55	48	99,393	255,816	251,222	72,961
Do	56-95	76	30,247	65,397	59,810	34,061
Silicon metal (excluding semiconductor grades)	96-99	98	9,950	125,966	126,077	5,775
Miscellaneous silicon alloys (excluding silicomanganese)	32-65	--	15,911	60,632	60,278	16,218

[r]Revised. W Withheld to avoid disclosing company proprietary data.

Legislation and Government Programs.—Modified portions of House bill 4781 entitled "Strategic and Critical Materials Stockpiling Act of 1986" were signed into law. The Strategic and Critical Materials Stockpiling Act gives Congress, rather than the President, the authority to set goals for the National Defense Stockpile, outlines criteria on which to base those goals, and centralizes management of the program in the U.S. Department of Defense (DOD). The President also granted DOD $3 million for Government-sponsored development of a high-purity polysilicon industry as part of the renewed Defense Production Act (DPA). DOD had requested the funds because the type of high-purity polysilicon needed for certain defense-related electronics is not available domestically. Title 3 of DPA gives the Administration the authority to expand capacity or develop technological processes through the use of loans and guaranteed purchase contracts.

Senate bill 262 and its counterpart, House bill 976 entitled "Fair Trade in Ferroalloys Act," stalled in the House Ways and Means Committee at the end of 1986. The Fair Trade in Ferroalloys Act would have given domestic producers some relief from import competition by establishing a "breakpoint" tariff where ferroalloy imports entering the United States below a given price were to be subject to an automatic duty.

A congressionally mandated study entitled "The Effects of a Loss of Domestic Ferroalloy Capacity" determined that defense requirements during a mobilization would create immediate shortages of silicon metal and other ferroalloys, assuming a complete loss of domestic capacity. The study also concluded that DOD should monitor peacetime trends in the ferroalloys industry and be prepared to react to any sudden decreases in the amount of production capacity for silicon metal or ferroalloys in general.[2]

In October, the President signed an executive order implementing import sanctions against the Republic of South Africa. The U.S. Customs Service stopped shipments of ferroalloys from the Republic of South Africa for about 2 weeks in early November as part of the new sanctions law. The law was to include a ban on the importation of all South African iron and steel products. Therefore, imports of ferroalloys, which were listed along with iron and steel products under the Tariff Schedule of the United States, were initially included in the ban. However, the U.S. Treasury Department later determined that ferroalloys would not be considered along with iron and steel products, and shipments were again allowed to pass customs.

DOMESTIC PRODUCTION

Production and shipments of silicon-containing ferroalloys overall showed significant decreases in 1986. Production of the standard 50% (25% to 55%) and 75% (56% to 95%) grades dropped more than 25% based on 1985 figures; shipments of the 50% and 75% grades declined by 5% and 25%, respectively. Production and shipments of silicon metal increased slightly, while production of the miscellaneous silicon alloys, comprised mostly of magnesium ferrosilicon, declined about 7%. Producer stocks of silicon-containing materials were down overall at yearend, owing to a sharp decrease in the 25% to 55% range.

Newmont Mining Corp. of New York, NY, announced plans to sell its 87.5% interest in Foote Mineral Co., which reported losses in 2 of the last 3 years. Foote's board of directors said Newmont was looking to sell the company in parts or merge the organization with another firm. Foote's ferrosilicon operations included production plants in Keokuk, IA, and Graham, WV. The Graham facility has been shut down since December 1985. International Minerals & Chemical Corp., Northbrook, IL, completed the sale of its industrial products operations, including its ferrosilicon production facilities in Bridgeport, AL, and Kimball, TN, to Applied Industrial Minerals Corp., Mundelein, IL. Ohio Ferro-Alloys Corp. (OFA), Canton, OH, filed for reorganization of its finances under chapter 11 of the U.S. Bankruptcy Code. The company planned to continue the production of silicon metal at its Montgomery, AL, facility while a financial restructuring plan was sought. OFA's other facilities, ferrosilicon plants in Philo and Powhatan Point, OH, have been closed since 1984.

SKW Alloys Inc. converted one of two ferrosilicon furnaces at its Niagara Falls, NY, facility to produce silicon metal. The converted 36,000-kilovolt-ampere (kV•A) furnace was expected to produce about 12,000 short tons of silicon metal in 1987. New York Power Authority officials authorized a modified allocation of 4,000 kilowatts to SKW (about a 25% increase over its present allocation), which will enable SKW to produce the higher energy consuming product. The furnace conversion cost approximately $7 million and provided 55 new jobs. The replacement power allocation will be subject to reduction if specified job levels are not maintained. Elkem Metals Co., Pittsburgh, PA, the largest domestic producer of ferroalloys, planned to modernize its power generating facility at its silicon metal plant in Alloy, WV. Elkem Metals expected the $10 million project to significantly lower the cost of producing electricity for smelting silicon metal. Elkem Metals' silicon metal furnace at Alloy is considered to be the largest in the Western Hemisphere.

Estimated ferrous scrap consumption by the domestic silicon ferroalloys industry to produce silicon ferroalloys was 220,000 tons in 1986, compared with 280,000 tons in 1985.

Table 2.—Producers of silicon alloys and/or silicon metal in the United States in 1986

Producer	Plant location	Product
Aluminum Co. of America, Northwest Alloys Inc	Addy, WA	FeSi and Si.
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	Do.
Do	Keokuk, IA	Silvery pig iron.
M. A. Hanna Co., Silicon Div	Wenatchee, WA	FeSi and Si.
Applied Industrial Minerals Corp. (AIMCOR)	Bridgeport, AL	FeSi.
Do	Kimball, TN	Do.
Moore McCormack Resources Inc., Globe Metallurgical Inc	Beverly, OH	FeSi and Si.
Do	Selma, AL	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.

CONSUMPTION AND USES

Overall, reported consumption of silicon materials in 1986 decreased about 8%, on a gross weight basis, compared with that of 1985. The more significant declines occurred in the consumption of standard 50% grade ferrosilicon (25% to 55%) and silicon metal, which are the largest categories on a volume basis. Consumption in these categories dropped 13% and 7%, respectively. Consumption of standard 75% grade ferrosilicon (71% to 80%) and miscellaneous silicon alloys increased slightly. Substantial declines occurred in the remaining ferrosilicon categories, while the consumption of silicon carbide (SiC), of which 98% was used in the production of cast irons, was essentially unchanged. Ferrous applications accounted for over 65% of the silicon materials consumed.

The overall decreases in the consumption of ferrosilicon and silicon metal paralleled declines in demand by the steel and aluminum industries. Ferrosilicon is used as a deoxidizing and alloying agent in the production of steel. The aluminum industry uses silicon metal in the production of wrought and cast products. Metallurgical-grade silicon metal produced by tonnage methods is also used as the basic raw material in the manufacture of ultrahigh-purity polycrystalline silicon for semiconductors, solar cells (photovoltaic (PV) cells), and other highly specialized applications. The Bureau of Mines does not collect data on these specialty grades of silicon, which are relatively low in quantity but have a high unit value.

Overall, consumer stocks of silicon materials declined more than 15% in 1986. The most significant decreases occurred in the 71% to 80% ferrosilicon and silicon metal categories.

Table 3.—Consumption, by major end use, and stocks of silicon alloys and metal in the United States in 1986

(Short tons, gross weight, unless otherwise specified)

End use	Silvery pig iron	Ferrosilicon[1]				Silicon metal	Miscellaneous silicon alloys[2]	Silicon carbide[3]
Silicon content (percent): Range	5-24	25-55	56-70	71-80	81-95	96-99	--	63-70
Silicon content (percent): Typical	18	48	65	76	85	98	48	64
Steel:								
Carbon	(4)	38,653	--	19,055	(4)	(4)	2,055	(4)
Stainless and heat-resisting	--	32,967	(4)	26,626	(4)	116	(4)	--
Full alloy	(4)	14,479	--	7,614	(4)	(4)	449	--
High-strength, low-alloy	--	5,149	--	499	--	23	(4)	(4)
Electric	--	(4)	(4)	21,834	--	--	(4)	--
Tool	--	50	(4)	1,959	--	--	--	--
Unspecified	38	7,006	92	21	602	1,014	230	173
Total	38	98,304	92	77,608	602	1,153	2,734	173
Cast irons	7,520	99,873	421	17,937	335	83	39,134	27,264
Superalloys	--	180	--	81	(5)	(5)	(5)	(5)
Aluminum alloys	--	(5)	--	--	(5)	41,701	(5)	--
Other alloys	(5)	2,786	--	(5)	(5)	6,987	(5)	(5)
Miscellaneous and unspecified	12	1,661	--	234	166	[6]72,655	473	384
Total	7,570	202,812	513	95,860	1,103	122,579	42,341	27,821
Percent of 1985	67	87	19	103	79	93	104	98
Total silicon content[7]	1,363	97,350	333	72,854	938	120,127	20,324	17,805
Consumers' stocks, Dec. 31	1,018	9,218	69	4,900	81	2,412	2,367	1,194

[1]Includes briquets.
[2]Primarily magnesium-ferrosilicon but also includes other silicon alloys. Average silicon content estimated as 48%, based on 1986 production survey.
[3]Does not include silicon carbide for abrasive or refractory uses.
[4]Included with "Steel: Unspecified."
[5]Included with "Miscellaneous and unspecified."
[6]Consists primarily of consumption of silicon metal for the production of silicones and silanes and estimated consumption for the production of fumed silica and other chemicals.
[7]Estimated based on typical percent content.

PRICES

Published prices of most domestically produced silicon materials remained unchanged throughout 1986, and those prices were generally lower than the average yearly prices of 1985, owing to a decline in the demand for silicon metal by the aluminum industry, a decrease in raw steel production, and competition from low-priced imports of silicon materials.

Posted prices for imported silicon ferroalloys showed a firming trend until midyear, and then gradually declined, ending somewhat higher than at the beginning of 1986. However, import prices stayed well below those posted for domestically produced materials throughout the year, and on average, were lower than the import prices in 1985. For example, the average posted price in 1986 for imported 50% grade ferrosilicon was 34.8 cents per pound on a contained silicon basis, significantly lower than the prices of 40.0 cents per pound for equivalent domestically produced ferrosilicon and 36.6 cents per pound for imported 50% grade material in 1985. The average price for imported 75% grade ferrosilicon was 32.9 cents per pound compared with 35.0 cents per pound in 1985 and 40.0 cents per pound for equivalent domestically produced material in 1986.

The published price for imported silicon metal containing 1% iron was lowered slightly in February and remained unchanged at yearend, averaging 55.6 cents per pound. This price was slightly lower than the yearly average for imported silicon metal in 1985, 57.4 cents per pound, and significantly lower than the 1986 posted prices for domestically produced silicon metal, which ranged from 62.0 to 67.4 cents per pound, depending on iron content. Although posted prices of domestically produced silicon metal were generally much higher than those of imports, domestic transaction prices as low as 55 cents per pound were reported in 1986.

FOREIGN TRADE

Exports of ferrosilicon declined 12% in terms of gross weight, reaching a 9-year-low level, while the value of exported ferrosilicon was 34% lower than that of 1985. The largest amount went to Canada, 8,163 tons, which accounted for 72% and 65% of total quantity and value, respectively. Ferrosilicon was exported to 25 other countries, with Mexico receiving the next highest quantity, 1,272 tons. Silicon metal exports, on the other hand, more than doubled in quantity compared with those of 1985. However, the value associated with that material increased only 6%. Over 75% of the silicon metal exported was shipped to 3 of 31 countries, namely, Japan, 2,056 tons; Canada, 1,068 tons; and the United Kingdom, 990 tons.

Imports for consumption of ferrosilicon increased by over 40% compared with those of 1985. The reported 223,031 tons was by far the largest amount ever imported by the United States. Imports of 75% grade (over 60% but not over 80% silicon) were the most significant, accounting for about three-quarters of the total ferrosilicon imports. Over two-thirds of the 75% grade material was imported from Norway, Brazil, and Venezuela, in decreasing order.

Compared with those of 1985, imports of silicon metal decreased by more than 20%. Quantities were down in all three of the silicon metal categories, with a 25% drop in the 99% to 99.7% range being the most significant. This range accounted for over 75% of the total silicon metal imports. As in 1985, Brazil and Canada were by far the largest suppliers of silicon metal to the United States, while Argentina more than doubled its share of the U.S. import market in the 99% to 99.7% range. The Federal Republic of Germany, Japan, and Italy, in decreasing order, continued to account for most of the imports in the high-purity, semiconductor-grade silicon class (over 99.7% silicon).

Table 4.—U.S. exports of ferrosilicon and silicon metal

Year	Quantity (short tons)	Value (thousands)
FERROSILICON		
1982	14,932	$11,996
1983	13,338	10,712
1984	29,364	21,135
1985	12,969	12,671
1986	11,331	8,306
SILICON METAL		
1982	2,411	34,335
1983	2,767	47,826
1984	4,420	88,543
1985	2,120	61,647
1986	5,378	65,157

Source: Bureau of the Census

Table 5.—U.S. imports for consumption of ferrosilicon and silicon metal, by grade and country

Grade and country	1985 Quantity (short tons) Gross weight	1985 Quantity (short tons) Silicon content	1985 Value (thousands)	1986 Quantity (short tons) Gross weight	1986 Quantity (short tons) Silicon content	1986 Value (thousands)
Ferrosilicon:						
Over 8% but not over 30% silicon:						
Brazil	--	--	--	22	6	$17
Canada	152	23	$9	--	--	--
Germany, Federal Republic of	171	17	5	65	11	62
United Kingdom	23	4	27	17	3	24
Total[1]	345	43	41	103	19	103
Over 30% but not over 60% silicon, with over 2% magnesium:						
Brazil	3,973	1,822	2,462	2,638	1,194	1,351
Canada	774	365	223	130	60	26
France	727	340	519	442	202	388
Germany, Federal Republic of	212	106	289	287	150	746
Italy	99	45	71	40	18	27
Japan	127	57	215	55	25	97
Mexico	--	--	--	17	8	11
Norway	1,662	743	1,186	189	84	135
Spain	12	5	17	--	--	--
Total[1]	7,586	3,484	4,981	3,797	1,741	2,781

See footnotes at end of table.

Table 5.—U.S. imports for consumption of ferrosilicon and silicon metal, by grade and country —Continued

Grade and country	1985 Quantity (short tons) Gross weight	1985 Quantity (short tons) Silicon content	1985 Value (thousands)	1986 Quantity (short tons) Gross weight	1986 Quantity (short tons) Silicon content	1986 Value (thousands)
Ferrosilicon —Continued						
Over 30% but not over 60% silicon, not elsewhere classified:						
Argentina	66	40	$60	--	--	--
Brazil	3,135	1,532	977	4,647	2,437	$2,707
Canada	11,547	5,568	3,697	15,321	7,303	4,159
France	2,628	1,497	2,209	1,792	1,017	1,387
Germany, Federal Republic of	261	145	270	837	461	876
Iceland	--	--	--	5,512	3,029	1,715
Japan	36	16	60	18	8	34
Mexico	--	--	--	11	6	7
Spain	1,111	644	1,103	1,115	640	1,012
U.S.S.R	16,132	7,518	4,542	15,425	7,338	3,638
Venezuela	6,969	3,828	1,672	5,013	2,406	1,182
Total[1]	41,887	20,788	14,590	49,690	24,644	16,717
Over 60% but not over 80% silicon, with over 3% calcium:						
Argentina	357	222	368	300	181	308
Brazil	6,134	3,860	5,377	7,151	4,438	6,179
Canada	31	24	15	54	34	51
France	1,080	653	1,052	1,925	1,194	1,741
Germany, Federal Republic of	602	367	576	1,069	674	913
Italy	37	24	35	570	352	508
Mexico	--	--	--	5	4	4
Netherlands	--	--	--	19	12	16
Spain	312	191	291	134	83	126
Total[1]	8,554	5,340	7,714	11,227	6,971	9,846
Over 60% but not over 80% silicon, not elsewhere classified:						
Argentina	5,741	4,416	2,817	--	--	--
Brazil	21,120	15,918	10,411	35,203	26,492	15,822
Canada	12,877	9,812	6,590	23,158	17,653	11,424
Chile	--	--	--	882	683	336
France	413	317	393	3,456	2,626	1,752
Germany, Federal Republic of	1,079	802	1,575	633	465	1,318
Iceland	5,295	4,011	2,229	8,271	6,331	3,602
Japan	--	--	--	36	22	67
Norway	23,598	17,632	10,293	42,299	32,157	18,454
South Africa, Republic of	4,144	3,168	2,076	5,707	4,298	2,355
United Kingdom	19	14	11	--	--	--
Venezuela	20,768	15,302	9,297	34,030	24,901	13,818
Yugoslavia	1,101	835	529	2,646	1,992	1,273
Total[1]	96,154	72,228	46,222	156,322	117,620	70,221
Over 80% but not over 90% silicon:						
Belgium-Luxembourg	19	17	16	--	--	--
Brazil	498	422	312	--	--	--
Norway	358	315	132	--	--	--
Total	875	754	460	--	--	--
Over 90% but not over 96% silicon:						
Brazil	--	--	--	209	201	151
Germany, Federal Republic of	20	19	11	56	55	46
Mexico	--	--	--	1,626	1,545	713
Total[1]	20	19	11	1,892	1,800	910
Total ferrosilicon	155,421	102,656	74,019	223,031	152,795	100,578
Silicon metal:						
Over 96% but not over 99% silicon:						
Argentina	440	NA	475	552	NA	445
Brazil	55	NA	48	255	NA	254
Canada	4,257	NA	4,898	5,849	NA	5,784
France	65	NA	79	48	NA	59
Italy	1,134	NA	1,020	--	NA	--
Spain	116	NA	115	--	NA	--
Sweden	551	NA	585	--	NA	--
Switzerland	19	NA	15	--	NA	--

See footnotes at end of table.

Table 5.—U.S. imports for consumption of ferrosilicon and silicon metal, by grade and country —Continued

Grade and country	1985 Quantity (short tons) Gross weight	1985 Quantity (short tons) Silicon content	1985 Value (thousands)	1986 Quantity (short tons) Gross weight	1986 Quantity (short tons) Silicon content	1986 Value (thousands)
Silicon metal —Continued						
Over 96% but not over 99% silicon —Continued						
United Kingdom	36	NA	$37	205	NA	$244
Yugoslavia	2,680		2,412	1,948		1,610
Total[1]	9,353	NA	9,684	8,856	NA	8,397
Over 99% but not over 99.7% silicon:						
Argentina	1,520	1,508	1,482	3,192	3,167	3,005
Belgium-Luxembourg	18	18	18	(2)	(2)	(2)
Brazil	13,283	13,122	13,071	12,620	12,526	12,200
Canada	6,027	5,959	7,231	6,012	5,960	6,795
China	165	162	157	--	--	--
France	3,869	3,837	4,012	2,282	2,265	2,321
Germany, Federal Republic of	--	--	--	11	11	17
Italy	1,093	1,087	1,105	--	--	--
Netherlands	136	134	137	--	--	--
Norway	1,081	1,072	1,100	70	70	60
Portugal	6,386	6,322	6,737	2,756	2,728	2,818
South Africa, Republic of	3,932	3,900	4,128	1,766	1,751	1,756
Spain	1,280	1,267	1,111	349	346	331
Sweden	1,111	1,101	1,098	768	762	714
Switzerland	757	749	765	--	--	--
Venezuela	20	20	21	--	--	--
Yugoslavia	884	869	780	1,436	1,423	1,488
Total[1]	41,563	41,128	42,954	31,263	31,006	31,507
Over 99.7% silicon:						
Belgium-Luxembourg	19		16	2		21
Canada	--		--	(2)		1
China	1		50	--		--
Denmark	21		639	2		120
Dominican Republic	4		172	--		--
France	5		591	1		212
German Democratic Republic	1		52	--		--
Germany, Federal Republic of	598		21,565	513		19,054
Italy	80	NA	3,353	56	NA	3,409
Japan	144		3,623	146		1,866
Korea, Republic of	--		--	(2)		14
Malaysia	(2)		1	--		--
Netherlands	(2)		22	--		--
Norway	--		--	6		12
Sweden	--		--	1		8
Switzerland	13		640	5		466
U.S.S.R	--		--	(2)		3
United Kingdom	(2)		5	(2)		90
Total[1]	885	NA	30,729	733	NA	25,276
Total silicon metal[1]	51,801	XX	83,367	40,851	XX	65,180

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.

WORLD REVIEW

World demand for silicon-containing ferroalloys declined compared with that of 1985, owing to a decrease in world steel production. However, demand was somewhat stable in the silicon metal market. Prices in both the ferroalloys and silicon metal world markets were under pressure as a result of overproduction. The overall sharp decline in world prices led to many companies restructuring their ferroalloy units and subsequent output reductions. Numerous claims were launched by the European Economic Community (EEC) against Brazil and other non-EEC countries, such as Norway, for dumping ferrosilicon into the common market.

Australia.—Construction of a new silicon plant near Hobart, Tasmania, began late in the year. The project, a joint venture between Pioneer Concrete Ltd. and French metals producer Pechiney, was scheduled for completion in mid-1987 and was expected to produce 13,000 tons per year of alloy and chemical-grade silicon metal. Pechiney, which holds a 40% share in the venture, was planning to market the silicon through its sales network in Australia and Pacific Rim countries.[3]

Brazil.—In September, the fourth International Ferroalloys Congress was held in Rio de Janeiro, where much of the discussion centered around Brazil's rapid expansion in the ferroalloys industry. In 1986, Brazil was the fifth largest producer of ferroalloys, including ferrosilicon and silicon metal, in the market economy countries. Associação Brasileira dos Produtores de Ferroligas (ABRAFE), the Brazilian association of ferroalloy manufacturers, estimated that Brazil's growth will continue because it is one of the few countries to show significant production increases (almost 50% since 1982) in recent years. Ranked fourth among market economy ferroalloy exporting countries, Brazil also has seen steady increases in its domestic consumption as a result of its growing steel industry. Silicon metal producers have been driven to meet domestic demand as exports have been increasing at a rate of greater than 10% per year. Investments were most active in this area in 1986, along with silicon-containing ferroalloys, as ABRAFE projected Brazil's share of the world market would reach 30% by the end of the decade.[4]

Inoculantes e Ferro-Ligas Nipo Brasileiros S.A., a ferrosilicon producer, planned to double its 13,000-ton-per-year capacity with a new 15,000-kV•A electric furnace, which was being built at its Pirapora plant in Minas Gerais and was scheduled to start production in mid-1987. Osaka Special Alloy Ltd., a Japanese concern, is a major partner in the venture.[5] Electrovale S/A Indústria e Cómercio's new 26,000-ton-per-year ferrosilicon plant, also in Minas Gerais, started production late in 1986. Electrovale is a joint venture owned 40% by the state-owned Cia. Vale do Rio Doce and 60% by Brazil's Metalur Ltda. and Japan's Kawasaki Steel Corp. and Mitsubishi Metal Corp. About one-third of production was to be exported to Japan with the remainder being consumed by Brazil's steel industry.[6]

An agreement was reached between Brazilian ferroalloys producer Ferro-Ligas Assofun S.A. and two Japanese companies, Nippon Kokan K.K. (NKK) and Mitsui Co. Ltd., to set up a joint ferrosilicon operation. Assofun, currently equipped with three furnaces capable of producing a total of 7,500 tons per year, planned to increase that capacity to 15,000 tons per year with a new 7,500-kV•A furnace, scheduled to start production in 1987. NKK would take up to 13,000 tons per year when the expansion is complete. The balance of production would be sold domestically.[7]

Cia. de Ferro-Ligas da Bahia S.A. (FERBASA) started full production at its 26,000-ton-per-year ferrosilicon plant in Pojuco. FERBASA invested $10 million in the new facility, which consists of two 18,000-kV•A furnaces.[8]

China.—Silicon producers in China made further inroads into the Japanese silicon market in 1986, as exports from China to Japan increased approximately 50% over those of 1985. The increase gave China a one-third share in the Japanese silicon market, placing it well ahead of any other country exporting silicon to Japan.[9] Further increases in exports are likely, as the Government has been soliciting foreign participation to provide equipment for more silicon metal capacity at the Chuyiong ferrosilicon plant.

France.—Pechiney announced late in the year consolidation plans for its ferroalloys subsidiary, Pechiney Électrométallurgie. The company was to lower standard ferrosilicon capacity from 82,000 tons per year to 38,000 tons per year by concentrating production at its Dunkirk plant, while the Saint Beron and Laudon plants would be shut down gradually beginning in 1987. Silicon metal capacity was also to be cut from 82,000 tons per year to 60,000 tons per year by 1988. Company officials indicated that the new plans would allow Pechiney to boost its production of specialty ferroalloys and concentrate on the production of silicon metal for specific chemical applications, such as silicones.[10]

Iceland.—Icelandic Metals, a silicon metal venture owned 60% by the Government of Iceland and 40% by RTZ Corp. Plc of the United Kingdom, began construction of two 21,000-kV•A electric furnaces with combined annual capacity of approximately 32,000 tons per year at Reydarsjordur. The company planned to import all of the needed raw materials such as silica, coal, and solid electrodes, and would be exporting a good share of the silicon produced to Japan.[11]

India.—Ispat Alloys Ltd. commissioned a new silicon metal and calcium silicide plant at Balgopalpur, Orissa. The plant is licensed to produce 2,750 tons per year each of silicon metal and calcium silicide, and Ispat expected to operate at near capacity for both by alternating the products in one furnace.[12]

Iran.—A new company formed by the state-owned Bank of Industry and Mines announced plans to build a 22,000-ton-per-year ferrosilicon plant, which was scheduled to start production in 1989. A $12 million contract for construction of the facility was awarded to Elkem Engineering, a subsidiary of Elkem A/S of Norway. Demand for the ferrosilicon was expected to come from Iran's growing steel industry.[13]

Japan.—Japan's ferrosilicon import market was disrupted in October when Daiichi Fuji Kogyo (DFK), a Tokyo-based ferrosilicon dealer, filed for voluntary liquidation. DFK had been buying domestically produced ferrosilicon for over 20 years and in recent years had begun handling imported material to serve the needs of Japan's numerous small-lot buyers. Although an estimated 11,000 tons of material was still unsettled, market stability was somewhat restored late in 1986. The aftereffects of this material entering the market were expected to be felt through the first quarter of 1987. Overall, Japanese imports of ferrosilicon were up an estimated 4% over a record-high level of 372,500 tons in 1985. Domestic production of ferrosilicon was down drastically from 168,650 tons in 1985 to about 110,000 tons. However, all of Japan's seven producers were still operating at yearend. Japan also saw a significant increase in silicon metal imports from China.[14]

Japanese companies made significant advances into different phases of the world's semiconductor silicon market. Mitsubishi Metal purchased Siltec Corp., a U.S.-based silicon wafer manufacturer, for $30 million, leaving Monsanto Electronics Materials Co. as the only U.S. owned merchant wafer producer. Late in the year, NKK purchased a 125-acre site in Millersburg, OR, where it plans to build a 1,100-ton-per-year polysilicon manufacturing plant. Polysilicon is the basic raw material used in the production of semiconductor chips for integrated circuits. Construction of the $60 million facility was to begin sometime in 1987, with the first production scheduled for mid-1988. NKK chose the Oregon site because of available low-cost electrical power and incentives from the Oregon State government.

Norway.—Early in the year, Elkem A/S finalized a complete takeover of Orkla Metall A/S and Co. by acquiring a 50% share in Orkla Metall from Orkla Industrier A/S and the remaining interest from Associated Metals & Minerals Corp., White Plains, NY. These acquisitions made Elkem A/S full owner of the Thamshavn Verk ferrosilicon plant. Elkem A/S also acquired Orkla Metall's 51% share in Bjolvefossen A/S's ferrosilicon plant as part of the takeover along with a contract for marketing Orkla Metall's ferrosilicon production. Overall, the takeover could raise Elkem A/S's 275,000-ton-per-year Norwegian ferrosilicon production by as much as 50%.[15]

Elkem A/S reported a huge loss in its ferroalloys division in 1986, most of which was attributed to high electricity taxes, which resulted in a 10% reduction in the work force. At the same time, the company was planning to further its interests in such products as microsilica, special-grade silicon, ceramic materials, and gallium.

Tinfos Jernverk A/S decided late in the year to shut down its 66,000-ton-per-year Notodden ferrosilicon and silicon metal production facility. Initially, company plans were to suspend production for only 1 or 2 months pending Government decisions concerning electric power and environmental issues, but at yearend, the operation had not been restarted, and the company was still seeking reductions in electricity taxes and some softening of pollution control regulations. Finnfjord Smelteverk A/S, which joined the A/S Fesil and Co. Group in 1986, also stopped production in November owing to transformer problems on its 24,000-kV•A electric furnace. Repairs were to be completed in early 1987, but the company estimated that about 9,000 tons of ferrosilicon production would be lost.[16]

Philippines.—In May, Electro Alloys Corp. (EAC) stopped production at its 16,000-ton-per-year ferrosilicon plant. EAC, a Japanese-Philippine joint venture, owned 53.2% by the Laurel Group and 46.8% by Nippon Denko Co. Ltd. and C. Itoh & Co. Ltd., had been exporting all of its ferrosilicon output to Japan.[17]

Portugal.—Production of silicon metal and ferrosilicon was stopped at Cia. Portuguesa de Fornos Electricos S.A.R.L.'s Nelas facility in early November when power to the plant was shut off. Fornos had been in difficult negotiations with the Portuguese state power authority; however, no progress had been made. Startup of the Nelas facility, as well as Milnorte-Metalurgia do Norte S.A.R.L.'s brand new furnace for silicon metal production, was also hinging on a satisfactory power contract.[18]

South Africa, Republic of.—A number of countries, including Japan, the United States, and members of the EEC, announced sanctions against the Republic of South Africa. In most cases, the sanctions included a ban on imports of iron and steel products from the Republic of South Africa, but ferroalloys were generally excluded.

TECHNOLOGY

Silicon continues to be the mainstay of the semiconductor manufacturing industry. A host of new materials, including gallium arsenide, are being studied for development as alternatives to silicon, but these materials are often much more costly than silicon and difficult to purify and fabricate into integrated circuits. The stages of processing and batch methods used to produce single crystals of silicon for wafer manufacturing have seen little change in recent years; however, a number of companies are currently working on new technology. Monsanto, the world's largest supplier of polished wafer substrates for semiconductors, completed the $23 million first phase of its silicon wafer manufacturing facility at Milton Keynes, United Kingdom. Initially, production at Milton Keynes will center on the polishing and cleaning of imported wafers, but Monsanto planned to include wafer modification and single crystal manufacturing processes in the future.[19] Other companies making advances into the world semiconductor silicon market included Japan's Mitsubishi Metal, NKK (see "Japan" in "World Review" section), and Ethyl Corp. Ethyl started constructing a $45 million polysilicon production unit at its chemical complex near Houston, TX. The new facility, which was scheduled for completion in 1987, would initially produce 1,100 tons per year and was designed for capacity expansion to three times that amount. The Federal Republic of Germany's Wacker Chemitronic (the world's largest producer of polysilicon), Hemlock Semiconductor Corp., and Union Carbide Corp. all announced plans in 1986 for expansion of polysilicon production capacity. Total world consumption of polysilicon in 1985 was approximately 6,000 tons, and industry sources estimated that the market is currently growing at a rate of 20% per year.[20]

PV cells, devices that generate electricity upon exposure to sunlight, are not yet economical or efficient enough to compete with most conventional power sources. However, these systems, once used primarily in space-related applications, have found uses in regions where conventional utilities are scarce. The obvious advantages of capturing an inexhaustible and nonpolluting source of energy and converting it into useful electrical power have provided the incentives for research in the field of PV systems. Today, PV cells can be installed at a cost equal to or less than that of a diesel generator to operate equipment such as communication relays and water pumps in remote areas. Other commercial success is being seen in products such as PV-equipped watches and calculators. The overall cost of solar power has dropped to about 10% of what it was in 1976.[21]

High-performance ceramics, such as silicon carbide, silicon nitride, and sialon (a mixture of alumina and silicon nitride) offer properties needed for these materials to become replacements for metals in engineering applications. These materials are able to withstand high temperatures while resisting corrosion and wear and providing special electrical, hardness, and strength properties. The hardness and wear resistance of some high-performance ceramics allow them to be used in the production of cutting tools and bearings. Electrical properties make these materials useful in capacitors, as substrates for integrated circuits, and as packaging for many electronic devices. Resistance to corrosion has led to the use of ceramics in the manufacturing of seals, valves, and pump components for chemical processing plants. Although ceramic materials do offer many desirable properties, their usefulness in structural applications has been restricted because of brittleness. Ceramic materials are also costly and sometimes difficult to fabricate into usable products. However, the outlook for future applications is very strong, assuming reduced costs and improved reliability.

SiC can be used in a number of forms (i.e., continuous fibers, chopped fibers, wiskers, or powder-like abrasives) as reinforcing media in the production of aluminum-based metal-matrix composites (MMC). SiC MMC's are being developed as alternatives to conventional alloys because of their low production costs and many extraordinary properties including light weight, strengths comparable to those of titanium alloys, heat and wear resistance, and good ductility.

They can be extruded, die-cast, rolled, and forged with conventional equipment. The automotive industry showed an increasing amount of interest in MMC's in 1985 and in 1986 was evaluating their potential for use in pistons, gears, brakes, drive shafts, and even engine blocks.[22] Ford Motor Co.,[23] Nissan Motor Co.,[24] and Mazda Motor Corp.[25] have made significant strides in the race to develop ceramic parts for automotive engines.

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Silver

By Robert G. Reese, Jr.[1]

Domestic mine production of silver declined for the second consecutive year, and the silver mining industry continued to respond to the declining silver price, which fell to levels equivalent to those of the mid-1970's. Exploration budgets for nonferrous metals other than gold were reduced. Labor concessions in terms of wages and job content, and improved productivity became major goals at many companies. Other companies continued to dispose of unprofitable mining assets in order to improve their balance sheets and to concentrate on other business lines. The low price had its most noticeable effect in the Coeur d'Alene area of Idaho, where a majority of the principal silver producing mines were closed during the year. The effect of these mine closures on domestic silver production was partially offset, however, by the opening of many new gold-silver heap-leach operations.

World mine production remained essentially the same as that of 1985. Silver consumption by market economy countries was estimated to have increased by about 34 million ounces[2] owing primarily to increased industrial consumption in the Federal Republic of Germany, Japan, and the United States, and to the increased use of silver in coinage by the United States.

Table 1.—Salient silver statistics

	1982	1983	1984	1985	1986
United States:					
Mine production thousand troy ounces	40,248	43,431	44,592	r39,433	34,220
Value thousands	$319,975	$496,850	$362,976	r$242,205	$187,183
Percentage derived from:					
Precious metals ores	68	76	80	70	63
Base metal ores	32	24	20	30	37
Placers	(1)	(1)	(1)	(1)	(1)
Refinery production:					
Domestic and foreign ores and concentrates thousand troy ounces	r48,615	r57,759	r59,331	r53,808	42,413
Secondary (old scrap) do	r29,999	r29,415	r27,842	r27,830	23,159
Exports:					
Refined do	12,876	13,658	10,340	12,611	10,109
Other do	12,594	18,294	r14,107	12,145	15,005
Imports for consumption:					
Refined do	96,917	161,199	93,546	137,398	125,365
Other do	20,541	18,692	21,420	r15,203	19,525
Stocks, Dec. 31:					
Industry do	20,467	r17,449	r21,217	r18,467	16,278
Futures exchanges do	106,182	151,232	137,631	173,144	162,089
Consumption:					
Industry and the arts do	118,840	r116,440	114,841	r118,555	118,940
Coinage do	1,846	2,128	2,665	355	7,427
Price, average per troy ounce[2]	$7.95	$11.44	$8.14	$6.14	$5.47
Employment[3]	2,900	2,400	2,600	3,000	2,200
World:					
Mine production thousand troy ounces	r371,159	r386,533	412,069	p421,041	e419,781
Consumption:[4]					
Industry and the arts do	r345,400	r340,700	r353,300	r357,200	380,700
Coinage do	12,800	19,600	8,700	r12,700	22,800

eEstimated. pPreliminary. rRevised.
[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 229 lode silver operations to which a survey form was sent, 79% responded, representing 99% of the total U.S. mine production shown in tables 1, 2, 3, 5, 6, and 7. Production for the remaining 48 firms was estimated using prior reported production levels adjusted for economic trends and for information from other sources, such as company annual reports, news or journal articles, and State agency reports.

Legislation and Government Programs.—On October 29, the President signed Public Law 99-582, the Bicentennial of the Constitution Coins Act, which authorized the U.S. Mint to produce, during the period January 1, 1987, through June 30, 1988, 10 million silver coins and 1 million gold coins to commemorate the bicentennial of the U.S. Constitution. Each silver coin was to weigh 0.86 ounce, be legal tender, and consist of an alloy of 90% silver and 10% copper. The silver for the coins was to be obtained from the National Defense Stockpile (NDS).

DOMESTIC PRODUCTION

Silver was produced from precious metal ores at 69 lode mines while 34 lode mines produced silver as a byproduct of the processing of copper, lead, and zinc ores. The 25 largest mines accounted for 89% of total domestic mine output. In 1986, 10 mines each produced more than 1 million ounces of silver; their aggregated production equaled 65% of total domestic production. Silver was also produced at 12 placer operations.

Arizona.—The Gladiator-War Eagle Mine, owned by Nor-Quest Resources Ltd., resumed commercial production in January. Production at the underground mine reportedly averaged about 100 short tons of ore per day, yielding 50 ounces of gold and 350 ounces of silver. An additional ball mill was installed near midyear, expanding the capacity to 150 tons per day. The mine had been inactive since 1982.

ASARCO Incorporated reported that its share of output from the Mission complex was 1.3 million ounces of silver, 61,600 tons of copper, and 1,800 ounces of gold in concentrates.[3] The Mission complex consisted of the Eisenhower, Mission, Pima, and San Xavier surface mines. Asarco owned each of these mines, except for the Eisenhower, which it operated under a partnership agreement with Anamax Mining Co. Following a June decision by Anamax not to renew the partnership agreement, Asarco was to acquire the Eisenhower Mine in April 1987, when the current agreement expires. A new 3-year labor agreement for the Mission complex was negotiated during 1986. The agreement, effective July 1, included wage reductions of $3.50 per hour, suspension of cost-of-living adjustments, and some reduced benefits. Part of the wage reduction was to be restored in each of the final 3 years of the contract.

On February 7, Phelps Dodge Corp. sold a 15% interest in its Morenci properties to Sumitomo Metal Mining Co. Ltd. and Sumitomo Corp., both Japan-based companies. Phelps Dodge's Morenci properties, which produced copper and byproduct silver, consisted of the Morenci and Metcalf Mines, two concentrators, and other property. The purchase price was $75 million. In August, Phelps Dodge agreed with the Environmental Protection Agency and the U.S. Department of Justice to pay $1 million in penalties for past water pollution violations at Morenci and to spend $8.9 million to construct a water control system at the mine.

Kennecott, a subsidiary of Standard Oil Co. (Ohio), sold its Ray Mines Div. to Asarco in November for $72 million in cash, assumption of certain liabilities, and variable payments based on future copper prices and the revenue from the Ray Mine. Included in the sale was the Ray copper-silver mine and mill, an electrowinning plant, and a copper smelter.

Cyprus Minerals Co. purchased the Sierrita Mine, Esperanza and Mineral Park properties, and other assets from Duval Corp., a Pennzoil Co. subsidiary. The March 31 acquisition increased Cyprus' reserves of copper-molybdenum-silver ore by nearly 349 million tons.

Colorado.—Exploration, development, and rehabilitation work continued at the London Mine project, a former gold-silver producer in Park and Lake Counties. HRG Resources Inc. sold its 50% interest in the project to its partner, Cobb Resources Corp., on June 30. Colosseum Colorado Inc. exercised an option that allowed it to acquire a 50% interest in the project from Cobb.

Galactic Resources Ltd. began commercial production at its Summitville Mine in April. The heap-leach operation began production less than a year after the construction contract was signed. Reserves were estimated at over 25 million tons, grading 0.4 ounce of gold and 0.1 ounce of silver per ton.

The Sunnyside Mine returned to commercial production at the beginning of August, following refurbishment of the mine and mill. According to Echo Bay Mines Ltd., the startup did not go as well as expected, owing to lower than anticipated ore grades, the lack of developed stopes, and to the equipment being in poorer condition than initially expected. Between August and December, Sunnyside produced nearly 163,000 ounces of silver and 18,000 ounces of gold.[4]

The Bulldog Mine, traditionally Colorado's largest silver producing mine, remained closed throughout 1986. The mine was closed in January 1985 owing to low silver prices. Homestake Mining Co., however, continued to operate Bulldog's carbon-in-pulp plant to process loaded carbon from the Homestake gold mine in South Dakota.

Idaho.—Clayton Silver Mines Inc. suspended operations at its Clayton Mine in Custer County on May 24. Clayton attributed the closure to the continued depression of the silver price. As a result, silver production declined to about 111,000 ounces in 1986 from nearly 262,000 ounces in 1985.[5] The mine remained closed throughout the remainder of 1986, and the company discontinued pumping water from the mine's lower levels.

Bunker Limited Partnership closed the Crescent Mine on May 29, owing to the low silver price. Earlier in the year, the company reduced the mine's operating rate by 50% and attempted to avoid layoffs by having the workers share jobs. The work force was divided into two teams, each of which would alternately work for 2 weeks and then be laid off for 2 weeks. Reportedly, about 60 workers were laid off when the mined closed.

On April 11, Hecla Mining Co. suspended operations at the Lucky Friday Mine, attributing the closure to the depressed silver price. In 1985, Lucky Friday had been the largest domestic silver mine, with an output of over 4.7 million ounces. In 1986, Lucky Friday's output dropped to about 1.3 million ounces.[6] Research on a new underhand longwall mining method utilizing rubber-tired diesel equipment was completed during the year. Hecla planned to begin using this new mining method when operations resume. At yearend, 61 workers were employed at Lucky Friday, compared with 291 employees at yearend 1985.

Pioneer Metals Corp. and its partner, Mining Finance Corp., bought a 75% interest in the Stibnite Mine from Superior Oil Co., a Mobil Corp. subsidiary, for about $2 million in April. The mine, which had been closed since 1984, resumed production in June and officially reopened in September. Reserves at the gold-silver heap-leach operation were estimated at approximately 2 million tons, grading 0.09 ounce of gold per ton. Gold and silver were recovered at the mine in a 2-to-1 ratio, respectively.

In mid-April, operations at the Sunshine Mine were suspended owing to the low silver price. The Sunshine Mine had been the second largest domestic silver producer in 1985. Prior to the closure, Sunshine Mining Co., operator of the mine, attempted to negotiate a concession package with the mine's employees, which reportedly would have reduced wages and benefits by 35%. The employees rejected the concessions. For the 3.5 months of operation in 1986, the Sunshine Mine produced nearly 1.2 million ounces of silver.[7] In 1985, the last full year of operation, the Sunshine Mine produced over 4.7 million ounces of silver.

Despite Sunshine's closure of the Sunshine Mine, the company's refinery continued to operate, processing doré from other companies, and from Sunshine's Sixteen-to-One mill in Nevada. The refinery produced over 2.5 million ounces of silver and 37,000 ounces of gold. Most of the silver produced by the refinery was fabricated into bars and coins by Sunshine, utilizing its fabricating and minting equipment. In 1986, the company used over 2.7 million ounces of silver to produce various types of bars and coins for retail sale.

Coeur d'Alene Mines Corp. began commercial production at the Thunder Mountain Mine on August 1. The low-grade surface mine used conventional heap-leach technology to produce gold and silver. During 1986, over 11,000 ounces of gold and 9,000 ounces of silver was produced.[8] On March 24, prior to commercial production, Coeur increased its interest in Thunder Mountain by acquiring an additional 10% holding from Phillips Petroleum Co. Coeur at yearend had a 70% interest in the property.

At its Coeur Mine, Asarco reported that

2.7 million ounces of silver in concentrate was produced, compared with 2.6 million ounces in 1985. Silver production at the Galena Mine, operated by Asarco, declined slightly to 4 million ounces contained in concentrate, from 4.1 million ounces in 1985.

Missouri.—AMAX Inc., operator of the Buick Mine, mill, and smelter, placed the facility on standby in mid-May. On May 30, Homestake acquired total ownership of the Buick facilities, by purchasing AMAX's 50% interest for $10 million in cash plus approximately $3 million in working capital. On November 1, Homestake and St. Joe Minerals Corp. reached an agreement to merge their Missouri lead-silver operations. The combined assets were placed under The Doe Run Co., a new jointly managed company in which Homestake has a 42.5% interest and St. Joe, a 57.5% interest. Included in the assets of Doe Run were the Buick Mine, mill, and smelter from Homestake, and five mines and three mills in the Viburnum lead belt and the Herculaneum lead smelter from St. Joe. In early November, the Buick Mine was reopened to provide feed material for the Herculaneum smelter. The Buick smelter remained closed.

Ore production at the Magmont Mine declined in 1986 from the record-high level mined in 1985, owing to a major groundfall in part of the mine. About 1 million tons of lead-zinc-silver ore was mined, compared with nearly 1.15 million tons in 1985.[9] Cominco American Incorporated and Dresser Industries Inc., partners in the mine, in cooperation with the U.S. Bureau of Mines, established an experimental pilot plant in the mill to recover cobalt by flotation during the lead recovery process.

In December, Asarco purchased the Milliken Mine, another producer of byproduct silver, from Ozark Lead Co., a subsidiary of Kennecott. Asarco reportedly purchased the mine to help assure a long-term source of lead concentrates for its Glover lead smelter. The mine was subsequently renamed the Sweetwater Unit after the name of the principal ore body. Asarco did not reopen the mine, which had been closed since 1983.

Reported production at Asarco's West Fork lead-zinc-silver mine was 33,600 tons of lead, 7,200 tons of zinc and 182,000 ounces of silver.[10] The company announced that it would spend an additional $3.3 million to increase production at West Fork to full capacity by mid-1987.

Montana.—Montana Resources Corp., a subsidiary of Washington Corp., resumed mining operations in the East Berkeley Pit, a copper mine that in past years had yielded substantial quantities of byproduct silver. The mid-July resumption was aided by power rate concessions, property tax savings, and a State-supported loan. Washington Corp. acquired the Berkeley Pit, which included the East Berkeley Pit and the Butte underground mine, from Anaconda Minerals Co. in September 1985. The Berkeley Pit was closed by Anaconda in 1983 reportedly because of low metal prices, and increased energy, labor, and freight costs. Montana Resources renamed the East Berkeley Pit, the Continental Pit.

Asarco reported that 4.1 million ounces of silver in concentrate was produced at the Troy Mine, an increase of over 400,000 ounces from that of 1985.[11] At its Rock Creek silver-copper project in the Cabinet Mountains Wilderness Area, Asarco reported that applications for patents for the mineral rights had been completed and would be submitted to the U.S. Government in 1987. Work was also completed on baseline environmental studies for the project.

Pegasus Gold Inc. reported that 226,000 ounces of silver was recovered from over 6.5 million tons of ore mined at its Zortman-Landusky gold-silver mine.[12] In 1985, Pegasus recovered nearly 158,000 ounces of silver from 5.3 million tons of ore; however, there was no mining in the Landusky Pit. In 1986, construction of a 6-million-ton pad for heap leaching was completed, and construction was begun on a 30-million-ton pad.

Nevada.—The Buckhorn Mine completed its first full year of operation after completion of a capacity expansion project. In 1986, 868,000 tons of ore was leached, yielding 149,000 ounces of silver and 29,000 ounces of gold.[13] Comparable figures for 1985 were 600,000 tons of ore milled to produce nearly 77,000 ounces of silver and 13,000 ounces of gold.

Echo Bay acquired the Borealis, Manhattan, and McCoy Mines from Tenneco Inc. in October. The purchase price was $130 million plus a 1.5% royalty on the sales of precious metals produced by the properties. The mines were surface operations, with the Borealis and McCoy Mines using heap leaching to recover gold and silver, while at the Manhattan Mine, conventional milling and flotation were used for precious metal recovery.

Pegasus began mining operations at its Florida Canyon gold-silver mine in September. Ore was mined at an average of 24,000 tons per day, crushed, and agglomerated before being leached. The agglomerated ore was placed on the leach pads using a material conveyor system similar to systems used by the coal industry for loading and stacking. According to Pegasus, this was the first application of the system to heap leaching, and resulted in the cost per ton of ore placed on the leach pad at Florida Canyon being almost as low as Pegasus' costs at the Zortman-Landusky Mine in Montana where the ore is neither crushed nor agglomerated.

At the Fortitude Mine, Battle Mountain Gold Co. recovered 259,000 ounces of gold and 969,000 ounces of silver, compared with 222,000 ounces of gold and 647,000 ounces of silver in 1985.[14] The increased production occurred in part because of higher ore grades, and to the installation of a new scavenger flotation circuit in midyear. The new circuit was used to recover a portion of the silver previously lost in the tailings. Battle Mountain reported that production costs at Fortitude continued to decline, owing to improved productivity, reduced mill costs, and a slight reduction in the waste-to-ore stripping ratio. At yearend, 382 workers were employed at Fortitude.

Freeport-McMoRan Gold Co. set annual production records at the Jerritt Canyon Mine, processing over 1.3 million tons of ore.[15] Mill capacity was increased to 4,000 tons per day by increasing the mill's chlorination capacity, which allowed additional refractory ore to be processed. Construction of heap-leach facilities was completed, and leach operations began in August.

Mining operations were begun at FMC Corp.'s Paradise Peak Mine, and the first gold-silver doré bars were poured April 24. The surface mine had an estimated 12 million tons of ore grading 0.1 ounce of gold per ton and 3.8 ounces of silver per ton. Mill capacity at Paradise Peak was 4,000 tons per day. By yearend, the operation had produced 143,000 ounces of gold and nearly 1.1 million ounces of silver.[16]

In July, Pegasus acquired the Relief Canyon Mine from Lacana Mining Corp. Lacana closed the mine in 1985, reportedly owing to difficulties in gold recovery caused by the ore's clay content. Pegasus discovered in its review of Relief Canyon that the recovery could be improved by crushing and agglomerating the ore prior to leaching. The mine returned to production in November 1986. Relief Canyon was operated as a unit of Pegasus' Florida Canyon Mine, and together the two operations produced nearly 6,000 ounces of gold and over 3,000 ounces of silver during the year.

Coeur d'Alene Mines placed its Rochester Mine into production during the year. Construction began in April with prestripping of the deposit, and approximately 5 months later, on September 22, the first doré was poured. The deposit contained an estimated 103 million tons of ore reserves grading 1.6 ounces of silver per ton, and 0.01 ounce of gold per ton. At full production, the Rochester was expected to produce 4 million ounces of silver and 43,000 ounces of gold annually. From September 22 through yearend, Rochester produced 544,000 ounces of silver and 4,200 ounces of gold.[17]

Sunshine suspended mining operations at its Sixteen-to-One Mine in June, reportedly owing to the low silver price, and to the limited known reserves at the mine. In 1985, Sixteen-to-One was the second largest silver producing operation in the State with an output of over 1.3 million ounces of silver and nearly 9,000 ounces of gold. For the 6 months of operation in 1986, the mine produced 848,000 ounces of silver, and 9,000 ounces of gold.[18] The mill at Sixteen-to-One continued to operate after the mine was closed, processing broken ore stockpiled above ground. In October, Sunshine commenced mining at its Weepah Mine, approximately 20 miles from Sixteen-to-One. Ore from this mine, primarily a gold deposit with a small amount of byproduct silver, was trucked to the Sixteen-to-One mill for treatment. Mining at Weepah was expected to be completed in early 1987.

AMAX began mining operations at its Sleeper Mine in January and milling operations in March. Production for the year was nearly 131,000 ounces of gold and 100,000 ounces of silver.[19] The 1986 production was higher than expected owing to the early startup and to encountering higher than anticipated ore grades. A heap-leach facility was placed in operation at the mine in September to treat low-grade ore.

Utah.—Kennecott began a 3-year program to modernize operations at its Bingham Canyon copper mine, an important producer of byproduct silver. Included in the modernization was installation of an in-pit ore crushing system and an ore conveying system, construction of new grinding and flotation facilities, and construction of a slurry transport system to move copper concentrates and tailings to the existing smelter and tailings pond. The modernization was expected to cost $400 million and be completed in late 1988. In July, Kennecott negotiated a new labor agreement with its unionized employees. The contract, which covered a 4-year period through June 30, 1990, resulted in a 30% reduction in labor costs by reducing salaries by 23%, eliminating the cost-of-living allowance, and by reducing other benefits. Changes in local work rules to improve operating efficiencies were also included in the new contract. The mine and concentrator, closed in March 1985 because of low prices, resumed operations in December.

At the Escalante Mine, Hecla milled nearly 306,000 tons of ore to produce 2.3 million ounces of silver.[20] Owing to the low silver price, Hecla reduced hourly wages for the mine's workers by 10%, and negotiated a temporary rate reduction with the Dixie Escalante Rural Electric Association to reduce costs.

Washington.—The Cannon Mine reached full commercial production in January, approximately 1 year after the start of mining operations. During the year, nearly 117,000 ounces of gold and over 178,000 ounces of silver was produced.[21] Production was adversely impacted by ground control problems, which, according to Asamera Inc., appeared to be isolated and could be handled with additional ground support, and to a 50-day shutdown near midyear to repair a cracked ball mill trunnion bearing. Exploration and development work continued on the portion of the ore body acquired from Tenneco Inc. in 1985.

Silver production at the Knob Hill Mine, primarily a gold mine, increased to over 134,000 ounces, from 102,000 ounces in 1985.[22] Hecla completed construction of new shaft and hoisting facilities at the mine. The new facilities provided access to the recently discovered Golden Promise ore body. In late May 1986, workers at the mine rejected unionization.

Other States.—An informal survey of Alaskan silver producers by the Alaska Division of Mining and Geological and Geophysical Surveys indicated that 24,000 ounces of silver was produced in Alaska during the year, compared with about 6,000 ounces reported to the Bureau of Mines on a voluntary basis by producers.

In Michigan, the unstable wall conditions encountered at the Ropes Mine in 1985 continued to be a problem in 1986. During the second quarter, Callahan Mining Corp. modified its mining operations so that a stockpile of broken ore would be maintained in the stope for wall support, to help stabilize the surrounding ground. In late November, a new ore-hoisting shaft at the mine became operative. During the year, nearly 609,000 tons of ore grading 0.096 ounce of gold per ton and 0.28 ounce of silver per ton were milled at Ropes.

Phelps Dodge bought Kennecott's two-thirds interest in the Chino Mine. Chino is a copper-silver producer in New Mexico, in which Kennecott and Mitsubishi Corp. were partners.

Production at Asarco's Amarillo, TX, refinery was reported as 32.5 million ounces of silver, a decrease of over 9.8 million ounces from the 1985 output.[23] The decrease was attributed to mine closures and limited availability of silver-bearing raw material in the open market.

CONSUMPTION AND USES

Overall domestic silver consumption increased in 1986, owing primarily to use of silver in official U.S. coinage. Notable was the issuance in the fourth quarter of the U.S. Government's silver Eagle coin series. Each Eagle coin contained 1 troy ounce of silver and was legal tender with a $1 face value. The Eagle coin was the first silver bullion coin minted by the Government and accounted for over 4.2 million of the 7.4 million ounces of silver consumed for coinage in 1986.

Reported industrial silver consumption increased slightly in 1986, owing in part to the continued growth of the U.S. economy and to lower silver prices. The increase may indicate that at the lower, more stable prices of 1986, silver may have been able to regain some of the usage lost to silver substitutes developed when silver prices were higher and more volatile a few years before.

STOCKS

Throughout 1986, silver depository stocks held by the Commodity Exchange Inc. (COMEX) fluctuated near the yearend 1985 level of 155.3 million ounces. Using the reported ending stocks for the last trading day each month, COMEX stocks ranged from a low of 137.7 million ounces in October to a high of 158.7 million ounces in August. At yearend, COMEX stocks were 145.4 million ounces. The depository stocks held by the Chicago Board of Trade (CBT) remained near the yearend 1985 level of 17.8 million ounces throughout the first half of 1986. In August, CBT stocks dropped slightly to 16.5 million ounces. Yearend stocks held by CBT were 16.7 million ounces.

Refiner, fabricator, and dealer stocks, as reported to the Bureau of Mines, declined about 8% by yearend. The decline in industrial stocks was probably due in part to a combination of expectations for continued weak prices, and to an ample supply of silver.

The quantity of silver held in the NDS declined in 1986, reflecting the use of NDS silver for the Statue of Liberty-Ellis Island commemorative coin program and the Eagle bullion coin program.

PRICES

As in 1985, the domestic silver price, as quoted by Handy & Harman, remained in a relatively narrow range when compared with the more volatile prices of the early 1980's. The price continued the downward trend begun in mid-1983, falling briefly below $5.00 per ounce in May and June. Prior to 1986, the last time the price was less than $5.00 was on June 21, 1982, during the last domestic economic recession. The price began the year at $5.73 per ounce, was $5.37 at yearend, and averaged $5.47 for the year. Analysts attributed movements in the silver price primarily to the collapse of oil prices and the corresponding disinflationary implications for commodity prices in general, and to a weaker U.S. dollar in terms of foreign exchange.

As with the Handy & Harman silver price, movement of the London spot price occurred within a relatively narrow range, and in general continued the downward trend begun in mid-1983. The London spot price, U.S. currency equivalent as quoted in Metals Week, began 1986 at $5.31 per ounce, rising to the peak for the year of $6.31 on January 16. The low for the year of $4.85 occurred on May 20. The yearend price was $5.28 and the average for 1986 was $5.46.

On March 24, the CBT and the Mid-America Commodity Exchange (MidAm) joined together under a partnership agreement that established the CBT as the sole voting and equity member of MidAm. Under the agreement, MidAm remained a separate exchange; however, CBT members were allowed to trade contracts on the MidAm. Both exchanges offered trading opportunities in silver futures contracts.

The amount of silver represented by futures contracts traded on COMEX declined to 19.2 billion ounces in 1986, from 24.1 billion ounces the previous year. The silver trading volume at the CBT declined from 1 billion ounces in 1985 to slightly more than 500 million ounces in 1986. Silver futures trading volume on the MidAm decreased by 52 million ounces to 10 million ounces in 1986.

FOREIGN TRADE

U.S. silver exports increased slightly in 1986, probably owing in part to a weakening of the U.S. dollar in terms of most foreign currencies. The countries to which the largest increases in U.S. silver exports went were the United Kingdom, with a 4-million-ounce increase, and France, with a 2.5-million-ounce increase. In the case of both the United Kingdom and France, most of the increase was in the form of waste and scrap material. Canada recorded the largest decrease in receipts of U.S. silver.

U.S. silver imports for consumption decreased despite an increase in U.S. consumption. The decrease was probably attributable in part to the decline in U.S. futures trading activity, the weaker U.S. dollar, and the continued low silver price. The countries with the largest decreases of silver exports to the United States were Switzerland, with a decrease of nearly 10.3 million ounces, and the United Kingdom, with a decrease of 7.8 million ounces. The lower imports from Switzerland and the United Kingdom primarily represented decreases in the shipment of refined bullion.

The United States was a net importer of silver. Net import reliance calculated as a percentage of apparent consumption was approximately 60%.

WORLD REVIEW

World mine production of silver in 1986 remained essentially the same as that of 1985. Increased production by some developing countries attempting to maintain their foreign exchange earnings was nearly enough to negate declining production in countries such as the United States. Exploration for new silver sources slowed as the silver price continued to decline for the third consecutive year. Most new discoveries of silver occurred as the byproduct of gold discoveries, with Australia, Canada, Mexico, and Peru being among the most active exploration targets.

Total consumption of silver in market economy countries, according to Handy & Harman, was 403.5 million ounces, an increase of 33.6 million ounces over the revised figure for 1985. Of the total, 380.7 million ounces was used in industrial applications, an increase of 23.5 million ounces over the 1985 level. The quantity of silver used for coinage increased from 12.7 million ounces in 1985 to 22.8 million ounces in 1986.[24]

The total silver required for industrial use and coinage, and for net exports to centrally planned economy countries, by all market economy countries, including the United States, exceeded their primary production by 112.2 million ounces. The shortfall was met with silver obtained from the following sources, according to analysts at Handy & Harman: old scrap, 65 million ounces; outflow from stocks held in India, 11.1 million ounces; demonetized coin, 1 million ounces; withdrawals from Government stocks, 13.5 million ounces; and liquidation of private bullion stocks, 21.4 million ounces. Estimated net exports to centrally planned economy countries was 14.0 million ounces.[25]

Australia.—Aberfoyle Ltd. reported that nearly 321,000 tons of ore grading 13.7% zinc, 7.5% lead, 0.5% copper, 6.1 ounces of silver per ton, and 0.1 ounce of gold per ton was milled at its Que River Mine in Tasmania.[26] In 1985, 285,000 tons of ore had been milled. Workers at Que River negotiated an agreement that introduced a 38-hour workweek and a new retirement plan. The agreement reportedly required Government ratification to become effective.

At Aberfoyle's Hellyer deposit, the adit being developed to gain access to the deposit reached the ore zone in June. Exploratory development of the ore body resulted in the mining of nearly 39,000 tons of ore, some of which was used to provide bulk samples for milling tests at the converted Cleveland tin mill. The tests showed that fine grinding and selective flotation will allow the recovery of approximately 65% of the silver from the fine-grained polymetallic Hellyer ore. In October, Aberfoyle decided to expand its Cleveland mill from pilot plant size to a full-scale commercial operation capable of processing 276,000 tons of ore per year. Hellyer was expected to begin commercial production in early 1987.

In October, Rio Tinto Zinc Corp. PLC (RTZ) reduced its holding in CRA Ltd. to 49% from 52.3%, thereby completing the "Australianisation" of CRA. Prior to RTZ's sale, CRA, an important producer of byproduct silver, was considered a "foreign" company under Australia's Foreign Takeovers Act of 1975. The benefit to CRA of being publicly owned and Australian controlled will be to make it easier for CRA to begin new projects in Australia, or to buy shares in other companies operating in Australia.

Ore production at CRA's Zinc Corp. Mine in New South Wales declined by 43% in 1986, owing to a 37% reduction in the work force and an 8-week strike between May and July following proposals by the company aimed at increasing the mine's productivity. Under a new agreement, fully integrated mining operations were increased to 110 hours per week by yearend, compared with 55 hours per week under the prior agreement. Management reported that other inefficient work practices were also eliminated. In 1986, 1.4 million tons of ore was produced, compared with 2.5 million tons in 1985.[27]

At its Woodlawn Mine, primarily a zinc-copper-silver-lead mine, CRA proceeded with development of an underground mine at the site. Open pit mining at Woodlawn was virtually halted by yearend. Woodlawn produced 960,000 tons of ore in 1986, compared with over 1 million tons the year before.

At the Elura Mine, North Broken Hill Holdings Ltd. reported that ore production in fiscal year 1986 increased by 14% to a record high 1.3 million tons, 10% higher than the mine's original design capacity.[28] The Elura mill produced 198,000 tons of zinc concentrate assaying 4.7 ounces of silver per ton, and 104,000 tons of lead concentrates assaying 36.2 ounces of silver per ton. In fiscal year 1985, the Elura mill produced 157,000 tons of zinc concentrate and 91,000 tons of lead concentrate assaying 3.1 and 32.2 ounces of silver per ton, respectively. As of June 30, 1986, Elura employed 286 people, compared with 292 the previous year.

Production at North Broken Hill Holdings' North Mine was adversely affected by 28 days of work stoppages. The dispute concerned company proposed changes in work practices to improve productivity. During fiscal year ended June 30, 1986, 488,000 tons of ore was treated to produce 72,000 tons of lead concentrates assaying 35.2 ounces of silver per ton. In fiscal year 1985, 555,000 tons of ore was milled to produce 66,000 tons of lead concentrates assaying 37 ounces of silver per ton. Additionally, in fiscal year 1986, the treatment of dump material yielded 3,700 tons of zinc concentrate and 325 tons of lead concentrate, assaying 21 and 35 ounces of silver per ton, respectively. Employment at the North Mine declined to 751 from 848 owing in part to a voluntary early retirement program offered by the company to reduce costs and improve productivity.

In 1986, Placer Development Ltd. combined all of its mining interests in Australia, Papua New Guinea, and the South Pacific region under a new subsidiary, Placer Pacific Ltd. Included in Placer Pacific was Placer Development's 70% interest in Kidston Gold Mines Ltd., operator of the Kidston Mine. The subsequent public sale of a 21.4% interest in Placer Pacific reduced Placer Development's interest in the Kidston Mine to 55%, fulfilling the Government of Australia's requirement for Placer Development to reduce its ownership of Kidston. During its first full year of operation, Kidston milled nearly 4.1 million tons of gold-silver ore.

At the Mount Isa Mine, MIM Holdings Ltd. treated 11 million tons of ore, of which 5.1 million tons was silver-lead-zinc ore. In fiscal year 1986, MIM produced 13.5 million ounces of refined silver.[29] The total quantity of ore treated was a record high for the mine, and occurred despite a 2-week work stoppage in November over a safety issue at a nearby project. A new labor agreement was negotiated with Mount Isa workers in December, covering a 2-year period. Development of a decline to house a conveyor system to transport ore from the southern copper ore body was more than 50% complete at the end of the fiscal year. The decline was being developed using Mount Isa's innovative continuous mining machine.

Pan Australian Mining Ltd. officially dedicated its Mount Leyshon Mine on October 10. The mine reportedly had 6.9 million tons of reserves grading 0.1 ounce of gold per ton and 0.2 ounce of silver per ton.

Canada.—Silver production at Brunswick Mining and Smelting Corp. Ltd.'s No. 12 Mine increased to about 6.7 million ounces in concentrate from about 6.2 million ounces in 1985.[30] Projects were under way in 1986 to enable mining of deeper ore at the mine. Efforts to contain costs and improve efficiency included a voluntary early retirement program that reduced employment by 7% to 1,498 and changes to the flotation circuit to improve zinc recovery. At its Smelter Div., Brunswick produced nearly 3 million ounces of doré from 236,000 tons of concentrate, dust, and residues. Smelter output improved owing to the fact that only one major shutdown occurred during the year, compared with three major shutdowns in 1985, and to improved sinter plant and blast furnace operation. In 1985, the Smelter Div. produced 2.7 million ounces of doré.

Cominco Ltd. and Lornex Mining Corp. Ltd. combined their operations in the Highland Valley area of British Columbia on July 1. The partnership, in which Cominco had a 55% interest and Lornex a 45% interest, allowed ore from Cominco's high-grade Valley Mine to be processed at Lornex's larger, more efficient mill. For the final 6 months of 1986, the partnership produced 340,500 ounces of silver.

At its Sullivan Mine, Cominco milled 1.86 million tons of ore with an average silver content of 1.4 ounces per ton. The tonnage milled was 22% lower than in 1985 owing in part to the mill's closure during July and August because of low prices. Employment at Sullivan declined from 986 in 1985 to 827 at yearend 1986.

At Cominco's Trail smelter-refinery complex, construction of a new lead smelter was begun. The new smelter was expected to be operational in 1989. Production of refined silver at the facility declined in 1986, owing to lower precious metal content of purchased concentrates, and to a 1-month shutdown of the facility in August to reduce zinc and lead supplies. In 1986, 7.9 million ounces of refined silver was produced, compared with 9.8 million ounces in 1985. Employment at Trail declined from 2,562 to 2,291 in 1986.

Kerr Addison Mines Ltd. acquired a

49.3% interest in Corp. Falconbridge Copper in late August from Falconbridge Ltd. Corp. Falconbridge Copper, a producer of base and precious metals, with three operating divisions, had a number of byproduct silver properties under development in 1986.

At its Opemiska Div., in Quebec, Corp. Falconbridge Copper produced 112,825 ounces of byproduct silver along with gold and copper.[31] Copper concentrates had to be stockpiled at the minesite from November 1986 through February 1987 owing to a strike at Noranda Inc.'s Horne smelter. The Opemiska Div. consisted of the Springer, Cook, and Perry underground mines. Employment at the division decreased by 58, to 306 workers at yearend 1986.

The Corbet Mine of Corp. Falconbridge Copper's Lac Dufault Div. was closed in September. By yearend, the mine was decommissioned and sealed. Production in 1986 was 19 million pounds of copper, 7 million pounds of zinc, 7,363 ounces of gold, and 121,861 ounces of silver.[32]

In December, NERCO Inc. acquired the Con Mine from Cominco for approximately $47 million. The underground mine, in Canada's Northwest Territories, began production in 1938. In 1986, the Con Mine produced 89,000 ounces of gold and 24,000 ounces of silver.[33]

Newmont Mining Corp. reported that 386,019 ounces of silver in concentrate was produced from the treatment of 7.6 million tons of ore at the Similkameen Mine in British Columbia.[34] Workers at Similkameen approved a new 45-month labor contract that reportedly reduced wages and benefits. The company also obtained electricity rate reductions as part of the Government-sponsored aid aimed at keeping the mine open.

Noranda continued to streamline its operations in 1986, owing in part to metal prices that remained near record lows in terms of constant dollars and to changing markets that have reduced or eliminated metal use in some applications. Operations were suspended at the Gallen Mine, a 51%-owned operation in Quebec, which produced 84,000 ounces of silver in 1985. Productivity was improved through the replacement of old equipment, increased use of computers in processing and purchasing, and by the elimination of some management layers.

Noranda reported that the Geco Mine produced 1.3 million ounces of contained silver, that Mattabi Mines produced 1.6 million ounces, and that the Lyon Lake Mine produced 1.2 million ounces.[35] In 1985, these mines produced 1.3 million ounces, 555,000 ounces, and 1.4 million ounces, respectively. In their first full year of operation since reopening, Noranda's Bell Mine produced 124,000 ounces of silver and the Brenda Mine produced 294,000 ounces of silver. Both mines were reopened in 1985, after obtaining labor and Government concessions. In 1985, after reopening, the Bell and Brenda Mines produced 32,000 and 80,000 ounces of silver, respectively.

The mill expansion project begun at Placer Development's Equity silver mine in October 1985 was completed in May 1986. The project allowed the ore to be treated more economically. In 1986, 3.3 million tons of ore was milled to produce 5.5 million ounces of silver, compared with milling 2.3 million tons of ore to produce 4.6 million ounces of silver in 1985.[36]

In September, Numachiaq Inc., a holding company formed by Teck Corp., MIM, and Metallgesellschaft AG, bought a 29.5% interest in Cominco from Canadian Pacific Enterprises Ltd. Teck had a 50% interest in the holding company, and MIM and Metallgesellschaft each had a 25% interest.

At the Beaverdell Mine in British Columbia, Teck milled 36,714 tons of ore to produce 348,311 ounces of silver.[37] In 1985, 336,426 ounces of silver was produced from 41,105 tons of ore. An exploration program to locate and delineate higher grade silver ore and additional gold ore was conducted at the mine under a British Columbia Government financial assistance program. The results were expected to be available in mid-1987.

Mexico.—Silver production by México Desarrollo Industrial Minero S.A. (MEDIMSA) increased in 1986, owing in part to the start of production at the new Rosario Mine and to increased production from the Charcas Mine. The Rosario Mine began commercial production in the first quarter of the year. Production rose at Charcas after completion of a capacity expansion project in 1985. MEDIMSA produced 25.6 million ounces of silver in 1986, compared with 22.9 million ounces the previous year.[38]

At the Real de Ángeles Mine, silver production increased 16%, to nearly 13 million ounces, owing to higher ore grades, increased millfeed, and improved recoveries.[39] In 1985, Real de Ángeles produced 11.2 million ounces by milling 5.4 million tons of ore grading 2.67 ounces of silver per ton. The 13 million ounces produced in 1986 was recovered from 5.7 million tons of ore grading 2.72 ounces of silver per ton. Mill throughput was aided by the installation of a secondary crusher. Instrumentation added to the grinding and flotation circuits helped increase silver recovery to 81.2% from 75.4%.

AMAX reported that the mines of its affiliated companies, Compãnia Fresnillo S.A. de C.V., Zimapán S.A., and Rosario México S.A. de C.V., produced approximately 12.8 million ounces of silver and 16,900 ounces of gold in fiscal year 1986. Lacana reported that its 30%-owned Torres mining complex in Guanajuato produced over 3.5 million ounces of silver. The slight decrease from the 3.8 million ounces produced in 1985 was attributed to the ore's lower silver grade, and lower tonnage milled.[40] Lacana reported that almost 299,000 ounces of silver was produced at its 40%-owned Encantada Mining Group in Coahuila, a significant decrease from the previous year's production of almost 1.2 million ounces. The three mines that make up the Encantada Group were closed in April, owing to the relatively low silver price, and remained closed at yearend.

Peru.—Silver production in Peru increased slightly despite strikes that idled facilities at Empresa Minera del Centro del Perú (Centromín Perú) and Southern Peru Copper Corp. for 7 and 5 weeks, respectively. Centromín Perú remained the largest Peruvian silver producing company, followed by Cía. de Minas Buenaventura S.A. and Cía. Minera Arcata S.A. In Peru, as in the United States, the continued low silver price forced mining companies to emphasize cost reduction and increased productivity. Capacity expansions and equipment replacement were among the most widely used approaches to achieve reduced costs of operation and increased productivity.

St. Joe sold its Cía. Minerales Santander Inc. and Cía. Minera del Madrigal S.A. subsidiaries near midyear to a group of companies headed by Docarb S.A., a Peruvian mining concern. In 1985, the Santander Mine reportedly produced 66,800 ounces of byproduct silver and the Madrigal Mine, 346,000 ounces of silver.

Other Countries.—In fiscal year 1986, St. Joe Gold Corp. began a project to expand the mill capacity at the El Indio Mine, in Chile, to 2,650 tons of ore per day. The expansion included some process changes, which were expected to increase gold recovery. In fiscal year 1985, St. Joe Gold raised the El Indio mill capacity to 2,100 tons of ore per day. The fiscal year 1986 expansion was made to enable the mill to treat ore from the El Tambo Mine, 5 miles southeast of El Indio. In September, St. Joe Gold began heap-leach operations at El Tambo. For the year ended October 31, 1986, El Indio produced nearly 1.1 million ounces of silver contained in either its direct smelting ore or in its mill products.[41]

Boliden AB bought the Black Angel Mine, a lead-zinc-silver producer in Greenland, from Greenex A/S in June. In 1985, the mine produced approximately 138,000 tons of zinc concentrates and 28,000 tons of lead concentrates.

TECHNOLOGY

Reported silver-related research and development was widespread in 1986. A sample of the reported work included (1) the development of various silver alloys for use in electrical contacts; (2) investigations into the antibacterial effect of silver in some medical applications; and (3) applications for various silver catalysts.

Numerous reports on silver-related research were summarized by the staff of the Silver Institute in its "New Silver Technology" publication.[42]

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[1]Physical scientist, Division of Nonferrous Metals.
[2]Ounce as used throughout this chapter refers to the troy ounce.
[3]ASARCO Incorporated. 1986 Annual Report. 32 pp.
[4]Echo Bay Mines Ltd. 1986 Annual Report. 56 pp.
[5]Clayton Silver Mines Inc. 1986 10K Report. 30 pp.
[6]Hecla Mining Co. 1986 Annual Report. 28 pp.
[7]Sunshine Mining Co. 1986 Annual Report. 60 pp.
[8]Coeur d'Alene Mines Corp. 1986 Annual Report. 28 pp.
[9]Cominco Ltd. 1986 Annual Report. 41 pp.
[10]Work cited in footnote 3.
[11]Work cited in footnote 3.
[12]Pegasus Gold Inc. 1986 10K Report. 72 pp.
[13]Work cited in footnote 9.
[14]Battle Mountain Gold Co. 1986 Annual Report. 36 pp.
[15]Freeport-McMoRan Gold Co. 1986 Annual Report. 32 pp.
[16]FMC Corp. 1986 Annual Report. 44 pp.
[17]Work cited in footnote 8.
[18]Work cited in footnote 7.
[19]AMAX Inc. 1986 10K Report. 69 pp.
[20]Work cited in footnote 6.
[21]Asamera Inc. 1986 Annual Report. 52 pp.
[22]Work cited in footnote 6.
[23]Work cited in footnote 3.
[24]Handy & Harman. The Silver Market, 1986. 71st Annual Report. 26 pp.
[25]Work cited in footnote 24.
[26]Aberfoyle Ltd. 1986 Annual Report. 24 pp.
[27]CRA Ltd. 1986 Annual Report. 60 pp.
[28]North Broken Hill Holdings Ltd. 1986 Annual Report. 60 pp.
[29]MIM Holdings Ltd. 1986 Annual Report. 33 pp.
[30]Brunswick Mining and Smelting Corp. Ltd. 1986 Annual Report. 21 pp.
[31]Kerr Addison Mines Ltd. 1986 Annual Report. 19 pp.
[32]Work cited in footnote 31.
[33]NERCO Inc. 1986 10K Report. 35 pp.
[34]Newmont Mining Corp. 1986 Annual Report. 46 pp.
[35]Noranda Inc. 1986 Annual Report. 52 pp.
[36]Placer Development Ltd. 1986 Annual Report. 46 pp.
[37]Teck Corp. 1986 Annual Report. 36 pp.
[38]Work cited in footnote 3.
[39]Work cited in footnote 36.
[40]Lacana Mining Corp. 1986 Annual Report. 37 pp.
[41]St. Joe Gold Corp. 1986 10K Report. 26 pp.
[42]Silver Institute. New Silver Technology, Silver Summaries From the Current World Literature. Jan.-Apr.-July-Oct. 1986; available from the Silver Institute, 1001 Connecticut Ave. NW., Washington, DC 20036.

Table 2.—Mine production of recoverable silver in the United States, by State

(Troy ounces)

State	1982	1983	1984	1985	1986
Alaska	2,080	4,123	W	W	W
Arizona	6,309,327	4,491,532	4,246,616	4,885,310	4,202,316
California	34,048	26,899	W	115,478	155,176
Colorado	1,934,312	2,145,616	2,199,888	548,696	644,574
Idaho	14,830,351	17,684,278	18,869,186	18,827,948	11,206,851
Illinois	W	W	W	W	W
Michigan	W	--	--	W	W
Missouri	2,241,159	2,021,343	1,401,070	1,635,301	1,459,185
Montana	6,168,711	5,707,963	5,652,847	4,009,979	4,773,264
Nevada	3,142,263	5,179,394	6,477,032	4,946,523	6,408,783
New Mexico	804,594	W	W	W	W
New York	27,212	33,137	W	W	W
Oregon	--	856	W	--	--
South Carolina	--	--	--	W	W
South Dakota	26,241	62,314	50,036	63,156	W
Tennessee	W	W	W	W	W
Utah	4,342,333	4,566,610	W	W	W
Washington	W	W	W	W	W
Total	40,248,409	43,430,937	44,591,671	r39,432,973	34,220,015

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	1982	1983	1984	1985r	1986
January	3,643	3,101	3,774	3,429	3,669
February	3,283	3,051	3,897	3,049	3,229
March	4,039	3,776	4,202	3,389	3,253
April	3,733	3,681	4,027	3,211	3,155
May	3,713	3,675	3,892	3,355	2,854
June	3,568	3,767	3,780	3,234	2,754
July	3,090	3,588	3,576	3,238	2,680
August	2,987	3,755	3,719	3,359	2,588
September	3,014	3,563	3,245	2,922	2,600
October	2,889	3,408	3,662	3,847	2,612
November	3,241	3,414	3,323	3,122	2,351
December	3,048	4,652	3,495	3,278	2,475
Total	40,248	43,431	44,592	39,433	34,220

rRevised.

Table 4.—Twenty-five leading silver producing mines in the United States in 1986, in order of output

Rank	Mine	County and State	Operator	Source of silver
1	Troy	Lincoln, MT	ASARCO Incorporated	Silver-copper ore.
2	Galena	Shoshone, ID	do	Silver ore.
3	Coeur	do	do	Do.
4	Candelaria	Mineral, NV	NERCO Metals Inc	Do.
5	Escalante	Iron, UT	Helca Mining Co	Do.
6	DeLamar	Owyhee, ID	NERCO DeLamar Co	Gold-silver ore.
7	Tyrone	Grant, NM	Phelps Dodge Corp	Copper ore.
8	Lucky Friday	Shoshone, ID	Hecla Mining Co	Silver ore.
9	Sunshine	do	Sunshine Mining Co	Do.
10	Paradise Peak	Nye, NV	FMC Corp	Gold ore.
11	Battle Mountain	Lander, NV	Battle Mountain Gold Co	Do.
12	White Pine	Ontonagon, MI	Copper Range Co	Copper ore.
13	Sixteen-to-One	Esmeralda, NV	Sunshine Mining Co	Silver ore.
14	Sierrita	Pima, AZ	Cyprus Sierrita Corp	Copper ore.
15	Morenci	Greenlee, AZ	Phelps Dodge Corp	Do.
16	Bagdad	Yavapai, AZ	Cyprus Bagdad Copper Co	Do.
17	Mission	Pima, AZ	ASARCO Incorporated	Do.
18	Rochester	Pershing, NV	Coeur Rochester Inc	Silver ore.
19	San Manuel	Pinal, AZ	Magma Copper Co	Copper ore.
20	Buick	Iron, MO	The Doe Run Co	Lead-zinc ore.
21	Pima	Pima, AZ	ASARCO Incorporated	Copper ore.
22	Leadville	Lake, CO	do	Lead-zinc ore.
23	Eisenhower	Pima, AZ	Eisenhower Mining Co	Copper ore.
24	Ray	Pinal, AZ	ASARCO Incorporated	Do.
25	Magmont	Iron, MO	Cominco American Incorporated	Lead ore.

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
1982	2,012	13,087,462	852,500	1,213,247	2,769,495	5,422,706	23,577,319
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	[r]26,888,194	[r]1,647,506	1,043,854	2,039,797	4,302,681	24,012,856
1986:							
Alaska	W	--	--	--	--	--	--
Arizona	W	W	W	--	--	W	W
California	W	W	W	--	--	--	--
Colorado	--	W	W	--	--	--	--
Idaho	--	748,327	25,979	W	W	W	W
Illinois	--	--	--	--	--	--	--
Michigan	--	W	W	--	--	--	--
Missouri	--	--	--	--	--	--	--
Montana	--	W	W	--	--	W	W
Nevada	--	17,598,863	2,625,779	W	W	W	W
New Mexico	--	W	W	W	W	--	--
New York	--	--	--	--	--	--	--
South Carolina	--	W	W	--	--	--	--
South Dakota	--	W	W	--	--	--	--
Tennessee	--	--	--	--	--	--	--
Utah	--	2,070,765	23,361	--	--	W	W
Washington	--	W	W	--	--	--	--
Total	6,490	42,914,649	3,858,979	869,099	1,809,687	5,555,677	15,835,513
Percent of total silver	([1])	XX	11	XX	5	XX	46

Year and State	Lode: Copper ore, Short tons	Lode: Copper ore, Troy ounces of silver	Lode: Lead ore, Short tons	Lode: Lead ore, Troy ounces of silver	Lode: Zinc ore, Short tons	Lode: Zinc ore, Troy ounces of silver
1982	190,713,274	9,420,220	9,407,482	2,244,737	713,228	27,212
1983	[2]171,614,767	[2]7,344,180	8,050,251	2,021,346	753,044	33,137
1984	[2]166,255,710	[2]6,526,427	5,272,047	1,723,368	923,843	61,505
1985	154,658,676	9,659,224	7,091,945	1,635,301	949,988	28,285
1986:						
Alaska	--	--	--	--	--	--
Arizona	115,058,758	4,093,610	--	--	--	--
California	--	--	--	--	--	--
Colorado	--	--	--	--	W	W
Idaho	--	--	--	--	--	--
Illinois	--	--	--	--	--	--
Michigan	W	W	--	--	--	--
Missouri	--	--	W	W	--	--
Montana	W	W	--	--	--	--
Nevada	--	--	--	--	--	--
New Mexico	W	W	--	--	--	--
New York	--	--	--	--	W	W
South Carolina	--	--	--	--	--	--
South Dakota	--	--	--	--	--	--
Tennessee	--	--	--	--	--	--
Utah	W	W	--	--	--	--
Washington	--	--	--	--	--	--
Total	[2]146,673,936	[2]10,800,155	W	W	W	W
Percent of total silver	XX	32	XX	W	XX	W

See footnotes at end of table.

Table 5.—Silver produced in the United States, by State, type of mine, and class of ore—Continued

Year and State	Lode				Total	
	Copper-lead, lead-zinc, copper-zinc, and copper-lead-zinc ores		Old tailings, etc.			
	Short tons	Troy ounces of silver	Short tons	Troy ounces of silver	Short tons	Troy ounces of silver
1982	2,125,147	919,329	433,446	[3] [4]435,585	223,115,992	40,248,409
1983	([5])	([5])	[6]856,550	[3] [7]1,007,082	208,262,215	43,430,937
1984	([5])	([5])	[6]15,377,223	[3] [7]726,280	221,801,849	44,591,671
1985	([5])	([5])	[6]4,271,240	[3] [7]403,570	[r]199,206,578	[r]39,432,973
1986:						
Alaska	--	--	--	--	--	W
Arizona	--	--	W	W	115,184,515	4,202,316
California	--	--	--	--	W	155,176
Colorado	--	--	W	W	3,133,937	644,574
Idaho	--	--	--	--	2,145,053	11,206,851
Illinois	--	--	--	W	--	W
Michigan	--	--	--	--	W	W
Missouri	W	W	--	--	5,616,767	1,459,185
Montana	--	--	--	--	16,531,454	4,773,264
Nevada	--	--	--	--	22,232,387	6,408,783
New Mexico	--	--	6,146	6,063	W	W
New York	--	--	--	--	W	W
South Carolina	--	--	--	--	W	W
South Dakota	--	--	--	--	W	W
Tennessee	W	W	--	--	W	W
Utah	--	--	--	--	W	W
Washington	--	--	--	--	W	W
Total	W	W	429,116	[3]450,062	202,059,244	34,220,015
Percent of total silver	XX	W	XX	1	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 copper-zinc ore and silver recovered from copper-zinc ore in Tennessee to avoid disclosing company proprietary data.
[3]Includes silver recovered from tungsten ore in California and silver recovered from fluorspar ore in Illinois.
[4]Includes silver recovered from molybdenum ore in Nevada.
[5]To avoid disclosing company proprietary data, copper-zinc ore and silver recovered from copper-zinc ore in Tennessee are included in totals for copper ore, and lead-zinc ore and silver recovered from lead-zinc ore in Colorado and Idaho are included in total "Old tailings, etc."
[6]Includes lead-zinc ore in Colorado and Idaho to avoid disclosing company proprietary data.
[7]Includes silver recovered from lead-zinc ore in Colorado and Idaho to avoid disclosing company proprietary data, and includes silver recovered from molybdenum ore in Nevada.

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)
1982	7,875,468	5,460,897	12,295,132	1,384,326
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	[r]14,875,363	2,701,360
1986	19,269,750	7,504,350	27,620,640	3,641,741

[r]Revised.
[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)
1982	--	--	20,170,600	6,845,223	202,592,304	5,256,331	32,719,805	353,088	681,369	223,115,992	40,246,397
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	--	--	[r]30,297,266	9,521,264	168,650,998	[r]4,523,641	[r]29,313,819	258,314	591,456	[r]199,206,578	[r]39,426,539
1986:											
Arizona	--	--	--	--	115,018,294	2,427,182	4,085,428	W	W	W	W
California	--	--	6,117,382	153,232	W	W	W	--	--	W	W
Colorado	W	W	2,749,483	67,411	W	W	W	W	W	3,133,937	644,574
Idaho	--	--	W	W	548,267	27,239	9,468,054	W	W	2,145,053	11,206,851
Illinois	--	--	--	--	--	W	W	--	--	--	W
Michigan	--	--	W	W	W	W	W	--	--	W	W
Missouri	--	--	--	--	5,616,767	568,054	1,459,185	--	--	5,616,767	1,459,185
Montana	--	--	W	W	7,642,033	45,539	4,450,065	W	W	16,531,454	4,773,264
Nevada	W	W	21,132,372	6,391,424	W	W	W	--	--	22,232,387	6,408,783
New Mexico	--	--	W	W	W	W	W	W	W	W	W
New York	--	--	--	--	W	W	W	--	--	W	W
South Carolina	--	--	W	W	--	--	--	--	--	W	W
South Dakota	--	--	W	W	--	--	--	--	--	W	W
Tennessee	--	--	--	--	W	W	W	--	--	W	W
Utah	--	--	2,376,482	2,313,361	W	W	W	--	--	W	W
Washington	--	--	W	W	W	W	W	--	--	W	W
Total	752,421	10,396	46,890,390	11,146,091	154,212,790	3,904,999	22,761,386	203,643	295,652	202,059,244	34,213,525

[r]Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."

[1]Includes old tailings and some nonsilver-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	1982[r]	1983[r]	1984[r]	1985[r]	1986
Concentrates and ores:					
Domestic and foreign	48,615	57,759	59,331	53,808	42,413
Old scrap	29,999	29,415	27,842	27,830	23,159
New scrap	35,195	38,158	42,091	44,643	43,390
Total	113,809	[1]125,331	129,264	126,281	108,962

[r]Revised.
[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]	1982	1983	1984	1985	1986
Electroplated ware	3,254	3,154	3,542	3,660	3,724
Sterlingware	6,579	7,022	3,638	3,527	3,935
Jewelry	6,260	[r]6,861	5,773	5,779	4,621
Photographic materials	51,769	51,827	55,322	57,895	55,449
Dental and medical supplies	1,688	1,532	1,569	[r]1,480	1,474
Mirrors	970	970	970	970	970
Brazing alloys and solders	7,384	5,837	5,889	[r]5,593	6,432
Electrical and electronic products:					
Batteries	4,167	2,800	2,671	2,470	3,722
Contacts and conductors	27,730	26,298	25,633	[r]27,509	27,406
Bearings	228	170	260	[r]190	375
Catalysts	2,418	2,424	2,448	2,409	2,313
Coins, medallions, commemorative objects	1,832	2,979	2,564	2,514	3,957
Miscellaneous[2]	4,562	4,567	4,562	4,559	4,562
Total net industrial consumption[3]	118,840	[r]116,440	114,841	[r]118,555	118,940
Coinage	1,846	2,128	2,665	355	7,427
Total consumption	120,686	[r]118,568	117,506	[r]118,910	126,367

[r]Revised.
[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)

	1982	1983	1984	1985	1986
Industry	20,467	[r]17,449	[r]21,217	[r]18,467	16,278
Futures exchanges	106,182	151,232	137,631	173,144	162,089
U.S. Department of the Treasury	36,768	34,565	31,889	32,621	33,819
U.S. Department of Defense	1,750	100	342	460	2,500
National Defense Stockpile	137,500	137,500	137,500	137,500	127,306

[r]Revised.

Table 11.—U.S. silver prices

(Dollars per troy ounce)

Period	Low Price	Low Date	High Price	High Date	Average
1982	4.88	June 21	11.21	Dec. 29	7.95
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:					
January	5.73	Jan. 2	6.20	Jan. 27	6.05
February	5.61	Feb. 28	6.03	Feb. 3	5.87
March	5.33	Mar. 31	5.77	Mar. 17, 18	5.64
April	5.05	Apr. 28	5.47	Apr. 11	5.23
May	4.87	May 20	5.25	May 30	5.11
June	5.01	June 27	5.38	June 10	5.15
July	4.99	July 21	5.11	July 8	5.05
August	5.11	Aug. 27	5.51	Aug. 11	5.22
September	5.19	Sept. 2	6.00	Sept. 22	5.68
October	5.55	Oct. 15, 17	5.81	Oct. 22	5.67
November	5.24	Nov. 26	5.81	Nov. 10	5.60
December	5.27	Dec. 30	5.47	Dec. 15	5.36
Year	4.87	May 20	6.20	Jan. 27	5.47

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
1982	47	$368	10,937	$87,644	1,610	$14,756	12,876	$105,977	25,470	$208,748
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:										
Belgium-Luxembourg	148	836	1,445	9,227	9	66	72	369	1,674	10,497
Brazil	--	--	25	147	42	306	744	4,442	811	4,894
Canada	4	29	878	5,082	364	2,001	1,358	8,394	2,603	15,507
France	--	--	4,308	23,451	17	123	--	--	4,326	23,574
Germany, Federal Republic of	--	--	222	1,355	318	1,918	17	105	557	3,379
Japan	--	--	55	305	364	2,458	4,152	22,638	4,571	25,401
Netherlands	--	--	60	477	1	7	--	--	61	485
Singapore	84	615	--	--	--	--	--	--	84	616
Sweden	--	--	1,250	6,794	86	471	--	--	1,335	7,265
Switzerland	--	--	--	--	134	894	1	8	135	901
Taiwan	--	--	--	--	245	1,693	--	--	245	1,693
United Kingdom	49	151	4,642	25,713	206	1,364	686	3,897	5,583	31,124
Uruguay	--	--	--	--	--	--	3,061	16,823	3,061	16,823
Other	--	--	30	176	21	135	18	109	69	420
Total[1]	284	1,630	12,913	72,729	1,805	11,436	10,109	56,785	25,114	142,581

[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
1982	12,530	$91,638	2,837	$11,979	5,173	$37,308	96,917	$786,154	117,458	$927,079
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:										
Belgium-Luxembourg	--	--	30	181	1	10	13,898	76,484	13,929	76,674
Bolivia	759	4,161	17	100	1	7	1	4	777	4,272
Brazil	437	2,431	1	3	21	102	203	1,267	661	3,804
Canada	560	3,151	1,516	8,386	2,018	11,489	42,787	238,328	46,881	261,354
Chile	227	1,191	--	--	5,888	32,538	418	2,430	6,534	36,160
Dominican Republic	--	--	--	--	857	5,200	586	3,584	1,444	8,785
Finland	--	--	--	--	108	570	--	--	108	570
Germany, Federal Republic of	--	--	--	--	4	35	1,346	7,655	1,349	7,690
Kenya	--	--	--	--	--	--	189	1,112	189	1,112
Korea, Republic of	--	--	--	--	43	184	354	2,200	396	2,384
Liberia	--	--	--	--	(3)	8	164	1,042	164	1,049
Malaysia	--	--	53	231	--	--	50	260	103	491
Mexico	3,333	18,727	62	432	167	864	44,426	236,691	47,989	256,713
Netherlands	--	--	--	--	--	--	1,791	10,148	1,791	10,148
Peru	36	140	164	870	457	2,575	9,428	52,953	10,086	56,538
United Kingdom	118	377	(3)	3	2,566	14,942	9,154	50,696	11,838	66,019
Yugoslavia	--	--	--	--	--	--	417	2,523	417	2,523
Other	45	748	23	167	10	65	155	917	234	1,896
Total[2]	5,516	30,926	1,867	10,372	12,141	68,590	125,365	688,296	144,890	798,183

[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.
[3]Less than 1/2 unit.

Source: Bureau of the Census.

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

(Thousand troy ounces)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Algeria[e]	110	120	120	120	120
Argentina	2,684	2,500	1,984	2,189	2,200
Australia	29,156	33,208	31,260	[e]35,000	35,000
Bolivia	5,472	6,025	4,560	3,580	3,200
Brazil[3]	760	486	829	[r e]1,013	1,490
Bulgaria[e]	930	930	930	930	910
Burma	526	558	455	568	[4]527
Canada	42,246	35,559	42,655	38,484	[4]39,190
Chile	12,288	15,055	15,766	16,633	[4]16,110
China[e]	2,500	2,500	2,500	[r]2,500	3,000
Colombia[5]	136	99	130	153	160
Costa Rica[e]	2	2	2	2	2
Czechoslovakia	1,061	964	1,029	[e]1,000	1,000
Dominican Republic	2,198	1,329	1,207	1,581	1,320
Ecuador	10	3	2	[e]2	2
El Salvador	86	22	22	(6)	--
Fiji	19	13	15	15	22
Finland	1,188	980	1,123	[e]1,100	1,100
France	983	696	770	849	[4]832
German Democratic Republic	1,450	1,380	1,290	1,400	1,200
Germany, Federal Republic of	1,279	1,167	1,225	1,090	965
Ghana[e]	[4]17	14	14	14	14
Greece	1,582	1,797	[e]1,800	[e]1,700	1,700
Greenland	405	492	334	[r e]300	[4]385
Guatemala[e]	3	--	--	--	--
Honduras	2,100	2,587	2,697	2,765	2,700
India[5]	463	469	862	816	800
Indonesia	1,134	1,135	1,121	1,175	1,270
Ireland	352	309	279	276	[4]262
Italy[5 7]	1,791	2,361	1,554	2,301	[4]1,813
Japan	9,843	9,877	10,403	10,915	[4]11,307
Korea, North[e]	1,600	1,600	1,600	1,600	1,600
Korea, Republic of	3,237	3,366	3,759	3,990	4,000
Malaysia (Sabah)	502	481	470	522	500
Mexico	59,175	63,607	75,340	73,167	75,200
Morocco[e]	2,640	2,850	2,410	[4]2,733	1,600
Namibia	2,812	3,535	3,255	3,404	[4]3,148
New Zealand	--	(8)	--	--	--
Nicaragua	76	63	[e]50	[4]30	25
Papua New Guinea	1,387	1,524	1,427	[e]1,483	1,500
Peru	[r]41,957	[r]50,477	53,080	58,230	61,920
Philippines	1,984	1,823	1,574	1,685	[4]1,688
Poland	21,123	21,798	23,920	26,717	27,000
Portugal	[r]31	[r]20	22	33	[4]17
Romania[e]	850	820	810	810	800
Solomon Islands	(8)	(8)	--	--	--
South Africa, Republic of	6,943	6,513	6,997	6,700	[4]7,145
Spain	3,787	1,496	4,999	9,482	7,500
Sweden	5,395	5,491	5,793	6,102	6,300
Taiwan	504	345	364	366	406
Tunisia	115	90	[e]85	26	30
Turkey[e]	220	220	220	220	220
U.S.S.R.[e 5]	46,900	47,200	47,400	47,900	48,200
United States	40,248	43,431	44,592	39,433	[4]34,220
Yugoslavia[5]	3,343	3,987	4,051	5,015	5,000
Zaire	1,751	1,288	1,225	1,516	1,500
Zambia	887	933	795	607	[4]861
Zimbabwe	918	938	893	799	800
Total	[r]371,159	[r]386,533	412,069	421,041	419,781

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

[1]Recoverable content of ores and concentrates produced unless otherwise specified. Table includes data available through June 30, 1987.

[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): 1982—123; 1983—247; 1984—250; 1985—434; and 1986—640 (estimated).

[4]Reported figure.

[5]Smelter and/or refinery production.

[6]Revised to zero.

[7]Includes production from imported ores.

[8]Less than 1/2 unit.

Slag—Iron and Steel

By Peter J. Linstrom[1]

Sales of iron and steel slag were essentially unchanged from those of 1985. A decrease in the sales of steel slag was offset by an increase in the sales of iron-blast-furnace slag. Air-cooled iron-blast-furnace slag continued to comprise the largest portion of iron and steel slag sold, accounting for roughly two-thirds of all iron and steel slag sold.

The construction industry was the major user of iron and steel slag products. Air-cooled iron-blast-furnace slag was used mainly for road base, concrete aggregate, asphaltic concrete aggregate, railroad ballast, and fill. The use of air-cooled iron slag for road base increased significantly, reaching levels close to those prior to a decline in sales in 1985. Granulated and expanded iron-blast-furnace slags were primarily used as a lightweight concrete aggregate and for the production of concrete products and cement. Steel slag was typically used as a road base and fill. The average unit values of iron slag and steel slag increased 5% and 7% over those of 1985, respectively.

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, 94 responded, representing nearly 100% of total sales or use data shown in table 1. Data for the nonrespondent were estimated based on prior year slag sales data. Of the 94 respondents, 4 reported their operations as idle.

DOMESTIC PRODUCTION

Production of iron and steel slags, byproducts of the ironmaking and steelmaking processes, is not reported to the Bureau of Mines. Domestic production of both iron and steel slags decreased in 1986 owing to decreased production of iron and steel. Sales and use of iron and steel slag did not change significantly from that of 1985. Consumption of iron-blast-furnace slag increased slightly, offsetting a small decrease in the consumption of steel slag. Although iron slag production decreased owing to a drop in iron production, increased sales of iron slag were possible owing to stockpiling of slag by some processors during periods of low demand for slag products. Slag sales generally reflect the demand generated by the construction industry for slag products.

Iron-blast-furnace slag sold or used increased slightly, totaling 15.4 million short tons valued at $92.8 million. Approximately two-thirds of this, in decreasing order, was produced in Indiana, Pennsylvania, Ohio, and Michigan. Of the iron slag sold or used, 88% was air cooled, 8% was granulated, and the remainder was expanded slag. During 1986, 34 plants processed iron slag. Steel slag sold or used decreased 5% in quantity to 5.7 million tons but increased in value to $17.9 million; 60 plants processed steel slag, and 4 plants were idle.

Of all iron and steel slag products sold, 88% traveled by truck with an average marketing range of 30 miles; 6% traveled by waterway with an average range of 560 miles; and 5% traveled by rail with an average range of 150 miles. The remaining 1% was used at the plant where it was processed.

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								Steel slag		Total slag[2]	
	Air-cooled		Granulated		Expanded		Total iron slag[2]					
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1982	13,617	56,816	597	3,237	539	4,800	14,752	64,854	4,764	14,641	19,516	79,495
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	1,177	25,024	702	8,827	15,380	92,750	5,689	17,883	21,068	110,633

[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.

CONSUMPTION AND USES

The construction industry accounted for most of the consumption of iron and steel slags. Iron and steel slags are used as substitutes for natural aggregates and other construction materials. Historically, iron and steel slags are used in place of other materials owing to lower costs, superior performance for many applications, or shortages of natural aggregates.

Almost all iron-blast-furnace slag produced is eventually utilized. Of the air-cooled blast furnace slag produced in 1986, 55% was used as road base, 13% was used as concrete aggregate, 7% as asphaltic concrete aggregate, and 6% as railroad ballast. The remaining 19% was used in roofing, sewage treatment, soil conditioning, ice control, and for producing concrete products, glass, mineral wool, and other miscellaneous uses. Expanded blast furnace slag, a product with a lower density than air-cooled slag, was mainly used as a lightweight concrete aggregate and in the production of concrete products and cement. The largest application for granulated blast furnace slag was cement manufacture. As a replacement for cement, granulated blast furnace slag offers savings in the raw materials and energy required to produce cement clinker. Growth areas for iron slag include use for road base and the production of concrete products. Changes in iron slag usage reflect a gradual trend toward applications that involve producing iron slag products that have a higher value owing to additional processing of the slag prior to sale.

Based on raw steel production, an estimated 2.8 million tons of steel slag was recycled to blast furnaces in 1986. The bulk of the remaining slag was used in aggregate applications. Of the steel slag sold or used in 1986, 45% was used as road base, 23% as fill, and 11% as asphaltic concrete aggregate. The remaining 21% was used for railroad ballast, ice control, and miscellaneous uses. Steel slag sales for use as an asphaltic concrete aggregate increased over that of 1985.

PRICES

The average price, f.o.b. plant, for all iron-blast-furnace slag sold increased 5% over that of 1985 to $6.03 per ton. The price of air-cooled iron slag decreased 7% to $4.36 per ton, but that of expanded iron slag increased 14% to $12.57 per ton. The average price for granulated iron slag was $21.26 per ton. Steel slag unit value was $3.14, up 7% over that of 1985. Often, the price of slag is dependent on the application for which the slag is used. Higher prices for some applications reflect the cost of additional processing to meet users' specifications.

FOREIGN TRADE

Basic slag, a byproduct of basic steelmaking processes, is imported for use as a fertilizer because of its high lime and phosphorus content. No significant quantities of basic slag were exported in 1986. Statistics developed by the U.S. Department of Commerce, Bureau of the Census, indicate that 27,137 tons of basic slag valued at $388,073 was imported from Canada, and 2,400 tons valued at $131,946 was imported from Japan.

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 schedule headings "Mineral Substances and Articles of Mineral Substances Not Specifically Provided For" or "Waste and Scrap Not Specifically Provided For." U.S. imports of slag are classified under the headings "Metal Bearing Ores and Metal Bearing Materials" or "Waste and Scrap Not Specifically Provided For."

WORLD REVIEW

Estimated world production of iron-blast-furnace slag and steel slag was 127 million tons and 56 million tons, respectively. These estimates are based on iron and steel production estimates for 1986. 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 or consumption because slag is thought of as a waste product rather than a resource.

European Economic Community.—Estimated 1986 production of iron-blast-furnace slag and steel slag based on estimated iron and steel production was 21 million tons and 9.9 million tons, respectively. The most recent data published by the Statistical Office of the European Economic Community (EEC) indicate that 20 million tons of iron-blast-furnace slag was produced in 1985. Production of basic slag, a type of steel slag, was 2.8 million tons in 1985.[2] Portugal and Spain joined the EEC in 1986; their production is included in the 1986 estimates but not in the 1985 statistics.

Japan.—The Japanese iron and steel industry is a leader in the development of efficient methods for processing slags and is a major slag producer. In contrast to the U.S. industry, slag processing in Japan is chiefly carried out by the iron and steel producers rather than outside contractors. Consumption and production of iron-blast-furnace slag and steel slag in 1986 were estimated to be 27 million tons and 14 million tons, respectively. These estimates represent modest increases over 1985 levels owing to increased iron and steel production. The Government of Japan no longer reports figures for slag production.

U.S.S.R.—The U.S.S.R. is a major producer of iron and steel slags. It has been a leader in the development of technology to produce glass ceramics from slags. Several plants in the U.S.S.R. produce a glass ceramic building product called slagsitall. The Karaganda Metallurgical Center recently announced that approximately 1 million tons per year of high-phosphorus slags would be produced at Karaganda for use as fertilizer. Studies showed that the slags produced better yields for sugar beets, potatoes, and corn compared with high-phosphate fertilizers.[3] Estimated production of iron-blast-furnace slag and steel slag based on estimated iron and steel production was 27.6 million tons and 8.7 million tons, respectively.

United Kingdom.—British Standard 6699, published in September 1986, provided specifications for the use of ground granulated blast furnace slag as a cementitious product. Previous standards allowed for the use of slag only as an additive to portland cement. The use of ground granulated blast furnace slag in the United Kingdom was expected to increase as a result of the new standard.[4]

TECHNOLOGY

National Slag Ltd., Ontario, Canada, developed improvements for its slag pelletizing process. The improvements included increased efficiency of the process and more uniform product quality. In the pelletizing process, liquid slag is treated with water to produce foamed slag, which is fed to a rotating drum that breaks the slag into droplets. Because the droplets produced by the pelletizer solidify rapidly, hydrogen sulfide emissions are reduced. The pellets produced are a form of low-density expanded slag and can be used as a lightweight aggregate or ground into a cementitious hydraulic product. Improvements to the process included an orifice system for metering slag flow, an improved feed system that produces a relatively uniform feed across the width of the pelletizer, improved systems for applying cooling water, and optimization of drum speed.[5]

The Novoipetsk Metallurgical Combine of the U.S.S.R. developed improvements to the blast furnace slag granulating plant at Novoipetsk. The new granulating process produces higher density slag with a lower moisture content and uses less energy and cooling water than the old process. An important part of the new process consisted of changes designed to increase the bulk density of the granulated slag. Production of a higher density slag increased the throughput of the process and reduced dewatering costs, since the slag with the higher bulk density retains less moisture. The higher bulk density product was achieved by improving the control of the water and slag flows to the granulator and using air with water to granulate the slag. The use of compressed air in the granulator helps break up the slag and reduces the amount of water required for granulation.[6]

Research on a process for recovering heat from slag in a granulated slag plant was conducted at the University of Birmingham, United Kingdom. A test apparatus consisting of a granulator and a fluidized bed for heat recovery was constructed. The granulator produces molten slag droplets through the collision of two jets of liquid slag. The slag droplets are fed to a fluidized bed system, which cools the slag and recovers the heat for use in other processes.[7]

A U.S. patent was granted for a method of recovering heat during the cooling of liquid slags. In this process, slag is cooled on the surface of a hollow cooling body through which a fluid is passed. Once the slag has been solidified, it is removed from the cooling body and further cooled by gas flow over the slag. Heat is recovered by both the cooling fluid in the first stage and the gas in the second stage.[8]

Electric furnace slag was being used as part of a waste treatment program at Atlas Steels' Welland, Ontario, Canada, plant. The slag is used in the solidification of waste pickling acids. The crushed slag is included because of its high silica content. Silica fixes heavy metals in the acid wastes, preventing them from being leached. All of the slag used in waste treatment is from Atlas Steels' electric furnace and is weathered and crushed prior to use.[9]

A system for removing liquid slag from ladles and processing it to produce granulated slag was developed by Kubota Ltd. in association with Nippon Steel Corp. The device uses vacuum to remove slag from the surface of molten metal. The liquid slag is then granulated by a jet of cooling water. The device includes provisions for protecting the suction head from the hot contents of the ladle.[10]

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[1]Physical scientist, Division of Ferrous Metals.

[2]Statistical Office of the European Economic Community. 1986 Iron and Steel Yearbook. 1987, p. 3.26.

[3]Kim, V. N., I. P. Basaev, A. M. Anokhin, A. A. Babenko, V. I. German, N. S. Chebanov, I. E. Kim, and D. Z. Serazetdinov. Use of Bank Converter Slags as Compound Fertilizers. Metallurgist (Engl. transl.), v. 29, No. 6, June 1985, p. 32.

[4]Higgins, D. D. BS 6699—A Standard for Ground Granulated Blast Furnace Slag. Concrete (London), v. 20, No. 8, Aug. 1986, pp. 13-15.

[5]Spencer, K. W., I. J. Ross, P. A. MacKenzie, and R. D. Sims. Method of Producing a Dry Grindable Vitrified Slag. Nat. Slag Ltd., Hamilton, Ontario, Canada, Jan. 1986, 12 pp.

[6]Butov, A. I., N. C. Ovharenko, B. F. Chernobrivets, and N. S. Antipov. Improving Slag Granulation at Units Near Blast Furnaces. Metallurgist (Engl. transl.), v. 29, No. 1, Jan. 1985, pp. 15-17.

[7]Harris, J. C., and N. A. Warner. Dry Granulation and Heat Recovery From Partly Solidified Slag Droplets. Steel Times, v. 214, No. 11, Nov. 1986, pp. 626-628.

[8]Mullner, P., and B. Enker. Method and Arrangement for Recovering the Sensible Heat of Slag. U.S. Pat. 4,572,281, Feb. 24, 1986.

[9]Stone, J. N., and G. F. Marasco. Integrated Treatment of Wastes at Atlas Steels. Iron and Steel Eng., v. 63, No. 14, Apr. 1986, pp. 43-47.

[10]———. Slag Removal by Vacuum Cleaner. Steel Times, v. 214, No. 11, Nov. 1986, p. 629.

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	1985				1986			
	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	4,424	17,488	W	W	5,079	16,235	W	W
Ohio	2,460	13,818	W	W	2,202	12,744	W	W
Total	6,884	31,306	7,483	35,708	7,281	28,979	7,998	34,229
Middle Atlantic:								
Maryland, New York, West Virginia	1,066	4,603	W	W	1,225	5,774	W	W
Pennsylvania	2,488	13,298	W	W	2,460	13,805	2,887	20,335
Total	3,554	17,901	4,696	37,789	3,685	19,579	W	W
West: Colorado, Texas, Utah	1,508	5,754	1,508	5,754	1,193	4,645	1,193	4,645
South: Alabama and Kentucky	875	5,719	875	5,719	612	3,363	612	3,363
Pacific: California	543	1,908	543	1,908	730	2,336	730	2,336
Grand total[2]	13,363	62,588	15,106	86,878	13,501	58,899	15,380	92,750

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 1986

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
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	--	1	1
Do	1	--	--	--	--	--	--
International Mill Service Co	--	--	--	1	--	1	--
Granite City:							
International Mill Service Co	--	--	--	1	--	1	--
St. Louis Slag Products Co. Inc	1	--	--	--	--	--	--
Peoria:							
International Mill Service Co	--	--	--	1	--	--	1
Total	2	--	--	5	--	3	3
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
Kokomo:							
International Mill Service Co	--	--	--	1	--	--	1
Total	2	1	--	4	--	3	2
Iowa: Keokuk:							
International Mill Service Co	--	--	--	1	--	--	1
Kentucky:							
Ashland:							
Heckett Co	1	--	--	--	--	--	--
Owensboro:							
Heckett Co	--	--	--	1	--	--	1
Total	1	--	--	1	--	--	1

See footnote at end of table.

Table 3.—Locations and processing methods of iron slag and sources of steel slag[1] in 1986 —Continued

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
Louisiana: LaPlace:							
International Mill Service Co	--	--	--	1	--	--	1
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

See footnote at end of table.

Table 3.—Locations and processing methods of iron slag and sources of steel slag[1] in 1986 —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
Oklahoma: Sand Springs:							
International Mill Service Co	--	--	--	1	--	--	1
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
Texas:							
Baytown:							
Heckett Co	--	--	--	1	--	--	1
Beaumont:							
International Mill Service Co	--	--	--	1	--	--	1
El Paso:							
International Mill Service Co	--	--	--	1	--	--	1
Lone Star:							
Gifford-Hill & Co. Inc	1	--	--	--	--	--	--
International Mill Service Co	--	--	--	1	--	--	1
Longview:							
International Mill Service Co	--	--	--	1	--	--	1
Midlothian:							
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 1986 —Continued

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
Texas—Continued							
Seguin:							
International Mill Service Co	--	--	--	1	--	--	1
Total	1	--	--	7	--	--	7
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	64	5	23	43

[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 1986, by method of transportation

Method of transportation	Quantity (thousand short tons)
Truck	18,587
Waterway	1,313
Rail	973
Not transported (used at plantsite)	195
Total	21,068

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	1985 Quantity	1985 Value	1986 Quantity	1986 Value
Asphaltic concrete aggregate	1,503	7,149	977	5,089
Concrete aggregate	1,613	8,740	1,753	8,799
Concrete products	495	2,226	513	2,474
Fill	1,299	4,366	779	3,257
Glass manufacture	110	W	107	W
Mineral wool	617	4,081	519	2,862
Railroad ballast	1,024	4,656	875	3,826
Road base	5,831	24,772	7,453	28,165
Roofing, built-up and shingles	156	1,114	74	660
Sewage treatment	445	2,314	W	W
Soil conditioning	48	173	W	W
Other[2]	221	[3]3,000	452	[3]3,767
Total[4]	13,363	62,588	13,501	58,899

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 uses 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	1985				1986			
	Granulated		Expanded		Granulated		Expanded	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Cement manufacture	(2)	(2)	W	W	W	W	W	W
Concrete products	--	--	--	--	--	--	W	W
Fill	(2)	(2)	W	W	W	W	--	--
Lightweight concrete aggregate	--	--	W	W	--	--	W	W
Road base	(2)	(2)	W	W	W	W	--	--
Soil conditioning	(2)	(2)	W	W	W	W	--	--
Other[3]	--	--	1,742	24,290	1,177	25,024	702	8,827
Total	(2)	(2)	1,742	24,290	1,177	25,024	702	8,827

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 uses 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	1985		1986	
	Quantity	Value	Quantity	Value
Asphaltic concrete aggregate	417	1,811	632	2,613
Fill	1,436	4,145	1,318	3,861
Railroad ballast	365	1,249	W	W
Road base	3,079	9,050	2,549	7,879
Other[2]	674	1,219	1,190	3,531
Total[3]	5,972	17,472	5,689	17,883

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 uses 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		
1982	4.17	5.42	8.91	4.40	3.07	4.07
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

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 1986, 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	5.21	2.32- 7.94	--	--	--	--	4.14	1.89-5.29
Cement manufacture	--	--	W	W	W	W	--	--
Concrete aggregate	5.02	2.67- 9.89	--	--	--	--	--	--
Concrete products	4.83	1.47- 7.25	--	--	W	W	--	--
Fill	4.18	1.62- 5.92	W	W	--	--	2.93	1.00-5.75
Glass manufacture	W	W	--	--	--	--	--	--
Lightweight concrete aggregate	--	--	W	W	W	W	--	--
Mineral wool	5.14	3.43-12.22	--	--	--	--	--	--
Railroad ballast	4.37	2.00- 7.60	--	--	--	--	W	W
Road base	3.78	1.92- 7.25	W	W	--	--	3.09	1.46-8.27
Roofing, built-up and shingles	8.96	4.73-11.56	--	--	--	--	--	--
Sewage treatment	W	W	--	--	--	--	--	--
Soil conditioning	W	W	W	W	--	--	--	--
Other	6.74	3.49-19.24	21.26	4.20-30.00	12.57	10.00-33.00	2.97	2.19-4.61

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

Sodium Compounds

By Dennis S. Kostick[1]

Domestic soda ash production decreased slightly; however, several producers improved their market share by increasing production to counter the supply imbalance created by the closure of a soda ash facility. U.S. consumption of soda ash decreased for the fourth consecutive year because of further erosion in certain end-use markets, which have encountered competition from substitute or alternate materials. Production of natural and synthetic sodium sulfate decreased in response to declining consumption of sodium sulfate by the detergent and glass container industries.

Domestic Data Coverage.—Domestic production data for soda ash and sodium sulfate are developed by the Bureau of Mines from monthly and annual voluntary surveys of U.S. operations. Of the eight soda ash operations and four sodium sulfate operations to which a survey request was sent, all responded, representing 100% of the total production data shown in table 1. Two soda ash producers did not report sales value on these forms; however, their data were estimated and included in table 1.

Table 1.—Salient sodium compound statistics

(Thousand short tons and thousand dollars)

	Soda ash		Sodium sulfate	
	1985	1986	1985	1986
United States:				
Production[1]	r8,511	8,438	r835	798
Value[2]	e$622,253	e$553,517	$76,237	$68,687
Exports	r 3 1,747	3 2,049	119	111
Value	r 3 $173,937	3 $241,238	$11,899	$10,183
Imports for consumption	56	106	r195	188
Value	$8,089	$15,023	$14,492	$13,829
Stocks, Dec. 31: Producers	4 428	4 294	5 31	5 72
Consumption, apparent	r6,750	6,590	r939	834
World: Production	p31,129	e31,363	p4,838	e4,738

eEstimated. pPreliminary. rRevised.

1Includes natural and synthetic. Total production data for sodium sulfate obtained from the Bureau of the Census.

2The value for soda ash includes synthetic soda ash. The value for synthetic sodium sulfate is based upon the average value for natural sodium sulfate.

3Export data from the Bureau of the Census were adjusted by the Bureau of Mines pending data reconciliation between the Bureau of the Census and the American Natural Soda Ash Corp.

4Includes synthetic soda ash.

5Natural only.

DOMESTIC PRODUCTION

Soda Ash.—The U.S. soda ash industry maintained its important position in the world market despite changes in the organization of some of the domestic producers. Declining profitability, because of stagnant domestic market conditions and prices, led to a partial restructure of the soda ash industry through parent corporation sales and joint ventures, company name changes, and activity consolidations and transfers. These measures were expected to streamline business operations and improve general operating economics.

General Chemical Corp., formerly Allied Chemical Co., permanently closed its synthetic soda ash plant at Syracuse, NY, which was both the first synthetic soda ash plant built in the United States and the last one to close. The closure reduced the overall industry nameplate capacity by 700,000 short tons per year, which contributed to raising the overall production performance of the industry to about 80% of total nameplate capacity. In addition, General Chemical sold a 49% interest in its Wyoming natural soda ash facility to Australian Consolidated Industries International (ACI), an Australian glass packaging manufacturer. The new company, General Chemical Partners, planned to export soda ash to ACI's glass plants in Australia, New Zealand, and Southeast Asia.

Another corporate structural change occurred at yearend when Chesebrough-Ponds Inc., which had acquired Stauffer Chemical Co. of Wyoming in 1985, was bought by the Unilever Group, a large Dutch-British consumer product producer. Also, Texasgulf Inc. changed the name of its soda ash operation to T. G. Soda Ash Inc. Kerr-McGee Chemical Corp. announced plans to consolidate its soda ash activities by terminating soda ash production at its Westend plant, thereby making the Argus plant the only soda ash producing facility in California. This action was expected to eliminate about 100,000 tons of annual production.

Sodium Sulfate.—Production of natural sodium sulfate was unchanged whereas recovery of synthetic sodium sulfate decreased 10%. The natural sodium sulfate industry operated at 76% and 78% of total nameplate capacity in 1985 and 1986, respectively.

Table 2.—Producers of soda ash and natural sodium sulfate in 1986

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	150	Westend, CA	Do.
Stauffer Chemical Co. of Wyoming[2]	1,960	Green River, WY.	Underground trona.
Tenneco Minerals Co	1,000	do	Do.
T. G. Soda Ash Inc	1,100	Granger, WY	Do.
Soda ash, synthetic:			
General Chemical Corp.[3]	700	Syracuse, NY	Ammonia-soda process.
Total	[4]10,560		
Sodium sulfate:			
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	70	Brownfield, TX.	Subterranean brine.
Do	150	Seagraves, TX	Do.
Total	510		

[1]General Chemical Corp. formed a joint venture with Australian Consolidated Industries International, which acquired 49% of the soda ash operation.
[2]Chesebrough-Ponds Inc., the parent corporation, was bought by the Unilever Group, a Dutch-British consumer product producer.
[3]The facility was permanently closed in Feb. 1986.
[4]Effective nameplate capacity prior to Feb. 1986 was 11,260 million tons.
[5]Solar ponds were flooded May 5, 1984; no significant production in 1986.

Table 3.—Synthetic and natural sodium carbonates produced in the United States

(Thousand short tons and thousand dollars)

Year	Synthetic soda ash (ammonia-soda process)[1]	Natural sodium carbonates[2]		Total quantity
	Quantity	Quantity	Value[3]	
1982	W	W	721,257	7,819
1983	W	W	[e]685,100	8,467
1984	W	W	[e]611,000	8,511
1985	W	W	[e]622,253	[r]8,511
1986	W	W	[e]553,517	8,438

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Includes quantities used to manufacture caustic soda, sodium bicarbonate, and finished light and dense soda ash.
[2]Soda ash and sesquicarbonate.
[3]Includes value for synthetic soda ash.

Table 4.—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
1982	463	401	864	W	W
1983	427	427	855	423	39,425
1984	428	444	872	435	40,125
1985	401	[r]435	[r]835	389	35,860
1986	467	331	798	396	34,102

[r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]All quantities converted to 100% Na_2SO_4 basis.
[2]Current Industrial Reports, Inorganic Chemicals, Bureau of the Census.
[3]Includes Glauber's salt.
[4]Data may not add to totals shown because of independent rounding.

CONSUMPTION AND USES

Domestic soda ash consumption continued its downward trend, reaching its lowest level since 1975. Glass containers continued to lose market share to plastic, aluminum, and paper containers primarily because of production economics and consumer preference. These factors plus the increased use of cullet, or recycled glass, resulted in lower soda ash and sodium sulfate consumption for glass container manufacture. Soda ash sales to the flat glass sector appeared weak through three quarters of the year. Because of strong fourth-quarter growth in new residential construction, both soda ash and sodium sulfate consumption in flat glass increased in 1986 from that of 1985. Strong flat glass and fiberglass demand throughout the year for the home repair and remodeling business also contributed to increased soda ash consumption in these glass markets.

Despite increasing demand for pulp and paper, sodium sulfate consumption declined because of changes under way in the Kraft pulping and papermaking industries. These changes were required in order to lower sulfur levels through recovering and recycling because of environmental and cost considerations. These reasons for restructuring also apply to the sulfite pulping method, which may be replaced by thermal-mechanical and chemithermal-mechanical pulping processes that require less sulfur and soda ash.

Soda ash consumption in soaps and powdered detergents increased because of a rise in demand for multicomponent builders that improve phosphate-restricted detergent performance in regions of the country that limit or ban the use of phosphatic laundry detergents. Although soda ash sales in this sector were strong, the market may have peaked because of increased consumer preference for liquid detergents, which represented more than 20% of the domestic detergent market. This preference is beginning to influence detergent manufacturers' formulations, which will reduce soda ash and sodium sulfate usage in the near future.

Table 5.—Estimated consumption of soda ash in the United States, by end use

(Thousand short tons)

End use	1985	1986
Glass:		
Bottle and container	2,200	2,150
Flat	700	750
Fiber	275	300
Other	225	275
Total	3,400	3,475
Chemicals	1,500	1,300
Soaps and detergents	600	650
Pulp and paper	350	200
Water treatment	r300	250
Flue gas desulfurization	175	200
Other[1]	r425	515
Total	r3,350	3,115
Grand total	r6,750	6,590

rRevised.
[1]Includes soda ash used in petroleum and metal refining, leather tanning, enamels, etc.

STOCKS

Soda Ash.—Yearend stocks of dense and light soda ash in plant silos, warehouses, terminals, and on teamtracks amounted to 294,000 tons, or 31% less than 1985 yearend inventories.

Sodium Sulfate.—Inventories of natural sodium sulfate increased 132%, primarily because of weak domestic demand.

PRICES

Soda Ash.—In July, the soda ash industry eliminated zone pricing and the temporary voluntary allowance on soda ash. The list price per ton, f.o.b. mine or plant, of $83 in Wyoming and $113.25 in California remained firm; however, market prices remained below these published prices. The average annual value of natural soda ash, f.o.b. Green River, WY, and Searles Valley, CA, was estimated to be $65.29 per ton.

Sodium Sulfate.—Despite weak domestic demand, sodium sulfate list prices remained firm while actual selling prices fluctuated. List prices of natural high-purity sodium sulfate ranged from $96 to $109 per ton, f.o.b. plant; byproduct list prices averaged $113, same basis. The average annual value of bulk natural product, f.o.b. mine or plant, was $86.11 per ton.

Table 6.—Sodium compounds yearend prices

		1985	1986
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	120.00
Dense, bulk, carlots, works	do	90.00	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	47.00- 53.00	65.00- 98.00
National Formulary (NF XII), drums	per pound	.235	.235

[1]East of Mississippi River.

Source: Chemical Marketing Reporter. Current Prices of Chemicals and Related Materials. V. 227, No. 27, Dec. 30, 1985, p. 27, and v. 230, No. 26, Dec. 29, 1986, p. 31.

FOREIGN TRADE

Soda Ash.—Exports reported by the Bureau of the Census amounted to 1,993,000 tons; however, exports to Canada appear to have been underreported by more than 73,000 tons, and some shipments to Brazil were credited to 1985. With the cooperation of Statistics Canada and the American Natural Soda Ash Corp. (ANSAC), total U.S. exports, as adjusted by the Bureau of Mines, were 2.049 million tons. Exports to 45 countries, on a regional basis, were as follows: Asia, 56%; South America, 16%; North America, 13%; Africa, 7%; Europe and Oceania, 3% each; and Central America and the Caribbean, 1% each.

On behalf of ANSAC, the U.S. Department of Commerce and the Office of the U.S. Trade Representative negotiated with Japanese Government officials for support in an effort to eliminate restrictive business practices of Japanese soda ash producers that inhibit U.S. exports to Japan. Several members of Congress provided their support by opposing certain barriers to imports into the Republic of Korea and Taiwan, where ANSAC anticipated expanding its export market.

Table 7.—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]
1983	1,636	154,584	91	11,380
1984	1,648	160,774	76	9,587
1985	r 2 1,747	r 2 173,937	119	11,899
1986	2 2,049	2 241,238	111	10,183

r Revised.
[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 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]
1983	144	10,312	199	17,609	343	27,921
1984	61	4,223	204	16,975	265	21,198
1985	40	2,549	r 155	11,943	r 195	14,492
1986	32	1,885	156	11,944	188	13,829

r Revised.
[1] Includes Glauber's salt as follows: 1983—3 tons ($1,648); 1984—12 tons ($4,997); 1985—none; and 1986—38 tons ($9,175).
[2] Customs, insurance, and freight (c.i.f.) value at U.S. port.

Source: Bureau of the Census.

Table 9.—U.S. imports for consumption of sodium carbonate

	1985		1986	
	Quantity (short tons)	Value[1] (thousands)	Quantity (short tons)	Value[1] (thousands)
Sodium carbonate, calcined	56,198	$8,085	105,917	$14,991
Sodium carbonate, hydrated and sesquicarbonate	4	4	48	32
Total	56,202	8,089	105,965	15,023

[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, completed a feasibility study of the sodium carbonate resources in the Makgadikgadi Pan. The company was seeking partners to form a consortium in order to provide $160 million for constructing a 300,000-ton-per-year-capacity plant. Investors from the Republic of South Africa expressed interest in a partnership because the Republic of South Africa imports about 250,000 tons of soda ash annually.[2]

China.—Construction began on three synthetic soda ash facilities in Hebei, Jiangsu, and Shandong, each with an annual production capacity of 660,000 tons. The projects were scheduled to be completed by 1990, the end of China's seventh 5-year plan. The plants would increase China's production capacity by 75% to 3.5 million tons per year.[3]

China also resumed development of its largest natural soda ash deposit, at Xilinguole Prefecture, Inner Mongolia. Construction had started in 1971 but was suspended in 1979 because a national capital construction effort was depleting state investment funds. Transportation and telecommunication facilities, water pipelines, and other infrastructure have already been completed. The deposit reportedly contains 43 million tons of alkali salts. By the target completion date of 1990, the project was to produce annually 500,000 tons of soda ash, 50,000 tons of caustic soda, 50,000 tons of sodium bicarbonate, and 30,000 tons of mirabilite.[4]

Spain.—FMC Corp.'s Spanish subsidiary, Foret S.A., purchased the natural sodium sulfate operation of Sociedad Unión Salinera de España in Villarrubia de Santiago in the Province of Toledo.[5] The facility has an annual production capacity of 150,000 tons.

Switzerland.—Solvay & Cie. S.A., the largest producer of soda ash in Western Europe, announced it will close its Swiss synthetic soda ash plant in mid-1987. The facility, which had a production capacity of 50,000 tons per year, reportedly was not sufficiently profitable to continue operations.[6]

Table 10.—Sodium carbonate: World production, by country[1]

(Short tons)

Country	1982	1983	1984	1985^{p}	1986^{e}
Albania^{e}	^{r}29,800	^{r}30,900	^{r}33,100	^{r}34,200	35,300
Australia^{e}	330,000	330,000	330,000	330,000	330,000
Austria^{e}	190,000	190,000	165,000	165,000	190,000
Belgium	361,170	^{r}286,341	451,224	$^{r\ e}$385,000	440,000
Brazil	219,360	231,485	^{e}210,000	^{e}210,000	220,000
Bulgaria	1,607,940	1,400,918	1,336,292	1,142,695	1,210,000
Canada^{e}	500,000	470,000	400,000	385,000	385,000
Chad$^{e\ 2}$	5,500	NA	NA	NA	NA
China	1,911,406	1,976,442	^{e}2,070,000	$^{r\ e}$2,220,000	2,310,000
Colombia	122,136	130,392	142,683	124,791	140,000
Czechoslovakia	117,313	104,694	111,711	^{e}110,000	110,000
Denmark^{3}	131	159	139	126	132
Egypt	45,496	47,399	53,072	54,132	55,000
France^{e}	1,100,000	1,100,000	990,000	990,000	825,000
German Democratic Republic	972,237	977,749	981,056	974,442	972,000
Germany, Federal Republic of	1,218,053	1,342,614	1,503,551	1,556,462	1,560,000
Greece^{e}	1,100	1,100	1,100	1,100	1,100
India	646,836	820,481	915,869	896,839	940,000
Italy^{e}	100,000	95,000	100,000	100,000	90,000
Japan	1,281,323	1,216,265	1,142,140	1,165,254	1,150,000
Kenya^{2}	176,855	213,506	249,177	251,062	250,000
Korea, Republic of	204,666	254,193	273,292	276,559	290,000
Mexico^{4}	^{r}436,625	^{r}438,279	466,277	504,197	500,000
Netherlands^{e}	460,000	460,000	440,000	^{r}420,000	420,000
Pakistan	109,254	113,932	131,376	130,169	145,000
Poland	822,323	909,406	1,011,921	^{e}940,000	940,000
Portugal^{e}	190,000	180,000	165,000	165,000	170,000
Romania	959,010	868,620	1,005,307	921,531	940,000
Spain^{e}	550,000	550,000	610,000	610,000	580,000
Switzerland^{e}	50,000	50,000	49,000	50,000	50,000
Taiwan	65,279	103,419	118,179	123,479	130,000
Turkey^{e}	66,000	132,000	220,000	331,000	386,000
U.S.S.R	5,250,303	5,620,679	5,639,418	^{e}5,730,000	5,840,000
United Kingdom^{e}	1,430,000	1,430,000	1,100,000	1,100,000	1,100,000

See footnotes at end of table.

Table 10.—Sodium carbonate: World production, by country[1] —Continued

(Short tons)

Country	1982	1983	1984	1985[p]	1986[e]
United States[5]	7,819,083	8,467,118	8,511,359	[r]8,511,055	[6]8,438,192
Yugoslavia	200,488	202,135	207,555	220,053	220,000
Total	[r]29,549,687	[r]30,745,226	31,134,798	31,129,146	31,362,724

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.
[1]Table includes data available through May 5, 1987. Synthetic unless otherwise specified.
[2]Natural only.
[3]Production for sale only; excludes output consumed by producers.
[4]Includes natural and synthetic; in 1985 Mexico produced 200,000 tons of natural soda ash.
[5]Includes natural and synthetic.
[6]Reported figure.

Table 11.—Sodium sulfate: World production, by country[1]

(Thousand short tons)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Natural:					
Argentina	47	50	36	[e]44	39
Canada	603	500	427	403	409
Chile[3]	1	1	1	1	1
Egypt	3	2	2	74	68
Iran[e]	11	13	13	13	13
Mexico[4]	519	436	456	440	441
South Africa, Republic of	3	1	1	(5)	(5)
Spain	232	345	405	530	468
Turkey	72	68	92	[e]94	99
U.S.S.R.[e 6]	397	397	397	[r]397	397
United States	[7]W	423	435	389	[8]396
Total	1,888	2,236	2,265	2,385	2,331
Synthetic:					
Austria[e]	61	61	55	55	61
Belgium[e]	276	276	276	287	292
Chile[9]	52	57	63	71	72
Finland[e]	44	39	39	39	39
France[e]	165	165	132	138	121
German Democratic Republic	157	168	181	190	187
Germany, Federal Republic of	236	138	141	153	171
Greece	8	8	[r e]8	[r e]8	8
Hungary[e]	11	11	11	11	11
Italy[e]	94	99	88	[r]83	83
Japan	282	287	307	305	291
Netherlands[e]	55	55	50	50	50
Portugal[e]	63	62	55	55	57
Spain[e 10]	187	187	187	[r]165	165
Sweden[e]	110	110	110	110	110
U.S.S.R.[e 6]	276	276	276	287	287
United States[11]	[7]864	432	437	446	[8]402
Total	2,941	[r]2,431	2,416	2,453	2,407
Grand total	4,829	[r]4,667	4,681	4,838	4,738

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Table includes data available through May 5, 1987.
[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, but production figures are not reported, and available general information is not adequate for the formulation of 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]Series reflects output reported by Industrias Peñoles S.A. de C.V., Mexico's principal producer, plus an additional 22,000 short tons (estimated) by a smaller producer.
[5]Less than 1/2 unit.
[6]Conjectural estimates based on 1968 information on natural sodium sulfate and general economic conditions.
[7]Natural sodium sulfate included with synthetic sodium sulfate production.
[8]Reported figure.
[9]Byproduct of nitrate industry.
[10]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.
[11]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).

TECHNOLOGY

A nonsulfurous pulping process was developed at the University of Wisconsin to counter rising costs associated with recovering sulfate chemicals and the deleterious effect on the environment from Kraft and sulfite pulping processes. A mixture of acetic acid, ethyl acetate, and water acts as a lignin solvent. The process yields a higher quality pulp, uses less energy, and is less capital intensive. Adopting this technique may assist U.S. paper companies to remain competitive internationally but reduce the demand for sodium sulfate and soda ash.[7]

Sodium sulfate produced as a byproduct from flue gas desulfurization processes, which use soda ash as an absorbant, is water soluble and, therefore, presents a potential environmental disposal problem. To prevent the problem from occurring, researchers with Industrial Resources Inc. in Colorado developed a method to stabilize sulfate-bearing fly ash with smectite clay and water. The composite becomes essentially impermeable and stable for landfill disposal.[8] Commercial adoption of this process has the potential of increasing soda ash demand for stack gas scrubbing.

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[1]Physical scientist, Division of Industrial Minerals.
[2]Mining Magazine. Botswana Soda Ash Study. V. 155, No. 5, 1986, p. 433.
[3]European Chemical News. Chinese Chemicals Revamp. V. 46, No. 1225, 1986, p. 6.
[4]China Economic Weekly. Sept. 8, 1986, p. 15.
[5]Chemical & Engineering News. FMC Buys Spanish Sodium Sulfate Producer. V. 64, No. 51, Dec. 22, 1986, p. 8.
[6]European Chemical News. V. 47, No. 1251, 1986, p. 10.
[7]Chemical Week. Ester Pulping Cuts Costs, Doubles Yield. V. 138, No. 11, pp. 34-35.
[8]———. A New Process for Handling Sodium FGD Wastes. V. 139, No. 2, p. 61.

Crushed Stone

By Valentin V. Tepordei[1]

A total of 1.02 billion short tons of crushed stone valued at $4.3 billion, f.o.b. plant, was estimated to have been produced in the United States in 1986, an increase of 2.2% over that of 1985. This tonnage is the fifth largest production ever recorded in the United States, and only 7.1% below the record-high production of 1.1 billion tons reported in 1979. About three-quarters of the crushed stone production continued to be limestone and dolomite, followed by granite, traprock, sandstone and quartzite, shell, calcareous marl, volcanic cinder, marble, and slate, in order of volume.

Foreign trade in crushed stone remained relatively minor. Exports and imports increased 23.1% and 7%, respectively. Ninety-six percent of the exported and 45% of the imported crushed stone was limestone. Apparent consumption of crushed stone was 1.02 billion tons.

Domestic Data Coverage.—To reduce the Federal Government's costs as well as respondent's reporting burden, the Bureau of Mines had implemented new canvassing procedures for its stone surveys. Beginning with 1981 data, the complete survey of crushed stone producers is conducted for odd-numbered years only.

For even-numbered years, the annual preliminary survey, which collects only total production information on a sample basis, is used to generate annual estimates at the State level. This survey canvasses most of the large companies in each State producing up to 75% of the State total tonnage. The production estimates for 1986 may be revised in the 1987 crushed stone chapter if additional information is furnished by producers at that time.

Table 1.—Salient U.S. crushed stone statistics

(Thousand short tons and thousand dollars)

	1982	1983	1984	1985	1986
Sold or used by producers:					
Quantity[1]	[e]790,030	861,600	[e]956,000	1,000,800	[e]1,023,200
Value[1]	[e]$2,918,300	$3,327,000	[e]$3,755,600	$4,053,000	[e]$4,255,000
Exports (value)	$19,026	$23,021	$23,970	$29,347	$36,957
Imports for consumption (value)	$16,382	[2]$12,610	[2]$17,543	[2]$11,640	[2]$12,451

[e]Estimated.
[1]Does not include American Samoa, Guam, Puerto Rico, and the Virgin Islands.
[2]Excludes precipitated calcium carbonate.

DOMESTIC PRODUCTION

The production estimates indicate that in 1986 the output of crushed stone increased in all geographic regions except the West South Central and the Pacific regions. The South Atlantic region continued to lead the Nation in the production of crushed stone with an estimated 276 million tons or 27% of the U.S. total. Next was the East North Central region with 153 million tons or 15% of the total, followed by West South Central with 136 million or 13%.

A comparison of the reported 1985 and estimated 1986 production data indicates that the largest increases were recorded in the Mountain region, 9.4%; New England, 5.1%; and Northeast and South Atlantic, 3.7%. Production decreased slightly in the West South Central and 2.6% in the Pacific region. Crushed stone was produced in every State except Delaware. The 10 leading States in the estimated production of crushed stone, in order of volume, were Texas, Florida, Pennsylvania, Georgia, Virginia, Missouri, Illinois, North Carolina, Tennessee, and New York. Their combined production represented 53% of the national total. Production increased in 31 States, including 7 of the top 10. The increases were significant in the following major producing States: New York, Georgia, Illinois, and Tennessee. The top three States, Texas, Florida, and Pennsylvania, showed a small decrease in their production.

Martin Marietta Corp. acquired Weaver Construction Co. of Alden, IA, the largest producer of crushed stone and sand and gravel in Iowa. Effective April 1986, all quarries owned previously by Weaver are being operated by Martin Marietta, one of the largest aggregates producers in the United States with more than 100 operations in the Midwest and Southeast.

In October, Redland Aggregates Ltd. of Groby, United Kingdom, a subsidiary of Redland PLC, signed an agreement with The Flintkote Co. of San Francisco, a subsidiary of Imasco Ltd. of Montreal, Canada, for the acquisition of Genstar Stone Products Co. of Hunt Valley, MD, the sixth largest producer of crushed stone in the United States. Redland made its first acquisition in the United States in 1983 when it purchased 80% of the holdings of McDonough Brothers operation of San Antonio, TX, known today as Redland Worth Corp.

In September, Redland announced the formation of a joint venture with Koppers Co. Inc. of Pittsburgh, PA, for the purpose of acquiring and operating aggregate producing plants in the United States. The newly formed company called Western-Moblie Inc., Denver, CO, will produce and supply construction aggregates in Colorado, Kansas, New Mexico, and Wyoming.

In December, Lone Star Industries Inc. of Greenwich, CT, sold 60% of its southeastern operations to Tarmac PLC of Wolverhampton, United Kingdom. This transaction included Lone Star's crushed stone, sand and gravel, cement, and concrete operations in North Carolina, South Carolina, and Virginia. This is the second acquisition in the United States by Tarmac, following the 1984 purchase of Lone Star's Florida aggregate operations.

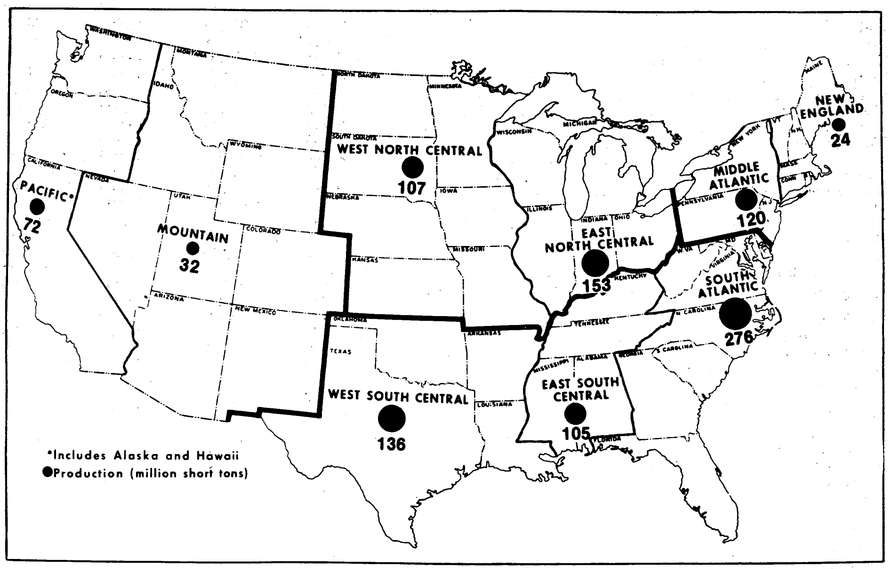

Figure 1.—Production of crushed stone in the United States in 1986, by geographic region.

Table 2.—Crushed stone[1] sold or used in the United States, by region

(Thousand short tons and thousand dollars)

Region	1985 Quantity	1985 Value	1986[e] Quantity	1986[e] Value
Northeast:				
New England	22,540	112,910	23,700	119,500
Middle Atlantic	115,595	570,333	119,600	609,100
North Central:				
East North Central	147,923	520,118	152,600	544,900
West North Central	106,035	369,972	107,200	385,700
South:				
South Atlantic	265,665	1,169,994	275,600	1,252,700
East South Central	103,525	404,456	104,700	438,000
West South Central	136,929	495,687	136,400	488,700
West:				
Mountain	28,971	106,938	31,700	119,000
Pacific	73,612	302,409	71,700	297,400
Total[2]	1,000,800	4,053,000	1,023,200	4,255,000

[e]Estimated.
[1]Includes volcanic cinder and scoria.
[2]Data may not add to totals shown because of independent rounding.

Table 3.—Crushed stone sold or used by producers in the United States, by State[1]

(Thousand short tons and thousand dollars)

State	1985 Quantity	1985 Value	1986[e] Quantity	1986[e] Value
Alabama	25,853	109,176	24,000	120,500
Alaska	1,907	8,535	2,000	8,500
Arizona	5,929	23,111	5,600	25,100
Arkansas	14,815	60,874	15,500	58,500
California	41,199	174,395	38,500	159,300
Colorado	7,037	25,930	8,000	30,700
Connecticut	7,277	43,937	7,700	45,800
Florida	69,266	287,237	69,000	288,200
Georgia	52,062	256,588	56,700	293,100
Hawaii	5,627	34,183	7,100	42,100
Idaho	2,019	6,977	3,700	12,700
Illinois	41,044	164,117	44,200	179,600
Indiana[2]	23,384	81,117	22,600	76,500
Iowa	23,657	94,496	23,400	98,000
Kansas	15,653	57,155	16,600	60,300
Kentucky[3]	38,022	134,978	38,400	137,000
Louisiana[4]	4,820	25,956	5,400	25,300
Maine	1,459	5,114	1,600	4,400
Maryland	24,406	98,584	26,400	126,000
Massachusetts	9,354	42,881	10,000	50,000
Michigan	30,685	95,953	27,800	83,900
Minnesota	7,756	22,601	8,300	26,300
Mississippi	1,582	4,282	1,600	4,400
Missouri	50,646	162,097	51,200	170,500
Montana[5]	1,730	5,044	2,200	6,200
Nebraska	4,175	19,134	4,000	17,900
Nevada	1,334	6,218	1,500	7,000
New Hampshire	1,612	6,434	1,800	5,900
New Jersey	15,692	94,339	15,300	95,400
New Mexico	3,641	15,232	3,900	15,300
New York	35,139	165,136	40,600	196,600
North Carolina	41,771	194,818	43,500	206,500
North Dakota	W	W	W	W
Ohio	38,310	136,544	39,300	147,300
Oklahoma	31,173	98,811	30,900	102,100
Oregon	15,336	54,244	15,100	53,400
Pennsylvania	64,765	310,859	63,700	317,100
Rhode Island[4]	1,135	7,016	1,000	5,700
South Carolina	17,079	72,520	18,200	76,700
South Dakota	4,071	14,412	3,600	12,600
Tennessee[6]	37,939	155,760	40,700	175,600
Texas	85,764	306,821	84,200	301,500
Utah	4,657	14,180	4,500	14,100
Vermont	1,689	7,468	1,600	7,600
Virginia	51,686	221,900	52,000	224,700
Washington	9,543	31,052	9,000	34,100
West Virginia	9,393	38,348	9,800	37,500

See footnotes at end of table.

Table 3.—Crushed stone sold or used by producers in the United States, by State[1] —Continued

(Thousand short tons and thousand dollars)

State	1985		1986[e]	
	Quantity	Value	Quantity	Value
Wisconsin	14,496	42,380	18,700	57,600
Wyoming[6]	2,030	7,329	1,700	5,900
Other	1,177	6,545	1,100	4,000
Total[7]	1,000,800	4,053,000	1,023,200	4,255,000

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

FOREIGN TRADE

Exports.—Exports of crushed stone increased 23.1% to 2.9 million tons, while the value increased 25.9% to $37 million. Ninety-six percent of the exported crushed stone was limestone, of which 99% went to Canada.

Imports.—Imports of crushed stone increased 5% to 2.9 million tons, and 7% in value to $10.9 million. About 51% of this tonnage was limestone, 75% of which came from Canada, 12% from Jamaica, and 8% from Mexico.

Imports of calcium carbonate fines increased 25% to 351,000 tons, while the value increased 8% to $1.5 million. Ninety-eight percent of the natural chalk came from the Bahamas, while most of the processed calcium carbonate was imported from France, 82%; Switzerland, 8%; the United Kingdom, 5%; and Japan, 4%.

In the second half of the year, Foster Yeoman Ltd. of Somerset, United Kingdom, started shipping crushed granite produced at the Glensanda Quarry in Scotland to Houston, TX. The location of the quarry on a remote peninsula allows the producer to receive low shipping rates from bulk carriers. The aggregates produced to U.S. specifications are being distributed in Texas, Louisiana, Mississippi, and Alabama.

Shipments of crushed stone from the Strait of Canso area in Nova Scotia, Canada, to the United States continued for the second year. The aggregates are being distributed in areas where demand is growing and alternate supplies are more expensive such as North Carolina, South Carolina, Florida, Louisiana, and Texas.

Table 4.—U.S. exports of crushed stone in 1986, by destination

(Short tons)

Destination	Quartzite	Limestone[1]	Other	Total
North America:				
Bahamas	--	23	6,845	6,868
Bermuda	--	1,153	391	1,544
Canada	486	2,774,387	70,067	2,844,940
Mexico	131	483	8,420	9,034
Other	5	970	710	1,685
Total	622	2,777,016	86,433	2,864,071
South America:				
Chile	--	2,373	--	2,373
Uruguay	--	--	240	240
Venezuela	--	18,222	939	19,161
Other	9	50	221	280
Total	9	20,645	1,400	22,054

See footnotes at end of table.

Table 4.—U.S. exports of crushed stone in 1986, by destination —Continued

(Short tons)

Destination	Quartzite	Limestone[1]	Other	Total
Europe:				
France	602	--	13,064	13,666
Germany, Federal Republic of	7,157	--	2,049	9,206
Netherlands	877	--	--	877
United Kingdom	556	108	2,272	2,936
Other	747	273	156	1,176
Total	9,939	381	17,541	27,861
Asia:				
Japan	2,151	42	63	2,256
Korea, Republic of	1,704	--	181	1,885
Taiwan	84	--	254	338
Other	107	162	918	1,187
Total	4,046	204	1,416	5,666
Oceania	31	619	187	837
Middle East and Africa	92	--	51	143
Grand total	14,739	2,798,865	107,028	2,920,632
Total value	$18,504,899	$14,134,687	$4,317,637	$36,957,223

[1]Includes ground limestone.

Source: Bureau of the Census.

Table 5.—U.S. imports for consumption of crushed stone and calcium carbonate fines, by type

(Thousand short tons and thousand dollars)

Type	1985		1986	
	Quantity	Customs value	Quantity	Customs value
Crushed stone and chips:				
Limestone	1,299	5,261	1,454	6,466
Marble, breccia	29	547	3	190
Quartzite	33	638	6	335
Slate	2	99	5	76
Other	1,361	3,664	1,396	3,836
Total[1]	2,725	10,209	2,864	10,902
Calcium carbonate fines:[2]				
Natural aragonite[3]	274	716	345	948
Chalk, whiting	7	715	5	600
Total[1]	281	1,432	351	1,548
Grand total[1]	3,006	11,640	3,215	12,451

[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

The 1985 production of stone in Canada was 86.6 million tons, valued at $407 million; about 99% of this output was crushed stone. The Province of Ontario continued to be the largest producer of stone with 37 million tons, valued at $169 million, followed closely by Quebec with 31 million tons valued at $149 million. Preliminary estimates of 1986 production of stone indicate an increase of 5% to 91 million tons valued at $426 million, with the Province of Ontario accounting for about 46% of the total output.

TECHNOLOGY

The 2d annual convention of the National Stone Association was held on February 2-6, 1986, in Las Vegas, NV, in conjunction with the biennial International Concrete & Aggregates Show. Major topics covered at the convention were retrofit automation in the crushed stone industry, an integrated approach to plant improvement through automation and its impact on productivity, and the Federal Highway Program and its impact on the future of the crushed stone industry. Over 40 educational seminars covering a range of specialized topics involving production, sales, marketing, and management practices also were held in conjuction with the convention. A sign of improved conditions in the aggregates industries was the significant number of new products displayed at the International Concrete and Aggregates Show including concrete pavement recycling, crushing, and screening equipment.

The Second Conference on Practical Automation, cosponsored by the National Stone Association and the U.S. Bureau of Mines, was held on October 5-7, in Chattanooga, TN. The actual case studies presented covered a wide range of subjects from automated delivery systems, plant flow automation, and sand classifier systems, to plant circuit automation, energy management, and advanced crusher technology. Several workshop sessions were also held that covered plant automation, advanced crusher technology, energy management, and production planning and market analysis.

The reduction of sulfur dioxide emissions in the atmosphere remains a major goal for the Government as well as the industry. As the support for the use of high-sulfur coal remains very strong, especially east of the Mississippi River in the States producing such coal, most power generating plants are installing or are planning to install flue gas desulfurization units. This trend will create an increased demand for limestone, which is by far the dominant scrubbing agent, currently accounting for over 70% of total consumption.[2]

As the quarry planning becomes more complex, substantial savings in time and costs can be achieved by applying microcomputer-aided deposit evaluation. Precise mathematical procedures rather than manual estimates can be performed, various reserve situations and quarry designs can be easily simulated and compared, and even three dimensional models of the deposits can be generated before a final decision is made.[3]

Several articles focusing on drilling and blasting,[4] crushing and grinding,[5] and screening[6] were published.

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[1]Physical scientist, Division of Industrial Minerals.

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Dimension Stone

By Harold A. Taylor, Jr.[1]

Production of dimension stone increased 5% to 1.16 million short tons valued at $173 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 6% in value to $15 million. The value of dimension stone imports for consumption increased 30% to $380 million, equivalent to 219% 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. The survey of dimension stone producers was not conducted in 1986, since it was an even-numbered year. The preliminary survey for 1986, which collected production information on a sample basis for the first 9 months only, was used to generate State annual preliminary estimates. Of the 391 dimension stone operations surveyed for 1985 and 1984, including those that were idle, 362, or 93%, responded, representing 96% of the estimated value shown in table 1. The final 1984 data are based on previous year data from the 1985 survey and update 1984 preliminary data for the first 9 months only. 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)

	1982	1983	1984	1985	1986
Sold or used by producers[1]	[e]1,089	1,090	[r] [e]1,141	[r]1,104	1,163
Value[1]	[e]$137,671	$147,843	[r] [e]$161,912	[r]$172,435	$173,269
Exports (value)	$18,678	$19,126	$23,007	$13,835	$14,623
Imports for consumption (value)[r]	$169,817	$191,663	$222,596	$291,246	$379,724

[e]Estimated. [r]Revised.
[1]Does not include Puerto Rico.

DOMESTIC PRODUCTION

In 1986, dimension stone was produced by 197 companies at 279 quarries in 36 States. Leading States, in order of tonnage, were Georgia, Indiana, and Vermont, producing together 43% of the Nation's total. Notable was an 8% increase in Georgia, a 13% increase in Indiana, and a 10% decrease in Vermont. Of the total production, 55% was granite, 25% was limestone, 11% was sandstone, 4% was slate, 3% was marble, and the remaining 2% was miscellaneous stone, including argillite, schist, soapstone, and traprock (basalt). Leading producing companies in terms of tonnage were Rock of Ages Corp., in New Hampshire and Vermont and Cold Spring Granite Co., principally in California, Minnesota, South Dakota, and Texas.

Granite.—Dimension granite includes all coarse-grained igneous rocks. Production increased slightly to 625,000 tons, and increased slightly in value to $97.0 million. Georgia continued to be the leading State producing 27% of the U.S. total, followed by Vermont and New Hampshire. These three States together produced over 55% of the U.S. total.

North Carolina Granite Corp. opened a $5 million addition to its facilities at Mount Airy. As a result of the investment, the firm can readily slab, polish, and finish granite panels to a thickness of 2 centimeters, and even do 1-centimeter work. The new Italian state-of-the-art equipment, which included multibladed gang saws, an automatic polishing line with an edge polisher, an automatic flame finisher, and several different kinds of diamond saws, enabled the firm to slab approximately 45,000 square feet of granite per month.

Cold Spring Granite was also in the process of updating its Cold Spring, MN, operations. Its new Italian state-of-the-art equipment included gang saws, a polishing and finishing line for thin tile and panel, and other related equipment.

Castellucci & Sons Inc. and Savema S.p.A. of Italy began production at their newly built joint-venture granite finishing plant at Quonset Point, RI. The $6 million plant has a capacity of 750,000 square feet of granite per year and can handle both domestic and imported rough blocks.

Rock of Ages of Vermont reported that it set an all-time company record of 225,000 cubic feet for granite block production from its quarries in September 1986. The firm said that this reflected its strong markets.

Limestone.—Dimension limestone includes bituminous, dolomitic, and siliceous limestones. Indiana, the leading State, produced 189,000 tons in 1986, compared with 168,869 tons in 1985 and 162,865 tons in 1984. Wisconsin, usually the second or third largest producer, totaled 18,786 tons valued at $842,000 in 1985 and 20,281 tons valued at $828,000 in 1984.

Marble.—English China Clays America Inc. acquired the assets and business of Moretti-Harrah Marble Co. of Sylacauga, AL, the sole producer of Alabama white marble. This important producer of dimension marble switched to making crushed marble for use as a filler. Therefore, Alabama white marble is no longer available on dimension stone markets.

Table 2.—Dimension stone sold or used by producers in the United States, by State

State	1984[r] [e]		1985		1986[e]	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Alabama	9,000	$2,231	[r]10,026	[r]$2,661	7,797	$968
Arkansas	W	W	5,145	305	5,145	305
California	22,778	1,658	23,181	2,449	22,794	2,582
Colorado	2,350	204	2,350	204	3,600	255
Connecticut	19,715	1,285	19,715	1,285	24,425	1,653
Georgia	183,886	19,660	[r]183,416	19,466	198,905	20,678
Illinois	1,750	107	1,750	107	1,750	107
Indiana	162,865	17,113	[r]168,869	20,186	190,995	20,252
Maryland	16,369	1,065	17,833	1,218	20,505	1,286
Massachusetts	63,882	11,688	72,577	13,724	78,728	14,928
Michigan	4,162	113	4,162	113	5,836	148
Minnesota	39,702	13,557	36,808	13,598	27,973	10,507
New Hampshire	82,838	5,681	[r]80,140	[r]6,625	82,294	6,451
New Mexico	19,515	185	20,495	277	21,615	378
New York	15,428	3,072	16,032	3,666	15,637	3,002
North Carolina	34,570	5,970	35,333	6,132	41,418	6,633
Ohio	55,195	2,364	53,067	3,661	35,698	2,708
Oklahoma	8,576	584	10,862	836	18,503	913
Pennsylvania	92,963	7,026	51,268	8,214	72,352	8,100
South Carolina	7,893	537	7,756	541	7,550	533
South Dakota	56,661	18,032	[r]51,493	[r]18,336	54,934	18,399
Tennessee	5,949	1,849	[r]5,864	[r]1,856	5,598	1,553
Texas	46,152	14,374	[r]35,870	[r]11,209	49,457	15,407
Vermont	111,106	23,963	116,166	26,346	104,610	27,075
Virginia	9,816	3,066	[r]10,132	3,136	9,542	3,128
Washington	761	53	761	53	1,223	69
Wisconsin	23,312	2,651	[r]21,919	2,733	22,912	2,878
Other[1]	43,648	3,823	[r]40,812	[r]3,497	31,551	2,371
Total[2]	1,140,842	161,912	[r]1,103,802	[r]172,435	1,163,347	173,269

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Includes Arizona, Idaho, Iowa, Kansas, Maine, Missouri, Montana, Oregon, Utah, 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	1984[r] [e] Quantity (short tons)	1984[r] [e] Value (thousands)	1985 Quantity (short tons)	1985 Value (thousands)	1986[e] Quantity (short tons)	1986[e] Value (thousands)
California	14,822	$1,236	7,369	$1,501	15,075	$1,257
Connecticut	11,310	919	11,310	919	11,742	826
Georgia	162,187	9,279	[r]158,591	[r]9,133	166,504	9,504
Massachusetts	62,547	11,528	71,242	13,564	W	W
New Hampshire	82,838	5,681	[r]80,140	[r]6,625	81,647	6,423
North Carolina	28,328	4,597	28,919	4,687	28,813	4,675
Oklahoma	W	W	6,112	734	6,346	762
Pennsylvania	9,132	1,866	W	W	9,132	1,898
South Carolina	7,893	537	7,756	541	8,052	568
South Dakota	56,661	18,032	51,493	18,336	53,402	18,236
Texas	37,421	11,259	W	W	W	W
Vermont	91,925	13,820	94,305	14,455	97,267	14,661
Wisconsin	3,031	1,823	3,133	1,891	3,253	1,956
Other[1]	54,272	11,530	[r]85,668	[r]21,979	144,009	36,239
Total	622,367	92,107	[r]606,038	[r]94,365	625,242	97,005

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Includes Colorado, Maine, Maryland, Minnesota, Missouri, New York, Rhode Island, Virginia, Washington, and data indicated by symbol W.

CONSUMPTION AND USES

Dimension stone was marketed over wide areas. Industry stockpiles were not monitored and production during the year was assumed to equal consumption.

Consumption of domestic dimension stone decreased slightly to 1.16 million tons valued at $173.3 million in 1986, compared with 1.10 million tons valued at $172.4 million (revised) in 1985 and 1.14 million tons valued at $161.9 million in 1984.

Consumption of domestic granite increased to 625,000 tons valued at $97.0 million in 1986, compared with 606,000 tons valued at $94.4 million in 1985 and 622,400 tons valued at $92.1 million in 1984.

Domestic limestone consumption was 290,800 tons valued at $43.0 million in 1986, compared with 281,300 tons valued at $34.3 million (revised) in 1985 and 282,800 tons valued at $31.3 million in 1984.

Domestic marble consumption, including travertine, totaled 34,900 tons valued at $23.0 million in 1986, compared with 34,630 tons valued at $21.5 million in 1985 and 28,200 tons valued at $19.9 million in 1984.

Consumption of domestic slate totaled 42,500 tons valued at $15.0 million in 1986, compared with 40,700 tons valued at $13.7 million in 1985 and 37,000 tons valued at $12.3 million in 1984.

A study of current industry practice described the physical properties and considerations involved in the design of thin stone veneers on buildings, a recently developed and a major new market. While well-known properties such as compressive strength, modulus of rupture, and water absorption were important, lesser known factors such as the volume changes accompanying temperature changes, response to freeze-thaw cycles, stone texture, and chemical weathering also were critical. Once the physical properties have been evaluated, design considerations such as stresses in the stone veneer and in its attachment to the building, the anchorage technique, safety factors, controlling the movement of the stone veneer when in service, and control of rainwater must be taken into account. Many of these factors still need more research and extreme care continued to be necessary in the use of thin stone veneer.[2]

An important review of world slate markets appeared in 1986. The U.S. market for slate has been gradually increasing, with much of the increase concentrated in slate roofing. The British market has been strong, particularly for slate roofing, but the domestic producers have many competitors, particularly the Spanish slate roofing producers and the domestic producers of artificial slate roofing products. While West German crude slate production decreased, the market for some slate items increased, particularly roofing. France continued to have the largest market for slate roofing in

Western Europe. The Spanish market for roofing slate has been large and growing, but most of the slate continued to be exported. The Italian market for slate roofing was also large, but much of Italian slate production continued to be exported as billiard table tops. The article also covered Australia, Belgium, India, Norway, Portugal, and the Republic of South Africa. In general, slate has been making a comeback worldwide, particularly in roofing, as part of an architectural trend toward use of natural materials.[3]

Table 4.—Dimension stone sold or used by producers in the United States, by use

Use	1984[e]		1985[r]	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Rough stone:				
Rough blocks for building and construction	248,483	$14,925	256,182	$16,908
Irregular-shaped stone[1]	208,561	5,538	153,424	6,085
Monumental	229,679	22,670	230,876	23,334
Other[2]	7,747	287	7,911	294
Dressed stone:				
Ashlars and partially squared pieces[3]	126,913	30,544	133,402	33,907
Slabs and blocks for building and construction	95,146	32,014	93,171	32,007
Monumental	64,531	25,978	58,214	25,395
Curbing	90,733	14,102	92,319	16,298
Flagging	34,681	4,285	43,901	5,239
Roofing slate	11,752	5,859	12,534	6,342
Structural and sanitary	5,264	2,634	5,906	3,028
Flooring slate	5,733	2,062	6,537	2,450
Other[4]	11,619	1,013	9,425	1,148
Total	1,140,842	[r] [5]161,912	1,103,802	172,435

[e]Estimated. [r]Revised.
[1]Includes rubble.
[2]Includes flagging, other rough stone not listed, and uses not specified.
[3]Includes veneer.
[4]Includes billiard tabletops, miscellaneous, and uses not specified.
[5]Data do not add to total shown because of independent rounding.

Table 5.—Dimension granite sold or used in the United States, by use

Use	1984[e]		1985[r]	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Rough stone:				
Rough blocks for building and construction	101,113	$8,163	105,902	$8,968
Irregular-shaped stone[1]	64,561	2,815	56,368	2,912
Monumental	223,229	22,189	223,990	22,881
Other[2]	1,823	35	1,823	35
Dressed stone:				
Ashlars and partially squared pieces	31,018	7,361	31,663	7,878
Slabs and blocks for building and construction	46,619	16,395	37,712	13,810
Monumental	53,205	19,661	48,077	19,995
Curbing	86,312	13,977	87,883	16,171
Other[3]	14,487	1,509	12,620	1,714
Total[4]	622,367	92,107	606,038	94,365

[e]Estimated. [r]Revised.
[1]Includes rubble.
[2]Includes uses not specified.
[3]Includes flagging, surface plates, and uses not specified.
[4]Data may not add to totals shown because of independent rounding.

Table 6.—Dimension limestone sold or used by producers in the United States, by use

Use	1984[e]		1985	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Rough stone:				
Rough blocks for building and construction	128,310	$5,723	r130,964	r$6,816
Irregular-shaped stone[1]	43,607	757	36,897	770
Other[2]	1,097	38	r1,097	r37
Dressed stone:				
Ashlars and partially squared pieces[3]	62,645	16,017	64,328	16,413
Slabs and blocks for building and construction	37,615	8,281	38,455	r9,780
Monumental	2,011	161	1,775	174
Curbing	552	18	532	18
Other[4]	6,994	302	r7,220	r311
Total[5]	282,831	31,298	r281,268	r34,320

[e]Estimated. [r]Revised.
[1]Includes rubble.
[2]Includes flagging.
[3]Includes veneer.
[4]Includes flagging and unspecified dressed stone uses.
[5]Data may not add to totals shown because of independent rounding.

Table 7.—Dimension marble sold or used by producers in the United States, by use

Use	1984[e]		1985[r]	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Rough stone:				
Rough blocks for building and construction	3,250	$660	3,486	$745
Irregular-shaped stone	3,530	154	W	W
Other[1]	--	--	7,288	506
Dressed stone:				
Slabs and blocks for building and construction	5,209	5,879	9,704	6,850
Other[2]	16,207	13,256	14,150	13,419
Total	28,196	19,949	34,628	21,520

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Includes monumental.
[2]Includes dressed ashlars and partially squared pieces, flagging and monumental.

Table 8.—Dimension sandstone sold or used by producers in the United States, by use

Use	1984[e]		1985	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Rough stone:				
Rough blocks for building and construction	15,680	$376	15,685	$377
Irregular-shaped stone[1]	96,330	1,789	54,869	2,144
Other[2]	4,186	171	4,251	177
Dressed stone:				
Ashlars and partially squared pieces[3]	26,348	1,151	29,465	2,493
Slabs and blocks for building and construction	5,703	1,461	7,300	1,568
Flagging	7,437	513	7,805	551
Other[4]	6,506	297	6,541	299
Total[5]	162,190	5,760	125,916	7,610

[e]Estimated.
[1]Includes rubble.
[2]Includes other rough stone not listed and uses not specified.
[3]Includes veneer.
[4]Includes curbing, stone shapes for interior uses (lintels, hearths, etc.), and uses not specified.
[5]Data may not add to totals shown because of independent rounding.

Table 9.—Dimension slate sold or used by producers in the United States, by use

Use	1984[e] Quantity (short tons)	1984[e] Value (thousands)	1985 Quantity (short tons)	1985 Value (thousands)
Flagging	14,168	$1,701	15,575	$1,799
Roofing slate	11,752	5,859	12,534	6,342
Structural and sanitary	5,264	2,634	6,018	3,073
Flooring slate[1]	5,845	2,107	6,537	2,450
Total	37,029	12,301	40,664	13,664

[e]Estimated.
[1]Includes a small amount of slate used for billiard tabletops.

PRICES

The average price for dimension stone decreased to $149 per ton, down 4% from $156 (revised) in 1985.

FOREIGN TRADE

Exports.—Exports of dimension stone, about one-half of which was granite, increased 6% in value to $14.6 million.

Imports.—Imports for consumption of dimension stone increased 30% in value to $380 million, mostly because of increases in imports of dressed granite and polished slabs of marble. Imports of polished marble slabs, mostly from Italy, increased 40% to $124 million. Imports of dressed granite increased 37% to $142 million, primarily because of a significant increase from Italy. On a value basis, marble accounted for 46% of imports, followed by granite, 42%; travertine, 6%; and slate, 3%.

Table 10.—U.S. exports of dimension stone, by type

(Thousand short tons and thousand dollars)

Type	1985 Quantity	1985 Value	1986 Quantity	1986 Value	Major destination in 1986 (percent[1])
Granite articles	NA	1,388	NA	1,530	Canada 55%.
Granite, rough	42.1	5,828	53.3	6,046	Japan 49%.
Limestone, dressed, for building or monumental	1.0	116	25.9	113	Canada 89%.
Limestone articles	2.6	100	4.8	178	Canada 57%.
Marble, breccia, and onyx, rough or squared	9.7	329	14.2	290	Canada 80%.
Marble, breccia, and onyx articles	NA	1,191	NA	1,727	Saudi Arabia 27%.
Slate building articles	NA	133	NA	118	Canada 51%.
Slate building articles, other	NA	1,568	NA	967	Canada 35%.
Stone, rough, for building or monumental	9.8	1,299	15.6	1,735	Japan 49%.
Stone, other, including alabaster or jet	NA	1,883	NA	1,919	Canada 44%.
Total	NA	13,835	NA	14,623	

NA Not available.
[1]By value.

Source: Bureau of the Census.

Table 11.—U.S. imports for consumption of dimension granite, by country

(Thousand cubic feet and thousand dollars)

Country	Rough[1]		Dressed[1]		Other n.s.p.f. undecorated[2] (value)
	Quantity	Value	Quantity	Value	
1984	5,217	5,395	3,539	73,070	5,478
1985:					
Brazil	5	11	239	3,353	260
Canada	2,439	4,107	252	10,073	5,785
India	6	127	42	1,255	19
Italy	192	157	5,519	73,687	1,926
Japan	--	--	20	383	34
Portugal	62	217	387	874	78
Saudi Arabia	155	129	499	534	28
South Africa, Republic of	37	555	2	60	--
Spain	(3)	12	538	8,626	54
Other	124	783	430	4,835	2,883
Total[4]	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	(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

[1]Does not include unmanufactured, nonmonumental granite.
[2]Quantity not reported. Does not include 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 12.—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)
1984	29,801	$60,957	$40,936	157,534	$16,371
1985:					
France	588	2,021	1,110	2	3
Germany, Federal Republic of	427	483	375	--	--
Greece	1,340	3,086	310	2	2
Italy	38,573	60,637	19,627	168,734	18,088
Mexico	1,143	1,934	3,673	779	284
Pakistan	35	137	593	--	--
Philippines	419	655	145	--	--
Portugal	3,753	4,719	1,424	42	9
Spain	7,419	11,168	1,743	3,437	143
Taiwan	910	1,583	8,662	--	--
Other	1,529	2,155	1,860	7,315	125
Total[4]	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

See footnotes at end of table.

Table 12.—U.S. Imports for consumption of major categories of dimension marble, travertine, and other calcareous stones, by country —Continued

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)
1986 —Continued					
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[4]	74,069	123,637	47,728	173,812	15,496

[1]Does not include certain special kinds of rough marble, breccia, or onyx.
[2]Quantity not reported.
[3]Suitable for use as monumental, paving, or building stone. Does not include travertine articles.
[4]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

Table 13.—U.S. imports for consumption of other dimension stone, by type

Type	1985 Quantity	1985 Value (thousands)	1986 Quantity	1986 Value (thousands)	Major source in 1986 (percent[1])
Granite, n.s.p.f., decorated	--	$402	--	$933	Italy 59%.
Limestone, dressed, hewn short tons	15,937	1,145	34,553	2,288	France 47%.
Marble and breccia, rough cubic feet	131,755	609	87,002	515	Italy 55%.
Marble, breccia, onyx, slab and tiles, unpolished square feet	1,563,636	1,881	914,748	2,593	Do.
Slate, roofing do	1,727,961	926	2,152,986	927	Spain 35%.
Slate, other, n.s.p.f	--	6,747	--	8,876	Italy 58%.
Travertine articles, undecorated	--	6,012	--	6,222	Italy 94%.
Travertine articles, decorated	--	2,105	--	1,532	Italy 97%.
Stone, unmanufactured short tons	35,769	1,156	30,940	966	France 48%.
Stone, dressed, building do	7,729	1,185	2,483	825	Mexico 48%.
Stone, other n.s.p.f., undecorated	--	1,837	--	2,034	Italy 17%
Stone, other n.s.p.f., decorated	--	2,646	--	3,723	Mexico 21%.

[1]By value.

Source: Bureau of the Census.

WORLD REVIEW

Some production of dimension stone occurred 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.

Brazil.—Brazil continued to be a significant producer of dimension stone. Approximately 40% of the domestic production of granite was exported in 1984-85. Based on exports, the estimated production of granite was 350,000 tons in 1984. A wide range of yellows, reds, grays, and other color granites were produced, including a few blacks and two exotic blues. Most of the production and consumption of granite was within 300 miles of the ocean in the southern part of the country, particularly in the States of Bahia, Espirito Santo, Minas Gerais, Rio de Janeiro, and São Paulo. Somibras Ltda. recently opened two granite quarries, one in Pernambuco State and the other in Paraiba State. Most Brazilian quarries were near enough to the surface so that weathering has separated the stone into boulders that can be excavated by bulldozers. Only 5% to 10% of domestic consumption of either granite or marble was monumental stone; the rest was entirely for building. The granite used in domestic building construction was mostly 2 and 3 centimeters thick while most of the 1-centimeter-thick granite was exported. Most of the construction market for granite was in new single family houses and for retrofitting houses by their owners. Brazil's exports of granite and marble were almost all rough blocks, including some slabbed rough blocks.

Brazilian Tijuca Black granite was expected to be quarried for only a few more years. The source of this well-known stone has been several quarries on the edge of the Tijuca Forest Park, one of the major parks in Rio de Janeiro. The Government of Brazil required the phasing out of quarrying within 5 years because the area has become ecologically sensitive. Marmindústria Ltda., one of the quarry owners, began exploration of several sites for a new black granite quarry in São Paulo State. Although black granite was available from a few other small quarries, none of the material was as solidly jet black as the Tijuca Black.

Most dimension stone in Brazil, including black granite, was recovered from so-called boulder quarries where the stone occurs as boulders as a result of separation from the rock mass by differential weathering along vulnerable zones, cracks, and faults. Boulder quarries are seldom encountered in countries with temperate climates because the weathering that occurred was slower and shallower than in the tropics. In the Tijuca Black granite quarry, the stone was separated by pulling the boulders down by winch and cable. The stone also was separated by drill and broach assisted by detonating very small amounts of explosive on the sides that have not been detached by pre-existing cracks along the planes of weakness.

Marmindústria was transferring production from its old plant in Rio de Janeiro to a new plant with new equipment in nearby suburban Caxias. This transfer was to result in an increased capacity to make finished products, most of which were to be exported.

Both Marmindústria and Somibras were attempting to purchase Italian finishing equipment for their dimension stone plants. Cacex, the Government's agency that controls machinery imports, has a broad uniform policy requiring use of Brazilian-made machinery, severely restricting the use of any kind of imported machinery. Cacex will approve the Italian equipment purchases if the firms can demonstrate that state-of-the-art equipment cannot be obtained domestically.

Finland.—A comprehensive review of the granite industry in Finland indicated that starting from only 30,800 tons in 1973, production had risen to almost 264,000 tons in 1984, 80% to 90% of which was exported. Of the total production, about 127,000 tons was Balmoral Red, with the balance being other types of granite. Growth in capacity was expected to continue. Much of the production was for monumental and tombstone applications in Finland and Western Europe. The industry has been conducting a vigorous and continuing search for new deposits of granite suitable for use as monumental and building stone. The industry was comprised of about 50 firms employing a total of approximately 1,000 employees and used advanced production methods to offset the need to operate in a harsh winter climate. The article also described quarrying methods and a number of the important quarries and firms.[4]

Ireland.—A major change in the limestone industry resulted from the introduction of the diamond wire saw 4 years ago. The use of the saw increased production by enabling the clean extraction of larger limestone blocks. A significant proportion of the stone as well as almost all of the portland stone imported from the United Kingdom was used for building restoration. A substantial amount of carving continued for both building items and for monuments. Most of the new construction market for Irish stone, especially granite, continued to be centered in Dublin and its suburbs.[5]

Italy.—An important study of Italian industrial minerals prominently featured the dimension stone industry. Italy produced 6.6 million tons of all kinds of dimension stone in 1985, one-half of which was rough block, with 47% of the total output being exported, 43% being used for building, and 10% being consumed for tombstones and monuments. Italian dimension stone production in 1985 was 30% granite, 40% marble, and 10% travertine. The substantial increase in Italian imports of stone in the last 5 years was probably related to increased difficulty in opening new quarries because of environmental restrictions and a market shift to colored granite rather than white marble. Turin Polytechnic was selected to handle a statistical data bank, which was scheduled to come on-line by 1988, for Italian dimension stone. Several major firms also were profiled.[6]

Thailand.—More than 40 firms produced rough marble blocks in 1985. These producers have been aided by a Government ban on imported marble. The northern region accounted for 44% of the 41,810 tons of marble produced in 1984, and for 58% of the 29,130 tons produced in 1983. Exports totaled 352 tons in 1984 and 1,880 tons in 1983. In 1985, a slowdown in local construction resulted in an oversupply of marble.[7]

Turkey.—The production capacity of the dimension marble industry was increased as a result of several new operations and expansions at existing facilities. The Etibank joint venture with the private sector on Marmara Island came on-stream with annual production capacity of 106,000 cubic feet of block and 320,000 square feet of slab. Mayas produced 353,000 cubic feet per year of travertine in 1984-85 in the Denizli area and brought on-stream in 1986 a finishing plant with a capacity of 5.4 million square feet per year of travertine veneer panels. Saim Budin began operation of a 53,000-cubic-foot-per-year-capacity facility for rough block in the Eskisehir region in 1984-85 and planned to expand to 80,000 cubic feet of rough block in 1986. The new operations, plus those previously operating, gave the country an estimated annual production capacity of 2.82 to 5.64 million cubic feet as rough block plus 18.8 million square feet as slab.[8]

United Kingdom.—Kirkstone Green Slate Quarries Ltd. installed some new saws and an automatic slab polisher at its Skelwith Bridge Works and a 10-bladed frame saw at the firm's Kirkstone Pass Quarry. The new equipment will be used to make cladding, flooring, and interior walls and surfaces for domestic and North American projects.

TECHNOLOGY

The actual costs of cutting various carbonate rocks in the United States was recently examined in a Bureau of Mines paper. Based on a survey of the firms using the diamond wire saw and the chain saw with tungsten carbide inserts, the cost of labor and the proportion of down-time (time the saw is not operating because of servicing or repair) were found to have strongly influenced the cost of cutting, while the cost of energy (electricity) had only minimal influence. The cost of labor ranged from $8 to $20 per hour, and the cost of electricity ranged from 8 to 22 cents per kilowatt hour. The cost of replacement parts and the life of the part also had significant influence on the cost of cutting.[9]

Chain saws using polycrystalline diamond inserts for cutting have been developed and were being tested in several Italian marble quarries. The inserts are composed of a 1.0-millimeter-thick polycrystalline diamond layer backed by a tungsten carbide substrate. The insert is kept sharp by the softer substrate wearing preferentially to constantly expose the sharp diamond cutting edge. According to Minazzana S.p.A. of Italy, the insert supplier, tests of a chain saw with these inserts in the Cervaiole Quarry showed that tool costs were cut by 60% compared with the conventional helicoidal wire and by 40% compared with the new diamond wire saw. The firm further stated that information from several Italian marble quarries demonstrated a typical marble cutting rate of 56.5 square feet per hour at a tool cost of $0.26 per square foot cut.

Maschinenfabrik Korfmann GmbH, a West German firm, announced a new patented-design chain saw using diamond segments on the pick teeth. This self-advancing machine could cut and move forward at a rate of 4.7 inches per minute, and was able to cut granite and hard sandstone. Commercial production of this chain saw was scheduled for late 1986.

N-E-D Corp. developed L-shaped segments for diamond circular saws. The L-shaped diamond segments, according to the firm, reduced power consumption by 50% or reduced cutting time by 40% in tests. The L-shaped segments were placed so that the leading edge projected alternately to the left and right of the blade, reducing stress on the blade and helping to keep the blade in track. This extended the blade life, decreased wear on machinery, and made more accurate cuts.

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[1]Physical scientist, Division of Industrial Minerals.

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Sulfur

By David E. Morse[1]

The United States retained its position as the world's foremost sulfur producer despite a decrease in output of over 500,000 metric tons compared with that of 1985. Production from Frasch mines, the largest source of discretionary sulfur, decreased 19%. Low prices for crude oil on world markets and increased domestic demand for refinery products contributed to a record-high output of recovered sulfur from U.S. petroleum refineries of over 3.5 million tons. Domestic sulfur demand decreased by 12% from that of 1985; imports decreased by nearly one-third; and exports increased by 39%. As a result, the United States became a net exporter of sulfur for the first time since 1974. Shipments of sulfur in all forms from domestic producers decreased by about 100,000 tons; shipments were about 50,000 tons greater than production.

Table 1.—Salient sulfur statistics

(Thousand metric tons, sulfur content, and thousand dollars unless otherwise specified)

	1982	1983	1984	1985	1986
United States:					
Production:					
Frasch	4,210	3,202	4,193	5,011	4,043
Recovered[1]	4,404	4,955	5,214	5,313	5,816
Other forms	1,173	1,133	1,245	1,285	1,228
Total	9,787	9,290	10,652	11,609	11,087
Shipments:					
Frasch	3,598	4,111	5,001	4,678	4,108
Recovered[1]	4,344	5,041	5,210	5,266	5,798
Other forms	1,173	1,133	1,245	1,285	1,228
Total	9,115	10,285	11,456	11,229	11,134
Exports, elemental[2]	961	992	1,334	1,365	1,895
Imports, elemental	1,905	1,695	2,557	2,104	1,347
Consumption, apparent, all forms	10,059	10,988	12,679	11,968	10,586
Stocks, Dec. 31: Producer, Frasch and recovered	4,218	3,223	2,419	2,799	2,748
Value:					
Shipments, f.o.b. mine or plant:					
Frasch	$434,660	$414,210	$546,106	$573,570	$508,512
Recovered[1]	425,217	384,214	416,878	485,084	533,752
Other forms	122,177	116,255	121,692	123,937	105,639
Total	982,054	914,679	1,084,676	1,182,591	1,147,903
Exports, elemental[3]	$122,143	$109,298	$156,067	$189,248	$251,664
Imports, elemental[4]	$164,885	$129,110	$200,189	$199,240	$142,220
Price, elemental, dollars per metric ton, f.o.b. mine or plant	$108.27	$87.24	$94.31	$106.46	$105.22
World: Production, all forms (including pyrites)	[r]50,559	[r]50,298	52,496	[p]54,587	[e]54,161

[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]Declared customs valuation.
[4]Includes value of exports from the Virgin Islands to foreign countries.

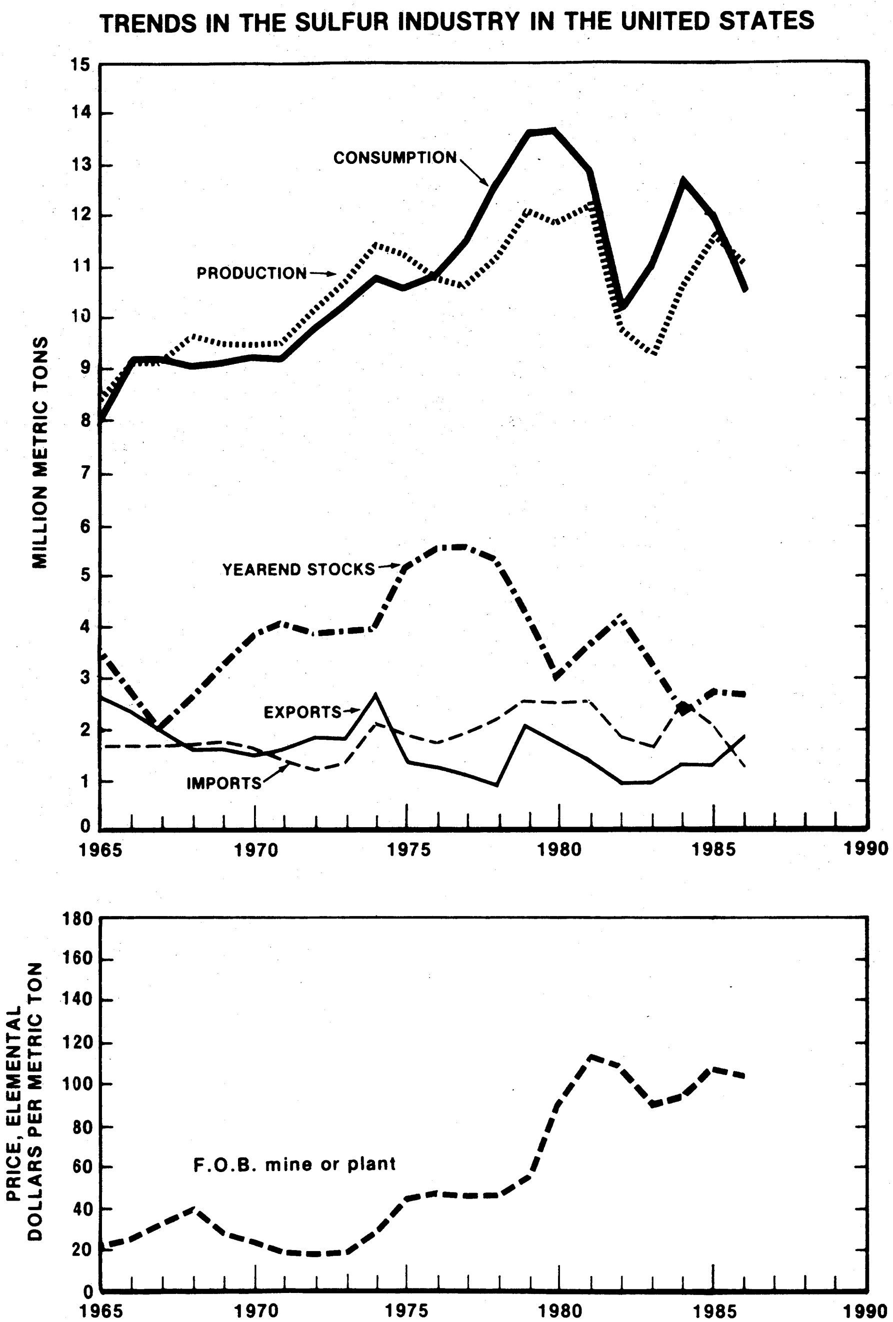

Figure 1.—Trends in the sulfur industry in the United States.

Shipments of sulfur from Frasch mines to domestic consumers decreased by 23% and supplied 31% of U.S. demand for elemental sulfur. The average annual price for all elemental sulfur declined domestically and worldwide because of the increased availability of sulfur and a stagnation of world demand. World sulfur stocks decreased by a moderate 350,000 tons compared with the average annual decline of 3 million tons during the previous 3 years.

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 181 operations to which a survey request was sent, 180 responded, representing 99.99% of the total production shown in tables 1 and 2. The production of the one nonrespondent was estimated using prior year production levels adjusted to reflect trends in output of their primary product and other guidelines.

DOMESTIC PRODUCTION

Sulfur is one of the few elements that occurs 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_2S) gas. Commercial production of sulfur, in the United States, either as elemental sulfur or combined in another chemical form, is accomplished by a variety of methods dictated by the sulfur source. Native sulfur associated with the caprocks of salt domes and in sedimentary deposits is mined by the Frasch hot water method in which native sulfur is melted underground and brought to the surface with an airlift. Sulfur from iron and base metal sulfides is usually recovered as sulfuric acid during roasting or smelting. Sulfur from coal may be produced in the elemental form or as ammonium sulfate during the production of coke; as sulfuric acid or sulfur dioxide when burning coal; or, when producing low-British-thermal-unit coal gas, as ammonium sulfate while scrubbing the gas with ammonia. Sulfur is recovered from petroleum and natural gas by absorbing the H_2S gas in an amine solution, then regenerating the H_2S, and processing it into elemental sulfur in a Claus converter.

Frasch.—In January 1986, the United States had four Frasch mines operating in Louisiana and Texas. 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 began rehabilitating its Caminada Pass, LA, property, which had last produced sulfur in 1968. At yearend 1986, the Frasch mining industry was operating at about 70% of capacity compared with 90% at yearend 1985.

Frasch sulfur output decreased nearly 1 million tons from that of 1985. Total shipments to consumers, however, declined by only 570,000 tons because of increased exports. Frasch sulfur accounted for 36% of total domestic production of sulfur in all forms, compared with 43% in 1985. Approximately 70% of Frasch sulfur shipments was for domestic consumption, and 30% for export.

Recovered.—Production of recovered elemental sulfur, a nondiscretionary byproduct from petroleum refining, natural gas processing, and coking plants, accounted for 52% of the total domestic output of sulfur in all forms, compared with 46% in 1985. Both production and shipments reached all-time high levels of over 5.75 million tons, owing to record-high production from the Nation's petroleum refineries that offset a decline in output from natural gas plants. Recovered elemental sulfur was produced by 56 companies at 154 plants in 26 States, 1 plant in Puerto Rico, and 1 plant in the U.S. Virgin Islands. Most of these plants were of relatively small size, with only 17 reporting an annual production exceeding 100,000 tons. By source, 55% was produced at 84 refineries or satellite plants treating refinery gases and 3 coking plants, and 45% was produced by 26 companies at 68 natural gas treatment plants.

The five largest recovered sulfur producing companies were Chevron U.S.A. Inc., Exxon Co. U.S.A., Shell Oil Co., Standard Oil Co. (Indiana), and Texaco Inc. These companies' 59 plants accounted for 60% of recovered elemental sulfur output during the year. In September, Exxon began operating a new large-scale natural gas facility in southwestern Wyoming.

The leading States in production of recovered sulfur in decreasing order were Texas, Mississippi, Wyoming, California, and Louisiana. These five States contributed 70% of total output; shipments from Texas accounted for 26% of total recovered sulfur shipments. The total value of recovered sulfur shipments increased 10% compared with that of 1985.

Table 2.—Production of sulfur and sulfur-containing raw materials in the United States

(Thousand metric tons)

	1985		1986	
	Gross weight	Sulfur content	Gross weight	Sulfur content
Frasch sulfur	5,011	5,011	4,043	4,043
Recovered sulfur[1]	5,313	5,313	5,816	5,816
Byproduct sulfuric acid (100% basis) produced at copper, lead, molybdenum, and zinc plants	2,928	957	2,811	919
Other forms[2]	814	328	767	309
Total	XX	11,609	XX	11,087

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]
1982	2,898	1,312	4,210	3,598	434,660
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

[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]
1982	1,960	2,444	4,404	4,344	425,217
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

[1]Includes Puerto Rico and the Virgin Islands.
[2]Includes a small quantity from coking operations and utility plants in 1982; includes only a small quantity from coking operations in 1983-86.
[3]F.o.b. plant.

Table 5.—Recovered sulfur produced and shipped in the United States, by State

(Thousand metric tons and thousand dollars)

State	1985			1986		
	Production	Shipments		Production	Shipments	
		Quantity	Value		Quantity	Value
Alabama	370	367	35,421	338	341	36,452
California	590	576	47,087	634	630	50,964
Florida	91	91	W	80	80	W
Illinois	193	194	19,895	372	368	36,581
Louisiana	405	403	45,053	524	527	57,418
Michigan and Minnesota	137	138	11,623	158	158	13,938
Mississippi	578	565	62,156	702	707	79,287
New Jersey	74	74	9,357	W	W	W
New Mexico	55	55	4,281	46	46	3,621
North Dakota	108	109	6,127	105	104	7,043
Ohio	36	36	3,891	46	46	5,188
Pennsylvania	50	50	4,475	52	53	4,540
Texas	1,500	1,496	147,426	1,517	1,516	141,223
Wisconsin	1	2	96	2	2	117
Wyoming	703	699	35,335	684	676	33,517
Other[1]	420	411	52,862	558	545	63,863
Total[2]	5,313	5,266	485,084	5,816	5,798	533,752

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Includes Arkansas, Colorado, Delaware, Indiana, Kansas, Kentucky, Montana, 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	1985		1986	
	Production	Shipments	Production	Shipments
PAD 1:				
Petroleum and coke	230	227	254	258
Natural gas	91	91	79	79
Total[1]	321	318	334	338
PAD 2:				
Petroleum and coke	495	495	715	712
Natural gas	111	112	107	106
Total[1]	606	608	822	818
PAD 3:[2]				
Petroleum	[r]1,494	[r]1,464	1,830	1,818
Natural gas	[r]1,480	[r]1,483	1,385	1,390
Total[1]	2,975	2,948	3,215	3,208
PAD 4 and 5:				
Petroleum	715	700	769	766
Natural gas	693	690	673	666
Total[1]	1,408	1,390	1,443	1,432
Grand total[1]	5,313	5,266	5,816	5,798

[r]Revised.
[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 8% of the total domestic production of sulfur in all forms. Seven acid plants operated in conjunction with copper smelters, and nine were accessories to lead, molybdenum, and zinc smelting and roasting operations. The five largest acid plants accounted for 74% of the output, and production in five States was 87% of the total. The five largest producers of byproduct sulfuric acid were ASARCO Incorporated, Chino Mines Co., Inspiration Consolidated Copper Co., Magma Copper Co., and Phelps Dodge Corp. Their eight plants produced 81% of the 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
1982	615	112	101	828	63,674
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

[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 3% of the total domestic production of sulfur in all forms during the year. Output of total sulfur contained in these products was less than that of 1985. The producers were Chevron, Shell Oil, Stauffer Chemical Co., and Tennessee Chemical Co. Tennessee Chemical announced that it would cease pyrites mining operations in 1987 and begin to burn purchased sulfur for sulfuric acid production at its Copper Hill, TN, operations. The company's sulfur-burning acid plant in Savannah, GA, was idle in 1986.

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
1982	265	32	48	345	58,503
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

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

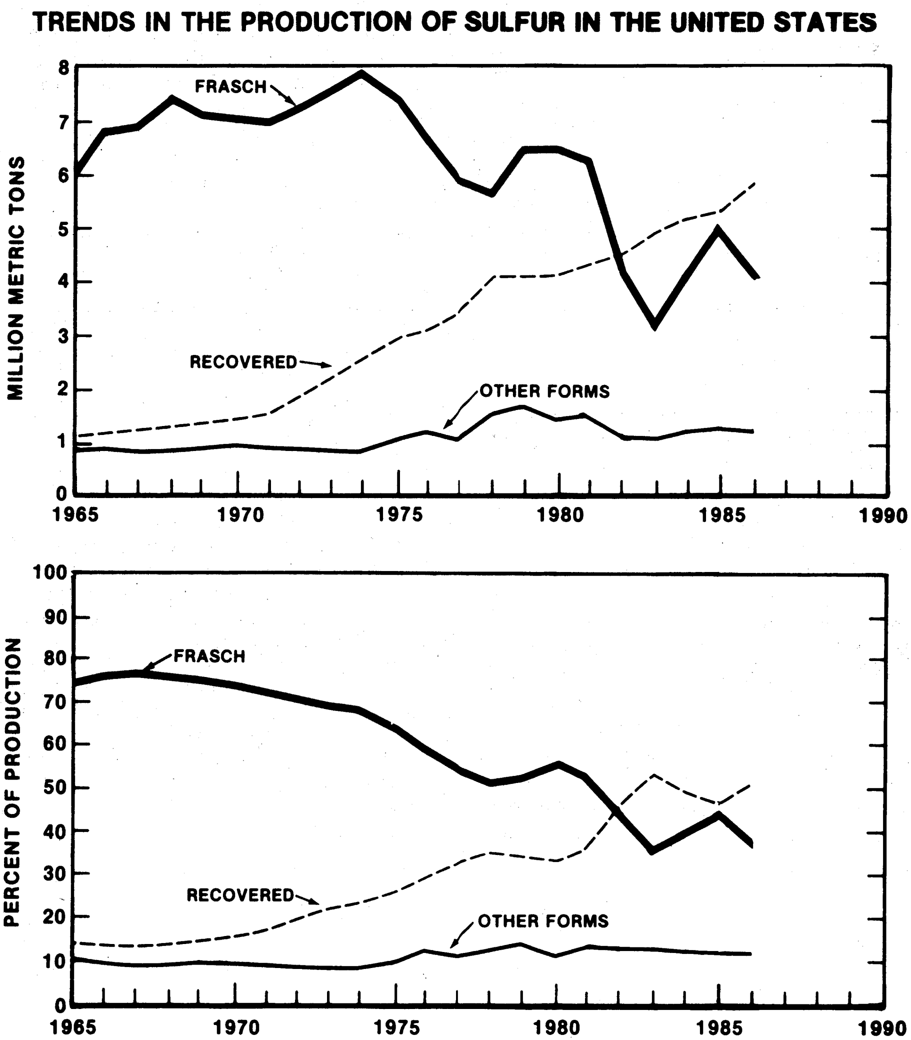

Figure 2.—Trends in the production of sulfur in the United States.

CONSUMPTION AND USES

Sulfur is a relatively unusual mineral commodity because most of it is converted to a chemical intermediate, sulfuric acid, for use in a myriad of chemical processes. Usually, the sulfur values do not become constituents of the final chemical product but are retained either in a byproduct or as wastes requiring disposal in an environmentally acceptable manner. In 1986, 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.

Apparent domestic consumption of sulfur in all forms decreased 12% from that of 1985. In 1986, 87% of the sulfur was obtained from domestic sources compared with 83% in 1985. The sources of supply were domestic recovered elemental sulfur, 49%; domestic Frasch sulfur, 27%; and combined domestic byproduct sulfuric acid, pyrites, H_2S, and sulfur dioxide, 11%. The remaining 13% 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 58 companies, and shipments of sulfuric acid were reported by 56 companies. Shipments of both elemental sulfur and sulfuric acid were reported by 12 companies.

The largest sulfur end use, sulfuric acid, represented 85% 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 also were tabulated as "Unidentified." Although supporting data are unavailable, 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 Bureau of Mines canvass and exports of 1.9 million tons reported by the Bureau of the Census may have been caused by differences in accounting between company records and compilations of the Census Bureau, or by sales to other parties that exported sulfur and were not included in the Bureau of Mines canvass.

Shipments of 100% sulfuric acid declined by over 2.5 million tons in 1986 because demand for the production of phosphatic fertilizers, the largest single end use of sulfuric acid, decreased 12%. Most of the falloff in demand, which occurred in the first three quarters of the year, was a result of decreased fertilizer sales to domestic farmers and significantly reduced exports of fertilizers. Shipments of sulfuric acid for petroleum refining and other petroleum and coal products, the second largest end use, increased 18% from those of 1985.

According to the 1986 canvass reports, company receipt of spent or contaminated sulfuric acid for reclaiming totaled 2.5 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 1.1 million tons of sulfuric acid. About 825,000 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, copper ores, explosives, and some unidentified sources.

The largest use of sulfur in all forms, for agricultural purposes, decreased from 8.6 million tons in 1985 to 7.7 million tons.

Table 9.—Apparent consumption of sulfur[1] in the United States

(Thousand metric tons)

	1982	1983	1984	1985	1986
Frasch:					
Shipments	3,598	4,111	5,001	4,678	4,108
Imports	690	604	722	724	726
Exports	731	601	911	986	1,250
Total	3,557	4,114	4,812	4,416	3,584
Recovered:					
Shipments[2]	4,344	5,041	5,210	5,266	5,798
Imports	1,215	1,091	1,835	1,380	621
Exports	230	391	423	379	645
Total	5,329	5,741	6,622	6,267	5,774
Pyrites, shipments	265	W	W	W	W
Byproduct sulfuric acid, shipments	828	831	962	957	919
Other forms, shipments[3]	80	302	283	328	309
Total, all forms	10,059	10,988	12,679	11,968	10,586

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	Quantity 1985	Quantity 1986
20	Food and kindred products	W	W
26, 261	Pulp and paper products	27	21
282, 2822	Synthetic rubber and other plastic products	25	W
287	Agricultural chemicals	579	551
28, 2816, 285, 286	Paint and allied products, inorganic pigments, industrial organic chemicals, other chemical products[1]	105	19
284	Soaps and detergents	31	52
29, 291	Petroleum refining and petroleum and coal products	189	92
281	Other industrial inorganic chemicals	222	76
30	Rubber and miscellaneous plastic products	W	W
	Sulfuric acid:		
	Domestic sulfur	6,880	7,017
	Imported sulfur	2,052	1,079
	Total	8,932	8,096
	Unidentified	733	620
	Total domestic uses	10,843	9,527
	Exports	1,112	1,511
	Grand total	11,955	11,038

W Withheld to avoid disclosing company proprietary data; included with "Unidentified."
[1]Does not include paints and allied products and inorganic pigments in 1986.

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	Quantity 1985	Quantity 1986
102	Copper ores	1,018	830
1094	Uranium and vanadium ores	62	98
10	Other ores	54	81
261	Pulpmills	705	701
26	Other paper products	89	48
285, 2816	Inorganic pigments and paints and allied products	331	363
281	Other inorganic chemicals	834	915
282, 2822	Synthetic rubber and other plastic materials and synthetics	742	766
2823	Cellulosic fibers including rayon	129	138
283	Drugs	52	50
284	Soaps and detergents	272	232
286	Industrial organic chemicals	1,010	973
2873	Nitrogenous fertilizers	191	251
2874	Phosphatic fertilizers	24,082	21,330
2879	Pesticides	74	72
287	Other agricultural chemicals	64	80
2892	Explosives	94	93
2899	Water-treating compounds	291	371
28	Other chemical products	151	136
29, 291	Petroleum refining and other petroleum and coal products	2,215	2,617
30	Rubber and miscellaneous plastic products	11	9
331	Steel pickling	212	211
333	Nonferrous metals	56	103
33	Other primary metals	161	41
3691	Storage batteries (acid)	206	151
	Unidentified	1,613	1,480
	Total domestic	34,719	32,140
	Exports	69	36
	Grand total	34,788	32,176

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] 1985	Elemental sulfur[1] 1986	Sulfuric acid (sulfur equivalent) 1985	Sulfuric acid (sulfur equivalent) 1986	Total 1985	Total 1986
102	Copper ores	--	--	333	271	333	271
1094	Uranium and vanadium ores	--	--	20	32	20	32
10	Other ores	--	--	18	26	18	26
20	Food and kindred products	W	W	--	--	W	W
26, 261	Pulpmills and paper products	27	21	259	245	286	266
28, 285, 286, 2816	Inorganic pigments, paints and allied products, industrial organic chemicals, other chemical products	105	[2]19	109	119	214	138
281	Other inorganic chemicals	222	76	273	299	495	375
282, 2822	Synthetic rubber and other plastic materials and synthetics	25	W	243	250	268	250
2823	Cellulosic fibers, including rayon	--	--	42	45	42	45
283	Drugs	--	--	17	16	17	16
284	Soaps and detergents	31	52	89	76	120	128
286	Industrial organic chemicals	--	--	330	318	330	318
2873	Nitrogenous fertilizers	--	--	62	82	62	82
2874	Phosphatic fertilizers	--	--	7,872	6,973	7,872	6,973
2879	Pesticides	--	--	24	24	24	24
287	Other agricultural chemicals	579	551	21	26	600	577
2892	Explosives	--	--	31	30	31	30
2899	Water-treating compounds	--	--	95	121	95	121
28	Other chemical products	--	--	49	45	49	45
29, 291	Petroleum refining and other petroleum and coal products	189	92	724	855	913	947
30	Rubber and miscellaneous plastic products	W	W	4	3	4	3
331	Steel pickling	--	--	69	69	69	69
333	Nonferrous metals	--	--	18	34	18	34
33	Other primary metals	--	--	53	13	53	13
3691	Storage batteries (acid)	--	--	67	50	67	50
	Exported sulfuric acid	--	--	23	12	23	12
	Total identified	1,178	811	10,845	10,034	12,023	10,845
	Unidentified	733	620	527	484	1,260	1,104
	Grand total	1,911	1,431	11,372	10,518	13,283	11,949

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.

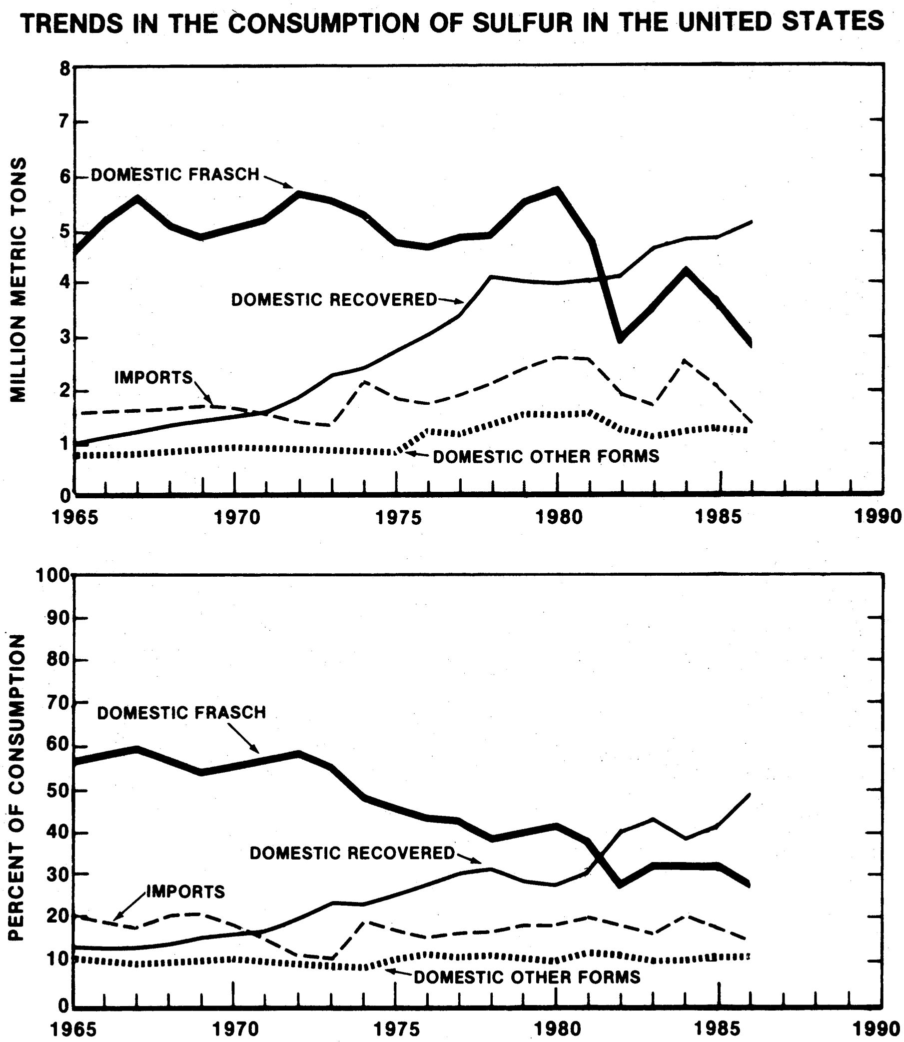

Figure 3.—Trends in the consumption of sulfur in the United States.

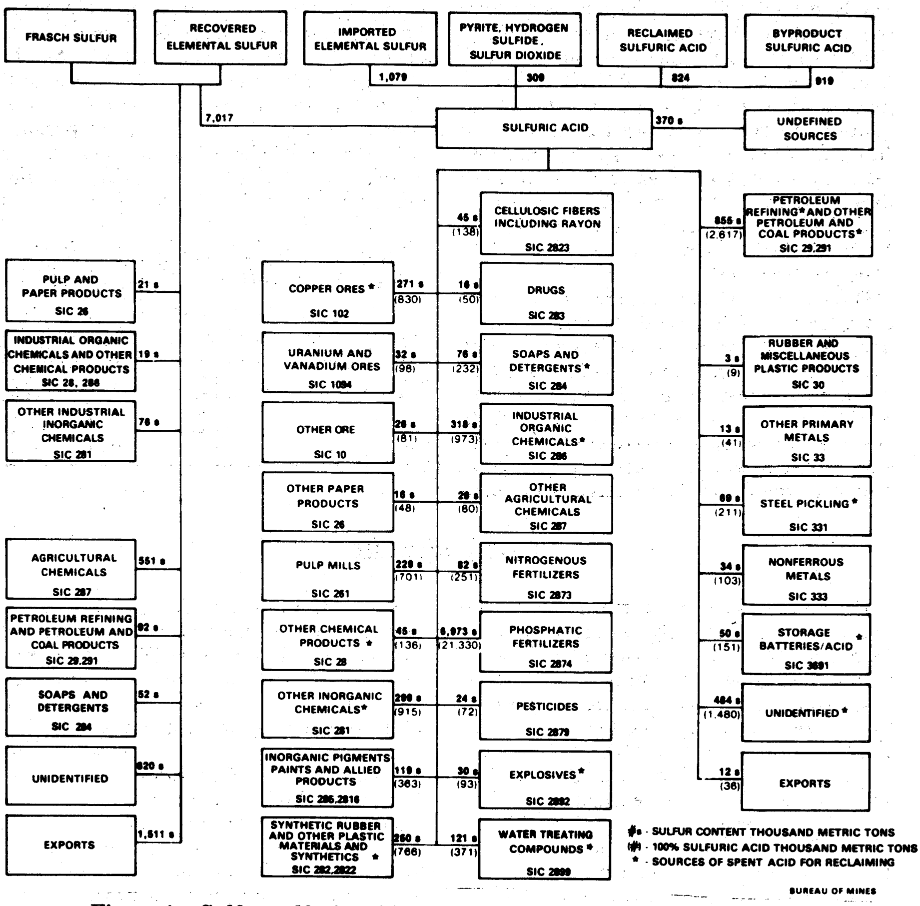
Figure 4.—Sulfur-sulfuric acid supply and end-use relationship in 1986.

STOCKS

Yearend inventories held by Frasch and recovered elemental sulfur producers were essentially unchanged, after inventory adjustments, from those at yearend 1985. Combined yearend stocks amounted to approximately a 3-1/3-month supply 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
1982	3,980	238	4,218
1983	3,070	153	3,223
1984	2,264	155	2,419
1985	2,598	201	2,799
1986	2,532	216	2,748

PRICES

The quoted price for liquid sulfur, exterminal Tampa, FL, was $157.50 per long ton until November when the quote was reduced $5.00 per long ton. Price discounts, which had begun in 1983 for large-volume customers, of $10 per long ton remained in effect. Spot and contract prices for sulfur, f.o.b. Vancouver, British Columbia, Canada, began the year at $135 per metric ton. Vancouver spot prices decreased to about $130 in June, $123 in September, and $110 by yearend. Contract prices from Vancouver decreased to $125 per metric ton by yearend. During the 2-year period, 1985-86, the Vancouver spot sulfur price declined nearly $50 per metric ton.

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 $106.46 to $105.22 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 value for Wyoming distorts the average calculation for all recovered elemental shipments.

Table 14.—Reported sales values of shipments of sulfur, f.o.b. mine or plant

(Dollars per metric ton)

Year	Frasch	Recovered	Average
1982	120.79	97.89	108.27
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

FOREIGN TRADE

Exports of elemental sulfur from the United States, including the Virgin Islands, increased 39% in quantity and 33% in value. According to the Bureau of the Census, exports from the west coast increased by 140,000 tons to 458,000 tons, or 24% of total U.S. exports. The United States became a net exporter of sulfur for the first time since 1974, with exports exceeding imports by over 500,000 tons in 1986. Morocco and Tunisia received 47% of U.S. exports for use in fertilizer production.

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 decreased by more than one-third in quantity; imports by rail from Canada decreased by 55%, while waterborne shipments from Mexico were unchanged. An estimated 215,000 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 the U.S. east coast.

The United States also had significant trade in sulfuric acid. Sulfuric acid exports decreased by 53% from those of 1985, mainly because of reduced sales to Brazil and Venezuela. Imports, mostly from Canada, increased in both quantity and value by over 300,000 tons and $10.8 million, respectively, from that of 1985.

Table 15.—U.S. exports[1] of elemental sulfur, by country

(Thousand metric tons and thousand dollars)

Country	1985		1986	
	Quantity	Value	Quantity	Value
Algeria	--	--	22	2,990
Argentina	31	3,216	11	1,605
Belgium-Luxembourg	394	48,678	249	30,907
Brazil	173	26,617	188	28,880
Canada	5	270	19	1,116
Chile	8	1,236	2	449
Colombia	17	2,591	14	1,869
Egypt	28	4,693	40	4,585
France	26	3,577	11	1,335
India	76	11,130	66	8,663
Indonesia	(2)	1	53	6,839
Israel	37	4,994	25	3,533
Italy	22	3,128	(2)	4
Mexico	97	9,799	139	13,768
Morocco	220	35,074	564	77,920
Netherlands	6	772	7	820
Philippines	11	1,594	(2)	191

See footnotes at end of table.

Table 15.—U.S. exports[1] of elemental sulfur, by country —Continued

(Thousand metric tons and thousand dollars)

Country	1985		1986	
	Quantity	Value	Quantity	Value
Romania	24	2,658	--	--
Senegal	--	--	56	7,101
Spain	15	2,288	(2)	6
Taiwan	23	2,883	49	6,590
Tunisia	83	11,856	322	42,215
Turkey	24	3,388	19	2,439
Uruguay	3	465	8	1,133
Venezuela	14	2,290	1	500
Yugoslavia	15	1,944	--	--
Other	14	4,104	31	6,206
Total[3]	1,365	189,248	1,895	251,664

[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	1985		1986	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Brazil	28,397	$982	66	$8
Canada	15,258	708	16,890	680
Chile	4,099	177	499	27
Dominican Republic	2,729	227	382	63
Ecuador	2,083	97	144	16
France	242	11	376	19
Jamaica	172	17	54	54
Japan	76	24	693	47
Korea, Republic of	1,388	716	1,208	848
Mexico	16,699	742	21,427	833
Namibia	--	--	1,495	60
Netherlands	2	2	77	24
Netherlands Antilles	4,357	213	6,400	320
Panama	2,368	121	3,613	193
Saudi Arabia	659	32	418	78
Switzerland	8,198	300	38	1
Trinidad and Tobago	1,561	65	38	5
Venezuela	31,960	1,367	6,664	476
Other	[r]5,072	[r]843	6,524	869
Total	125,320	[1]6,645	67,006	4,621

[r]Revised.
[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	1985		1986	
	Quantity	Value[1]	Quantity	Value[1]
Canada	1,354	110,231	605	50,342
Mexico	724	85,778	726	89,709
Venezuela	24	2,972	16	1,891
Other[2]	2	259	(3)	278
Total	2,104	199,240	1,347	142,220

[1]Declared customs valuation.
[2]Includes China, the Federal Republic of Germany, Italy, Japan, New Caledonia, and the United Kingdom in 1985; and the Dominican Republic, France, the Federal Republic of Germany, and Japan in 1986.
[3]Less than 1/2 unit.

Source: Bureau of the Census.

Table 18.—U.S. imports of sulfuric acid (100% H_2SO_4), by country

Country	1985 Quantity (metric tons)	1985 Value[1] (thousands)	1986 Quantity (metric tons)	1986 Value[1] (thousands)
Belgium	38	$46	16	$8
Canada	426,909	17,871	589,174	20,511
Denmark	--	--	8,408	457
Finland	--	--	15,712	590
France	23	28	67	184
Germany, Federal Republic of	46	30	33,183	2,544
Italy	--	--	6,943	283
Netherlands	4,475	429	2,877	118
Spain	9,560	611	61,843	2,888
Sweden	(2)	5	21,583	828
Switzerland	--	--	596	381
United Kingdom	1	11	19,167	1,006
Other	r3	r7	131	86
Total[3]	441,055	19,038	759,702	29,883

rRevised.
1Declared c.i.f. valuation.
2Less than 1/2 unit.
3Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

WORLD REVIEW

World production of sulfur in all forms decreased slightly but remained near the record-high level established in 1980. Elemental sulfur output declined because of reduced Frasch output in the United States and decreased production from the Lacq "sour gas" field in southwestern France. World demand was also lower; nevertheless, demand continued to outstrip production and required withdrawals from stocks. Stock withdrawal, however, was only a moderate 350,000 tons compared with the nearly 9 million tons withdrawn during the preceding 3 years.

International trade in elemental sulfur decreased about 0.5 million tons to 15.5 million tons. Canada continued to be the world's leading exporter, followed by Poland, the United States, Mexico, Saudi Arabia, the Federal Republic of Germany, and France, in descending order of export quantity. The Morocco and U.S.S.R. were the largest importers. Other nations with significant sulfur imports, in decreasing order of quantity, were the United States, Brazil, Tunisia, India, and the United Kingdom.

International sulfur prices softened, declining slowly during the first half of the year, and then more rapidly, especially during the fourth quarter. Spot-prices, which were about $130 per ton, f.o.b. Vancouver, British Columbia, Canada, and Persian Gulf ports early in the year, declined to about $110 per ton by yearend.

Canada.—Shipments of sulfur in all forms were about 7.72 million tons, or 1.2 million tons greater than output, but 11% less than 1985 shipments. Exports decreased by over 1 million tons. Sulfur exported from the port of Vancouver, British Columbia, decreased 0.5 million tons to 5.6 million tons from the record-high volume of 1985. Exports by rail to the United States decreased by 600,000 tons and were less than 1 million tons for the first time in more than a decade. Despite the decrease in exports during 1986, Canada remained the world's largest exporting country.

Pacific Coast Terminals (PCT), one of two sulfur export facilities at Vancouver, was engaged in a major capital investment project to install a computer-controlled "stakrake" storage and reclaim system designed to increase sulfur-handling efficiency. PCT was owned by the Canadian sulfur industry through Sultran Ltd. Sultran, owned by a group of major Canadian sulfur producers, was primarily responsible for the orderly movement of sulfur from producing areas to the export terminals at Vancouver.

Canadian sulfur stocks in block, in Alberta Province and awaiting shipment at Vancouver, declined to 8.5 million tons. Canadian stocks had been used to supply most of the shortfall in world production during the 1980's and had decreased considerably from

20.1 million tons at yearend 1979.

Iran.—Sulfur production remained significantly less than capacity because of the ongoing war with neighboring Iraq. Some sulfur exports were transferred overland eastward beyond the range of Iraqi aircraft.

Iraq.—Sulfur exports continued to be routed overland through neighboring countries because safe passage could not be assured for Iraqi material in the Persian Gulf. Production increased but remained well below capacity at natural gas plants and the Mishraq Frasch mine.

Mexico.—Frasch sulfur output increased to nearly 1.6 million tons, which reflected efforts to bring the Patapa facility, adjacent to the Jaltipan Mine, up to its design capacity of 350,000 tons per year. Production increased at Coachapa in the Salinas Basin, and engineering work was well under way to supply services to the nearby Otapan deposit; sulfur production from Otapan was planned to begin in 1987. Sulfur continued to be imported from the west coast of Canada and the United States because of difficulties in transporting sulfur to the Lázaro Cárdenas fertilizer facility on the Pacific coast from the sulfur mining areas near the gulf coast.

Poland.—Sulfur exports of about 3.9 million tons included 1.9 million tons to Eastern Europe and 1.1 million tons to Western Europe; most of the remainder was shipped to Brazil, India, and Morocco.

Saudi Arabia.—An increase in sulfur production of 200,000 tons in 1986 reflected increased associated gas and petroleum output. Sulfur was also produced from nonassociated sour gas, which was used to meet the country's gas requirements. Production of sulfur exceeding demand for exports and internal consumption resulted in an increase in stocks of nearly 400,000 tons.

U.S.S.R.—Yearend television announcements of accomplishments during 1986 included a statement that the first phase of the Astrakhan natural gas processing complex was completed. Contractors from France and the Federal Republic of Germany had been working on the complex since 1984. Construction on the second phase began in 1986. Each phase of the complex, near the Volga River Delta on the north side of the Caspian Sea, was planned to process up to 250 billion cubic feet per year of gas in four trains. Plans included capacity to produce 2.7 million tons per year of sulfur from the gas, which contains 16% to 25% H_2S.[2] The two-phase complex was designed to be the largest sulfur producing facility in the world.

The blowout and fire that had occurred at the Tengiz oil-gas-condensate field in 1985 was extinguished in March 1986.[3] The field, on the northeastern shore of the Caspian Sea, was expected to begin production in 1988 with the recovery of 1,600 tons per day of sulfur from associated gas.[4]

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[1]Physical scientist, Division of Industrial Minerals.
[2]European Chemical News (London). V. 44, No. 1175, 1985, p. 30.
[3]The Oil and Gas Journal. V. 84, No. 34, 1986, p. 4.
[4]Work cited in footnote 2.

Table 19.—Sulfur: World production in all forms, by country and source[1]

(Thousand metric tons)

Country[2] and source[3]	1982	1983	1984	1985[p]	1986[e]
Algeria: Byproduct, natural gas and petroleum[e]	10	15	20	20	20
Australia:					
Byproduct:					
Metallurgy	146	170	190	[e]190	190
Petroleum	17	13	13	13	13
Total	163	183	203	[e]203	203
Austria:					
Byproduct:					
Metallurgy	10	9	10	[e]10	9
Natural gas and petroleum	38	32	28	24	24
Gypsum	27	26	26	[e]26	26
Total	75	67	64	60	59
Bahamas: Byproduct, petroleum[e]	5	5	3	[r]1	--
Bahrain: Byproduct, petroleum	34	49	[e]50	42	45
Belgium: Byproduct, all sources[e]	270	250	240	[r]250	260
Bolivia: Native	6	3	2	3	6

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]	1982	1983	1984	1985[p]	1986[e]
Brazil:					
Frasch	--	1	[e]1	[e]2	2
Pyrites	54	55	[e]55	[e]60	65
Byproduct:					
Metallurgy	30	150	[e]150	[e]150	160
Petroleum	100	110	[e]110	[e]125	135
Total	184	316	[e]316	[e]337	362
Bulgaria:[e]					
Pyrites	[r]80	[r]80	[r]75	[r]65	80
Byproduct, all sources	[r]59	[r]56	[r]62	[r]53	62
Total	[r]139	[r]136	[r]137	[r]118	142
Canada:					
Pyrites[e] [4]	8	9	10	10	10
Byproduct:					
Metallurgy	627	678	875	822	760
Natural gas	5,226	5,390	5,260	5,296	[5]5,161
Petroleum[e]	160	170	165	150	150
Tar sands	259	330	296	392	[5]435
Total	6,280	6,577	6,606	[r] [e]6,670	6,516
Chile:					
Native:					
Refined	7	16	14	15	57
From caliche	98	83	40	64	60
Byproduct, metallurgy	32	32	32	30	30
Total	137	131	86	109	147
China:[e]					
Native	200	200	200	300	300
Pyrites	1,800	2,300	2,100	2,200	2,500
Byproduct, all sources	300	350	350	400	300
Total	2,300	2,850	2,650	2,900	3,100
Colombia:					
Native	33	31	36	41	40
Byproduct, petroleum	[r] [e]3	6	10	10	10
Total	[r]36	[r]37	46	51	50
Cuba:[e]					
Pyrites	20	5	--	--	--
Byproduct, petroleum	8	8	8	8	8
Total	28	13	8	8	8
Cyprus:[6] Pyrites	[e]26	21	10	31	30
Czechoslovakia:[e]					
Native	5	5	5	[5]6	6
Pyrites	60	60	60	[5]62	60
Byproduct, all sources	10	10	10	[5]12	10
Total	75	75	75	[5]80	76
Denmark: Byproduct, petroleum	7	[e]9	11	7	15
Ecuador:[e]					
Native	5	5	5	4	4
Byproduct:					
Natural gas	5	5	5	5	5
Petroleum	5	5	5	5	5
Total	15	15	15	14	14
Egypt: Byproduct, natural gas and petroleum	2	1	[e]2	[e]2	5
Finland:					
Pyrites	177	224	211	[e]210	210
Byproduct:					
Metallurgy	270	264	265	[e]260	250
Petroleum	40	48	45	[e]45	40
Total	487	536	521	[e]515	500

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]	1982	1983	1984	1985[p]	1986[e]
France:					
Byproduct:					
Natural gas	1,690	1,653	1,589	1,386	[5]946
Petroleum	235	157	163	[e]160	180
Unspecified[e]	110	100	110	[r]177	180
Total	2,035	1,910	1,862	1,723	1,306
German Democratic Republic: Byproduct, all sources[e]	360	360	350	330	315
Germany, Federal Republic of:					
Pyrites	229	--	--	--	--
Byproduct:					
Metallurgy[e 7]	400	400	350	320	300
Natural gas	872	632	851	964	1,000
Petroleum[e]	220	195	190	200	190
Unspecified[e]	100	95	90	85	85
Total[e]	1,821	1,322	1,481	1,569	1,575
Greece:					
Pyrites	55	67	78	[e]78	75
Byproduct:					
Natural gas[e]	[5]97	115	120	[r]130	130
Petroleum	8	5	[e]5	[e]5	5
Total[e]	[5]160	187	203	[r]213	210
Hungary:[e]					
Pyrites	3	3	2	2	1
Byproduct, all sources	9	9	9	9	10
Total	12	12	11	11	11
India:					
Pyrites	22	25	18	7	10
Byproduct:					
Metallurgy[e]	100	110	115	120	120
Petroleum	5	4	[e]5	1	1
Total[e]	127	139	138	[r]128	131
Indonesia:[6] Native	1	3	5	4	4
Iran:[e]					
Native	10	20	30	30	30
Byproduct, natural gas and petroleum	10	[r]16	[r]130	[r]150	150
Total	20	[r]36	[r]160	[r]180	180
Iraq:[e]					
Frasch	300	300	500	500	600
Byproduct, natural gas and petroleum	40	40	70	70	70
Total	340	340	570	570	670
Ireland: Pyrites[e]	6	--	--	--	--
Israel: Byproduct, natural gas and petroleum[e]	10	10	10	10	10
Italy:					
Native	10	9	8	1	--
Pyrites	269	271	192	280	[5]309
Byproduct, all sources[e 8]	210	210	200	200	185
Total[e]	489	490	400	481	494
Japan:					
Pyrites	276	272	259	253	158
Byproduct:					
Metallurgy	1,268	1,239	1,191	1,201	1,174
Petroleum	1,051	1,102	1,142	1,044	1,029
Total	2,595	2,613	2,592	2,498	2,361
Korea, North:[e]					
Pyrites	200	200	200	200	200
Byproduct, metallurgy	30	30	30	30	30
Total	230	230	230	230	230

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]	1982	1983	1984	1985[p]	1986[e]
Korea, Republic of:					
Pyrites	--	(9)	(9)	--	--
Byproduct:[e]					
Metallurgy	54	54	54	55	55
Petroleum	36	36	36	35	35
Total[e]	90	90	90	90	90
Kuwait: Byproduct, natural gas and petroleum	141	145	151	198	260
Libya: Byproduct, natural gas and petroleum[e]	[r]12	[r]14	[r]14	[r]14	14
Mexico:					
Frasch	1,391	1,225	1,364	1,551	[5]1,592
Byproduct:					
Metallurgy[e]	100	100	160	160	160
Natural gas and petroleum	425	377	461	469	[5]413
Total[e]	1,916	1,702	1,985	[r]2,180	2,165
Namibia: Pyrites	58	81	104	[e]100	100
Netherlands:[e]					
Byproduct:					
Metallurgy	100	100	(10)	(10)	--
Petroleum	65	105	[r]245	[r]250	250
Total	165	205	[r]245	[r]250	250
Netherlands Antilles: Byproduct, petroleum	[e]90	87	63	[e]25	40
New Zealand: Byproduct, all sources	(9)	1	1	[e]1	1
Norway:					
Pyrites	213	179	215	191	200
Byproduct:					
Metallurgy[e]	83	95	[r]50	[r]62	60
Petroleum	8	8	8	10	10
Total	304	282	273	263	270
Oman: Pyrites[e]	--	11	31	31	31
Pakistan:					
Native	1	1	1	1	1
Byproduct, all sources[e]	19	26	26	26	26
Total	20	27	27	[e]27	27
Peru:					
Native	(9)	(9)	(9)	(9)	(9)
Byproduct, all sources	73	65	64	68	66
Total	[r]73	65	64	68	66
Philippines:					
Pyrites	30	29	38	77	100
Byproduct, metallurgy	--	57	95	[e]100	120
Total	30	86	133	[r e]177	220
Poland:[e 11]					
Frasch	4,428	4,460	4,500	[5]4,386	4,400
Native	492	500	490	490	500
Byproduct:					
Metallurgy	160	170	170	170	170
Petroleum	30	30	30	30	30
Gypsum	20	20	20	20	20
Total	5,130	5,180	5,210	5,096	5,120
Portugal:					
Pyrites	116	124	140	155	[5]144
Byproduct, all sources	2	5	4	[e]5	5
Total	118	129	144	[r e]160	149
Qatar: Byproduct, natural gas	[r]12	[r]19	33	37	37
Romania:[e]					
Pyrites	200	200	200	200	150
Byproduct, all sources	150	150	150	150	140
Total	350	350	350	350	290

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]	1982	1983	1984	1985[p]	1986[e]
Saudi Arabia: Byproduct, natural gas and petroleum	[e]900	695	833	1,100	1,300
Singapore: Byproduct, petroleum	15	4	6	[e]5	5
South Africa, Republic of:					
Pyrites	465	474	464	562	[5]602
Byproduct:[e]					
Metallurgy	135	125	[5]91	[5]85	90
Petroleum[12]	25	32	30	[r]100	110
Total	625	631	585	[r]747	802
Spain:					
Pyrites	1,029	1,073	1,094	1,231	[5]1,195
Byproduct:					
Coal (lignite) gasification[e]	3	3	3	2	2
Metallurgy[e]	[5]130	120	125	115	105
Petroleum[e]	10	8	9	[r]7	8
Total[e]	[r]1,172	1,204	1,231	[r]1,355	1,310
Sweden:					
Pyrites	[r]206	208	202	207	216
Byproduct:					
Metallurgy[e]	[r]109	125	[r]159	[r]161	159
Petroleum	22	20	26	25	25
Total	337	353	387	393	400
Switzerland: Byproduct, all sources	3	3	3	3	3
Syria: Byproduct, natural gas and petroleum[e]	[5]22	30	35	35	35
Taiwan: Byproduct, all sources	20	27	29	43	63
Trinidad and Tobago: Byproduct, petroleum[e]	[5]13	8	7	5	5
Turkey:					
Native	32	35	41	38	35
Pyrites[e]	2	2	--	--	--
Byproduct, all sources[e]	75	75	78	80	80
Total[e]	109	112	119	[r]118	115
U.S.S.R.:[e]					
Frasch	800	800	800	850	875
Native	[r]1,800	1,800	1,800	1,700	1,700
Pyrites	3,500	3,400	3,400	3,350	3,300
Byproduct:					
Metallurgy	425	450	450	475	500
Natural gas	2,700	2,750	2,800	2,900	3,000
Petroleum	425	450	450	450	450
Total	[r]9,650	9,650	9,700	9,725	9,825
United Arab Emirates: Abu Dhabi:					
Byproduct:					
Natural gas	--	--	35	104	90
Petroleum	[e]5	10	15	1	1
Total	[e]5	10	50	105	91
United Kingdom:					
Byproduct:					
Metallurgy	61	69	71	69	70
Petroleum	59	55	75	80	105
Spent oxides	3	3	1	([10])	--
Total	123	127	147	149	175
United States:					
Frasch	4,210	3,202	4,193	5,011	[5]4,043
Pyrites	265	W	W	W	W
Byproduct:					
Metallurgy	828	831	962	957	[5]919
Natural gas	1,960	2,371	2,407	2,373	[5]2,246
Petroleum	2,444	2,584	2,807	2,940	[5]3,570
Unspecified	80	302	283	328	[5]309
Total	9,787	9,290	10,652	11,609	[5]11,087
Uruguay: Byproduct, petroleum[e]	2	2	2	2	2
Venezuela: Byproduct, natural gas and petroleum[e]	85	85	86	88	90

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]	1982	1983	1984	1985[p]	1986[e]
Yugoslavia:					
Pyrites and pyrrhotite	353	298	301	323	300
Byproduct:[e]					
Metallurgy	200	180	160	170	200
Petroleum	4	3	3	3	3
Total[e]	557	481	464	496	503
Zaire: Byproduct, metallurgy[e]	25	36	37	36	36
Zambia:					
Pyrites	1	25	18	28	[5]19
Byproduct, all sources	[5]84	80	80	80	80
Total	85	105	[e]98	[r e]108	99
Zimbabwe:[e]					
Pyrites	25	25	25	[r]25	25
Byproduct, all sources	5	5	5	5	5
Total	30	30	30	[r]30	30
Grand total	[r]50,559	[r]50,298	52,496	54,587	54,161
Of which:					
Frasch	11,129	9,988	11,358	12,300	11,512
Native	[r]2,700	2,711	2,677	2,697	2,743
Pyrites	[r]9,748	[r]9,721	9,502	9,938	10,090
Byproduct:					
Coal (lignite) gasification[e]	3	3	3	2	2
Metallurgy	[r]5,323	5,594	5,792	5,748	5,667
Natural gas	[r]12,562	[r]12,935	13,100	13,195	12,615
Natural gas and petroleum, undifferentiated	[r]1,695	[r]1,460	1,840	2,180	2,391
Petroleum	[r]5,151	[r]5,328	5,737	5,784	6,475
Spent oxides	3	3	1	([10])	--
Tar sands	259	330	296	392	435
Unspecified sources	[r]1,939	[r]2,179	2,144	2,305	2,185
Gypsum	47	46	46	46	46

[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 2, 1987.

[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]Byproduct pyrite and pyrrhotite from the processing of metallic sulfide ores.

[5]Reported figure.

[6]In addition, may produce limited quantities of byproduct sulfur from oil refining.

[7]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."

[8]Includes recovery from gypsum, if any.

[9]Less than 1/2 unit.

[10]Revised to zero.

[11]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.

[12]Estimates for 1985 and 1986 include byproduct production from synthetic fuels.

Talc and Pyrophyllite

By Robert L. Virta[1]

Total domestic production and sales of crude and processed talc and pyrophyllite increased slightly from those of 1985. Exports of talc decreased slightly in tonnage and increased 14% 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 98 mines and mills to which a survey request was sent, 83 responded, representing 85% of the U.S. production data shown in table 1. Production for the 15 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)

	1982	1983	1984	1985	1986
United States:					
Mine production, crude:					
Talc	1,049	980	1,042	1,188	1,219
Pyrophyllite	87	87	85	81	83
Total	[1]1,135	[1]1,066	1,127	1,269	1,302
Value:					
Talc	$19,540	$18,998	$21,755	$27,768	$29,687
Pyrophyllite	1,131	1,282	1,412	1,420	1,540
Total	20,671	20,280	23,167	29,188	31,227
Sold by producers, crude and processed:					
Talc	915	1,038	1,101	1,067	1,070
Pyrophyllite	110	125	97	[r]81	83
Total	1,025	1,163	1,198	[r]1,148	1,153
Value:					
Talc	$82,104	$104,739	$112,515	$114,542	$111,924
Pyrophyllite	3,557	4,057	3,578	[r]3,273	3,366
Total	85,661	108,796	116,093	[r]117,815	115,290
Exports[2] (talc)	232	218	256	237	234
Value	$12,957	$12,916	$16,162	$14,282	$16,302
Imports for consumption (talc)[3]	27	44	45	47	52
Value	$6,264	$7,691	$9,156	$9,532	$8,715
Apparent consumption[4]	820	989	1,009	1,079	1,120
World: Production	[r]7,785	[r]7,781	8,396	[p]8,661	[e]8,529

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Data do 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) enacted a ruling, effective July 21, 1986, that limits worker exposure to actinolite, anthophyllite, asbestos, and tremolite to 0.2 fiber per cubic centimeter per 8-hour work period.[2] OSHA also required employee training and medical surveillance when exposure levels exceed 0.1 fiber per cubic centimeter. A 9-month administrative stay was placed on that portion of the ruling covering the nonasbestiform varieties of actinolite, anthophyllite, and tremolite.[3] Worker exposure to the nonasbestiform varieties was limited to 2.0 fibers per cubic centimeter by the administrative stay.

The Environmental Protection Agency proposed standards under Section 3 of the Clean Air Act to limit particulate emissions from new, modified, and reconstructed calciners and dryers at mineral processing plants. Seventeen minerals and concentrates including talc are covered under the proposal. The proposed standard would limit particulate emissions to 0.09 gram per dry standard cubic meter for calciners and dryers installed in series, and 0.025 for dryers alone.[4]

The allowable depletion rates established under the Tax Reform Act of 1969 remained at 22% for domestic and 14% for foreign block steatite.

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, 3.8% 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 1985.

DOMESTIC PRODUCTION

Talc.—U.S. mine production of crude talc increased slightly in tonnage and 7% in value. Talc, including soapstone, was produced at 34 mines in 9 States. Ten mines that operated in California, Montana, New York, Texas, and Vermont accounted for 71% 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. and Pfizer Inc., Minerals, Pigments & Metals Div., with mines in California and Montana; R. T. Vanderbilt Co. Inc. in New York; and Windsor Minerals Inc. in Vermont and California.

The Clay and Mineral Div. of United Catalysts Inc., a subsidiary of the Federal Republic of Germany's Süd-Chemie AG, purchased Southern Talc Co. of Chatsworth, GA. Southern Talc's Rock Cliff Mine was closed, and its Earnest Mine was reopened. A higher-quality talc was produced at the Earnest Mine than at the Rock Cliff Mine by using selective mining techniques.[5]

The Montana Talc Co., a joint venture between NICOR Mineral Ventures and Meridian Land and Minerals Co., began operating its mine and mill facilities near Ennis, MT. The talc was used primarily in paint, paper, and plastics.[6]

The Alberene Stone Co. of Schuyler, VA, was purchased by Suomen Vuolukivi Oy of Finland. The purchase included the 27-acre plantsite, machinery, buildings, and a lease on the extraction rights for the quarries. Suomen Vuolukivi plans to make fireplaces, wood stoves, cooking ware, and other soapstone products. The plant will operate as the New Alberene Stone Co.[7]

Cyprus obtained surface and mineral rights to 3,000 acres of land near Alpine, AL, including a mine that previously supplied the Alpine mill facilities with cosmetic-grade talc. In addition, drilling indicated large reserves of high quality talc. Talc mined from Cyprus' Montana talc operations will continue to be processed at the Alpine mill.[8] The company also announced a reorganization of its four industrial minerals divisions into one organization. Several regional offices will be closed, and its international marketing group will be expanded.[9]

Acqui-Tal Inc. merged with Vermont Talc Co. The Acqui-Tal mill facilities at Johnson, VT, were upgraded and new milling equipment installed. Production from the Johnson mill, which uses flotation processing, will supplement output from Vermont Talc's Chester mill.[10] Vermont Talc also planned to open a mine near Troy to supply talc to the Johnson mill. Drilling on the 600-acre parcel indicated a large reserve of asbestos-free talc.[11]

The Pennsylvania Bureau of Mines and

Reclamation issued mining and mine drainage permits for a talc mine in Fulton Township. The open pit has a proposed depth of 300 feet.[12]

Pyrophyllite.—Pyrophyllite was produced by four companies operating six mines in California and North Carolina. Total production increased slightly from that of 1985.

Table 2.—Crude talc and pyrophyllite produced in the United States, by State

(Thousand short tons and thousand dollars)

State	1985		1986	
	Quantity	Value	Quantity	Value
California	100	2,493	64	1,528
Georgia (talc)	16	111	9	61
North Carolina	85	1,604	83	1,552
Texas (talc)	261	5,245	283	6,456
Other[1] (talc)	807	19,735	863	21,630
Total	1,269	29,188	1,302	31,227

[1]Includes Arkansas, Montana, New York, Oregon, Vermont, Virginia (1985), and Washington.

CONSUMPTION AND USES

Apparent domestic consumption of crude and processed talc and pyrophyllite increased slightly. Sales of talc and pyrophyllite increased slightly in tonnage and decreased slightly in value.

End-use distribution of ground talc was ceramics, 35%; paint, 17%; paper, 13%; roofing, 11%; plastics, 7%; cosmetics, 5%; rubber, 3%; insecticides, 1%; and other 8%.

The largest portion, 55%, of domestically produced ground pyrophyllite was used in ceramics, 17% was used in refractories, 11% in insecticides, and 17% other.

Table 3.—End uses for ground talc and pyrophyllite

(Thousand short tons)

Use	1985			1986		
	Talc	Pyrophyllite	Total	Talc	Pyrophyllite	Total[1]
Ceramics	296	72	368	343	64	407
Cosmetics[2]	46	3	49	46	3	49
Insecticides	7	12	19	6	13	18
Paint	144	2	146	168	2	170
Paper	125	--	125	127	--	127
Plastics	70	1	71	69	1	69
Refractories	5	20	25	3	20	22
Roofing	100	2	102	106	2	108
Rubber	27	--	27	25	([3])	25
Other[4]	101	12	113	90	13	103
Total[1]	921	124	1,045	983	116	1,099

[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 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 1986, 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	62.00- 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 1986, for talc, c.i.f. main European ports, follow:

Norwegian:	
Ground (ex store)	$126-$140
Micronized (ex store)	161- 224
French, fine-ground	168- 266
Italian, cosmetic-grade	245
Chinese, normal (ex store):	
UK 200 mesh	197
UK 325 mesh	206
New York, paint, minimum 20-ton lot	175

FOREIGN TRADE

Exports.—Talc exports decreased slightly, although its value increased 14%. Prices ranged from $31 to $530 per ton, averaging $70 per ton.

Mexico was the major importer of U.S. talc, accounting for 48% of the tonnage shipped, followed by Canada, 25%; Japan, 9%; and Belgium-Luxembourg, 6%. Canada and Mexico led in value of imports, each with 27% of the total. Sixty countries imported U.S. talc.

Imports.—U.S. imports for consumption of talc increased 11%. Imports from Canada increased 26%. Canada was the leading source of imported talc with 72%, followed by Australia with 18%. Canada and China accounted for 67% of the value of all imported talc.

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
1982	18	1,263	63	4,208	9	439	102	3,083	40	3,964	232	12,957
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

[1]Excludes powders—talcum (in package), face, and compact.
[2]Probably includes shipments in transit through Canadian ports.
[3]Includes 56 countries.
[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)
1984	14,868	$2,040	27,978	$5,126	1,807	$1,030	$960	44,653	$9,156
1985:									
Brazil	--	--	143	23	1,220	464	16	1,363	503
Canada	10	2	29,524	4,111	131	180	29	29,665	4,322
China	--	--	--	--	1,013	889	271	1,013	1,160
France	4,217	240	838	130	--	--	--	5,055	370
Italy	5,511	1,025	84	21	155	251	--	5,750	1,297
Korea, Republic of	437	44	1,672	344	92	54	--	2,201	442
Other[2]	597	39	973	511	278	259	629	1,848	1,438
Total	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[3]	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

[1]Data may not add to totals shown because of independent rounding.
[2]Includes 15 countries.
[3]Includes 17 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 45% of the world's talc and pyrophyllite production.

Australia.—Thames Mining NL acquired the Mount Seabrook talc mine in Western Australia following settlement of a dispute over the legal ownership of the mine. Thames Mining also began mapping and drilling at its Livingstone talc deposit, near Mount Seabrook, to determine reserves and potential mining sites.[13]

Thames Mining granted Cyprus exclusive rights to purchase all cosmetic-grade talc produced at the Mount Seabrook Mine and a 1-year option to be the exclusive purchaser of its industrial-grade talc.[14]

Canada.—International Larder Minerals Inc. acquired the Harvey Hill Copper Mine near Quebec and began modifying existing mine and mill facilities for talc production. Proven talc reserves were estimated at 4 million tons, with additional probable reserves of 2.2 million tons.[15]

Steetley Talc Ltd. continued a multiyear expansion program for its Timmons Mine and mill facilities. The expansion plans included installing a ball mill, cyclone classifiers, and flotation cells. These upgrades would double production to approximately 60,000 tons and increase its product line. Steetley Talc produced talc for use in cosmetics, paint, paper, plastics, and rubber.[16]

Bakertalc Inc. planned an expansion of its Highwater mill facilities in Quebec. The expansion was to include the purchase of a pebble mill to wet-grind talc ore for feed to a flotation circuit, doubling production capacity to 20,000 tons per year.[17]

United Kingdom.—Shetland Talc Ltd., jointly owned by Dalriada Mineral Ventures Ltd. and Anglo-European Minerals Ltd., obtained permission for exploratory drilling in a talc-magnesite deposit near Cunningsburgh in the Shetland Islands.[18]

A/S Norwegian Talc modified facilities at Hartlepool for milling dolomite, mica, and talc. The company previously had processed the ore in Norway and shipped it to distribution facilities in Europe. Nortalc Milling Ltd. operated the mill facility, and Norwegian Talc (UK) Ltd. directed sales.[19]

Table 6.—Talc and pyrophyllite: World production, by country[1]

(Short tons)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Argentina (talc, steatite, pyrophyllite)	31,849	32,729	30,629	[e]29,000	28,000
Australia	168,424	[r]194,644	265,844	[e]276,000	276,000
Austria (unground talc)	129,072	134,623	147,722	144,903	132,000
Brazil (talc and pyrophyllite)[3]	446,731	437,025	455,637	[4]468,500	468,500
Burma	[r]182	141	100	141	143
Canada (shipments)	79,567	106,924	138,891	139,993	138,000
Chile	312	702	465	1,432	2,400
China[e]	1,050,000	1,050,000	1,050,000	1,100,000	1,100,000
Colombia	6,878	7,318	7,479	9,492	8,800
Egypt	9,139	4,981	13,463	8,488	9,400
Finland	358,251	351,009	360,976	[e]364,000	364,000
France (ground talc)	304,723	315,812	322,315	342,705	353,000
Germany, Federal Republic of (marketable)	16,789	15,773	19,030	22,835	22,000
Greece (steatite)	2,973	2,388	1,887	1,901	2,000
Hungary[e]	18,700	18,700	19,300	18,700	17,700
India (pyrophyllite and steatite)	379,129	389,162	460,473	422,111	419,000
Italy (talc and steatite)	180,746	175,239	157,329	142,875	[4]166,676
Japan[5]	1,644,982	1,615,791	1,652,303	1,580,978	[4]1,470,889
Korea, North[e]	185,000	185,000	185,000	185,000	185,000
Korea, Republic of (talc and pyrophyllite)	651,594	696,810	935,475	1,027,880	992,000
Mexico	13,525	12,161	9,811	32,959	22,000
Nepal[6]	3,310	16,825	8,372	6,630	7,700
Norway[e]	110,000	110,000	[4]157,554	[r]165,000	165,000
Pakistan (pyrophyllite)	22,669	17,588	17,161	22,248	23,000
Paraguay	165	132	165	[r e]132	132
Peru (talc and pyrophyllite)	[e]9,500	[4]5,767	10,183	551	1,100
Philippines	1,111	968	1,022	380	1,100
Portugal	5,445	6,018	6,838	3,976	4,400
Romania[e]	66,000	66,000	72,000	72,000	72,000
South Africa, Republic of[7]	15,226	12,337	15,886	15,925	15,000
Spain (steatite)	[r]76,816	76,574	79,628	97,859	94,000
Sweden	19,569	23,210	19,712	15,432	[4]2,205
Taiwan	33,798	29,821	20,591	19,357	[4]23,757
Thailand (talc and pyrophyllite)	24,249	22,209	31,393	47,926	45,000
U.S.S.R.[e]	560,000	560,000	570,000	570,000	570,000
United Kingdom[e]	21,000	17,600	[r]21,000	[4]22,046	22,000
United States (talc and pyrophyllite)	1,135,415	1,066,400	1,127,421	1,268,750	[4]1,302,179
Uruguay	1,262	755	1,828	[r e]1,700	1,700
Zambia	299	1,447	405	10,504	[4]293
Zimbabwe	298	607	314	482	440
Total	[r]7,784,698	[r]7,781,190	8,395,602	8,660,791	8,528,514

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

[1]Table includes data available through May 26, 1987.

[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]Reported figure.

[5]Includes talc, pyrophyllite, and pyrophyllite clay.

[6]Data based on Nepalese fiscal year beginning mid-July of year stated.

[7]Includes talc and wonderstone.

TECHNOLOGY

The National Institute of Occupational Safety and Health conducted a study of respirable crystalline silica exposures at a wall and floor tile manufacturing plant. The silica content of the pyrophyllite used in manufacturing the tile was estimated to be 13% by weight. Total dust and respirable dust samples were collected at work stations and at various locations within the raw materials storage building and processing building. Low employee exposures to dust were maintained through proper plant design, automated material transfer, effective ventilation, and good maintenance.[20]

Talc crayons have been used by industry to mark steel for cutting and welding and, traditionally, were cut from block talc. This technique is no longer cost effective because of competition from imports. Research was conducted on fabricating talc crayons from ground talc using mixtures of ball clay, binders, kaolin, and talc. Crayons formed using a mixture of talc containing 6% organic binder had good physical characteristcs in both uncured and cured states and had excellent marking properties.[21]

A transmission electron microscope study of talc-containing fibers was conducted.

Three fiber types were observed—talc fibers, anthophyllite fibers, and anthophyllite fibers intergrown with talc. The fibrous morphology was attributed to crystal structure defects.[22]

A study was conducted on the dust reduction capabilities of five commercially available bag valves—paper, polyethylene, extended polyethylene, double trap, and foam. Dust levels were monitored during bagging, conveying, and pallet loading. The extended polyethylene valve was the most effective valve type. It reduced dust exposures 62% relative to the standard paper valve at the operator location and 66% at the bag stocker location. The length of the bag valve and the valve material were the most important factors in determining valve effectiveness.[23]

A survey of mineral filler and extender consumption by the paint, paper, and plastics industries was conducted for the period 1972 to 1984. In general, the market for fillers and extenders in North America, including talc, grew at a rate of 1.2% for paint, 4.5% for paper, and 6.3% for plastics. In Western Europe, these rates were 5.3%, 3.1%, and 7.4%, respectively. Talc accounted for a small segment of the markets, ranging from 2% to approximately 15% of the total consumption. Talc consumption was affected primarily by the geographic distribution of talc deposits and by the cost and availability of talc relative to other filler and extender minerals.[24]

Mineral fillers and coating pigments were used by the European paper industry to improve paper gloss, smoothness, brightness, opacity, and ink receptivity. Since 1976, the use of mineral fillers has increased 5%, and the use of mineral coating pigments has increased 44%. Minerals were chosen as fillers and coating pigments according to the type of paper being produced, the chemistry of the processing solutions, the equipment used to make the paper, the process used for printing, and the ink type. Talc competed with kaolin and calcium carbonate as a mineral filler. Its share of the European market increased from 16% in 1974 to 22% in 1984. Despite this increase, the use of talc continued to be influenced by the geographic distribution of talc deposits.[25]

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Thorium

By James B. Hedrick[1]

Mine production of monazite, the principal source of thorium, decreased in 1986. Associated Minerals (USA) Ltd. Inc. was 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). W. R. Grace & Co.'s 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.

Major nonenergy uses were in aerospace alloys, mantles for incandescent lanterns, refractory applications, and welding electrodes. 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 molds for casting high-temperature metals and alloys and thoriated tungsten elements in microwave-generating 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 entitled "Rare Earths and Thorium." 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)

	1982	1983	1984	1985	1986
Exports: Metal, waste and scrap	0.34	1.06	1.01	1.64	17.01
Imports: Compounds, gas mantles, metals	23.22	45.80	45.37	69.34	19.71
Shipments from Government stockpile excesses	--	--	--	2.17	--
Apparent consumption, nonenergy applications[e 2]	22.89	44.74	44.36	74.36	72.38
Prices, yearend, dollars per kilogram, ThO_2:[3]					
Nitrate, mantle-grade	$10.60	$10.60	$10.10	$10.10	$13.60
Oxide, 99% grade	$24.50	$31.00	$35.85	$35.85	$40.00

[e]Estimated.

[1]Some data through 1985 have been revised to reflect only refined products; excludes monazite concentrates.

[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 used to produce thorium products until 1985.

[3]Rhône-Poulenc Inc.

Legislation and Government Programs.—Sales of materials held in the NDS, including thorium nitrate, continued to be suspended during 1986 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 1986. Under the first law, the Department of Defense Authorization Act, 1986, (Public Law 99-145), which was signed November 8, 1985, a total of 22,680 kilograms (50,000 pounds) of thorium nitrate was authorized for disposal in fiscal year 1986. In fiscal year 1987, beginning October 1, 1986, the second law, the Department of Defense Authorization Act, 1987, (Public Law 99-661), which was signed November 14, 1986, decreased the amount of thorium nitrate authorized for disposal to 4,536 kilograms (10,000 pounds).

Environmental Impact.—New Jersey announced plans to study the toxic effects of thorium at several sites in the State. An independent consultant was employed to analyze soil samples collected from Maywood, Rochelle Park, and Lodi. The thorium was processed during World War II in New Jersey by the now defunct Maywood Chemical Co. to produce lamp mantles. Contaminated thorium byproducts stored behind the Maywood plant were unknowingly hauled off for landfill in the surrounding area.[2]

DOMESTIC PRODUCTION

Australian-owned Associated Minerals was the only commercial minerals sands operation in the United States to produce monazite in 1986. The monazite was obtained as a byproduct of sands mined for titanium and zirconium minerals at Green Cove Springs, FL. Associated Minerals installed an underwater bucketwheel excavator on its dredge, resulting in improved mining recoveries and higher production from compacted areas of the ore body.[3]

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 processors reported consumption of an estimated 40.5 metric tons of thorium oxide equivalent in 1986, a decrease of 33.5 tons from the 1985 level. Nonenergy uses accounted for almost 0.5 ton of the total, and energy uses accounted for the remainder. The approximate distribution of thorium by end use, based on information supplied by producers, primary processors, and several consumers, was as follows: refractory applications, 50%; lamp mantles, 24%; aerospace alloys, 15%; welding electrodes, 5%; and other applications, including ceramics and lighting, 6%.

Almost all thorium used in metallurgical applications was alloyed with magnesium. Magnesium-thorium alloys used by the aerospace industry are lightweight and possess high-strength and excellent creep resistance at elevated temperatures, properties that are useful in aerospace applications. Small quantities of thorium were used in nickel alloys for high-strength, high-temperature applications.

Thorium oxide has the highest melting point of all the oxides at 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 are used to join stainless steels, nickel alloys, and other alloys that require a continuous and stable arc to achieve high-quality welds. The nitrate form was also used to produce thoriated tungsten alloys used in the cathodes of magnetron power tubes for microwave ovens. Thorium is used because of its ability to emit electrons at relatively low temperatures when heated in a vacuum. Magnetron tubes are used to emit electrons at microwave frequencies in microwave ovens and in radar systems.

Thorium was used in other types of electron tubes, in lamps 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 HTGC 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, 1986, 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 1,243,846 kilograms of thorium oxide equivalent contained in ore, metal, and various compounds.

PRICES

The average declared value of imported monazite increased during 1986 to $374 per ton, up $25 from the 1985 value. The price range of Australian monazite (minimum 55% rare-earth oxide including thoria, f.o.b.-f.i.d.[4]), as quoted in Australian dollars (A$) in Metal Bulletin (London), was A$850-A$900 per ton at yearend 1986, unchanged from the yearend 1985 price. Changes in the U.S.-Australian foreign exchange rate in 1986, resulting from the continued economic strength of the U.S. dollar against Australian currency, caused the corresponding U.S. price range to decrease slightly from US$580-US$614 in 1985 to US$565-US$598 in 1986.[5]

The yearend price for monazite, based on a thorium oxide content of 7%, was approximately $8.07 to $8.54 per kilogram of thorium oxide contained.

Rhône-Poulenc 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, 1986, as follows: thorium oxide, 99% purity, $40.00; 99.99% purity, $61.30. Thorium nitrate at 99.5% purity (mantle-grade) was quoted at $13.60 per kilogram.

Thorium alloy prices quoted by Magnesium Elektron were unchanged from the 1985 yearend price of $30.11 per pound for thorium hardener in single drum quantities and $4.58 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)

	1984		1985		1986		Principal destinations and sources, 1986
	Quantity	Value	Quantity	Value	Quantity	Value	
EXPORTS							
Thorium ore, monazite	229,983	$157,608	743,103	$415,024	581,854	$326,846	All to France.
Metals[1]	890	46,905	1,440	182,373	14,949	954,604	Federal Republic of Germany 7,866; United Kingdom 5,428; Netherlands 632; Belgium 525; Brazil 238; France 217; other 43.
IMPORTS							
Ore and concentrate:							
Thorium ore, monazite ---metric tons	5,661	2,202,377	5,694	1,984,486	2,960	1,105,996	Australia 2,660; India 300.
ThO_2 content	395,760	XX	398,580	XX	211,700	XX	
Compounds:							
Nitrate	17,957	220,360	16,848	210,910	21,534	283,841	France 18,684; Canada 2,850.
Oxide	35,026	299,994	50,777	841,331	7,084	166,334	Netherlands 3,736; France 3,345; other 3.
Oxide equivalent, in gas mantles[e] [2]	1,169	426,230	1,877	449,112	1,668	495,797	Malta 993; Canada 189; India 189; United Kingdom 96; Brazil 86; Hong Kong 49; Italy 28; Federal Republic of Germany 27; Taiwan 11.
Other	588	195,111	499	171,463	658	187,119	United Kingdom 445; Federal Republic of Germany 202; Switzerland 11.
Metals and alloys	79,990	NA	[r]62,805	NA	60,062	NA	All from United Kingdom.
Unwrought, waste and scrap	--	--	680	18,334	--	--	

[e]Estimated. [r]Revised. NA Not available. XX Not applicable.
[1]Unwrought, wrought, 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, for the seventh consecutive year, was the destination of all of the U.S. exports of thorium ore, including monazite. Australia continued to be the principal U.S. source of thorium-bearing monazite, as it has been since 1977. India lifted its 1946 ban on the export of thorium-bearing monazite in 1985 and resumed shipments worldwide, including shipments to the United States. Although monazite was imported primarily for its rare-earth content, domestic production of thorium compounds from the concentrate was resumed in 1985. Thorium products processed and manufactured in the United States in 1986 were derived mainly from imported materials, primarily thorium compounds and rare-earth concentrates from France and magnesium-thorium alloys from the United Kingdom.

WORLD REVIEW

Australia.—Renison Goldfields Consolidated Ltd. (RGC) was successful in its bid to acquire Allied Eneabba Ltd. In purchasing Allied Eneabba, RGC issued 2.4 million shares and paid $8 million to obtain additional reserves of monazite-bearing minerals sands, mining leases adjacent to RGC's properties in Eneabba, a heavy minerals sands mine at Eneabba, and a processing plant at Narngulu, all in Western Australia. The acquisition made RGC the world's principal minerals sands producer and largest producer of thorium-bearing monazite. RGC's share of the world's monazite capacity was estimated at 40%. RGC's monazite production increased substantially to 8,527 tons as a result of including production from Allied Eneabba's operations for the second half of the year.[6]

Prior to the acquisition of RGC, Allied Eneabba and Asahi Chemical Industry Co. Ltd. were studying the feasibility of building a rare-earth and thorium separation plant at Geraldton, Western Australia, to process monazite. RGC reported that it was continuing study of the proposed project, but acknowledged that both Allied Eneabba and RGC still had long-term contracts to supply monazite to Rhône-Poulenc of France.[7]

Union Oil Development Corp. reportedly sold its stake in the Brockman deposit in Western Australia to West Coast Holdings Ltd. for A$400,000, retaining a 2.55% net profits interest in the deposit. The multi-mineral deposit contains gallium, hafnium, niobium, rare earths, tantalum, thorium, yttrium, and zirconium in 4.29 million tons of ore.[8]

Westralian Sands Ltd. reported record high earnings in 1985. However, production of thorium-containing monazite decreased during the year from 3,100 to 2,100 tons. Both the Yoganup Extended Mine and North Capel Mine operated at full capacity in 1985. Westralian Sands planned to open a new heavy minerals sands mine, the Yoganup North Mine, at Boyanup, Western Australia, in early 1987.[9]

Japan.—Five companies, Santoku Metal Industries Co. Ltd., Newer Japan Metals & Chemicals Co. Ltd., Toshiba Corp., Japan Tungsten Co. Ltd., and Matsushita Electric Industrial Co. Ltd., processed thorium in Japan. Their products were primarily thoriated tungsten alloys for welding electrodes or thoriated tungsten elements used in microwave oven magnetron tubes.[10]

Thailand.—The Metal Mining Agency of Japan announced plans to build a pilot plant in Thailand to recover rare earths and other metals from tin milling wastes. One of the minerals likely to be recovered from the milling residues is thorium-bearing monazite. Planned capacity of the joint venture plant was 1 ton of tin processing wastes per day.[11]

Table 4.—Monazite concentrate: World production, by country[1]

(Metric tons)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Australia	9,562	15,141	16,260	18,735	10,500
Brazil	1,814	5,256	3,622	1,213	2,000
India[e 3]	4,000	4,000	4,000	4,000	4,000
Malaysia[4]	[r]582	1,051	4,451	5,808	1,000
Mozambique	3	4	[e]4	[e]4	4
Sri Lanka	304	[e]300	147	[e]200	200
Thailand	162	277	298	245	200
United States	W	W	W	W	W
Zaire	32	15	2	--	--
Total	[r]16,459	26,044	28,784	30,205	17,904

[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. 28, 1987.
[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]Data are for fiscal years beginning Apr. 1 of that stated.
[4]The 1982-83 figures are exports and the 1984-86 figures are production.

TECHNOLOGY

Researchers at Japan Tungsten reportedly developed a cerium tungsten alloy to replace thoriated tungsten welding electrodes and microwave elements. Marketed under the trade name ceritan, the new alloy was produced with 0.8% to 1.2% cerium oxide replacing 1% to 2% thorium oxide. The company reported reduced dissipation during arc testing by using cerium and improved arc stability resulting from the uniform fiber shape produced by cerium oxide in the new alloy.[12] Research to develop substitutes for thorium has been increasing in recent years, stemming from environmental concerns about thorium's radioactivity and the problems associated with complying with governmental regulations.

The properties of thorium-mercury alloys were studied at the University of Genova, Italy. Literature reported the existence of ThHg, $ThHg_2$, and $ThHg_3$. Research revealed the existence of a new phase, Th_2Hg, which has the crystal structure common to other Th_2X alloys.[13]

[1]Physical scientist, Division of Nonferrous Metals.
[2]American Metal Market. Thorium's Toxic Effects To Be Studied. V. 94, No. 19, Jan. 28, 1986, p. 6.
[3]Renison Goldfields Consolidated Ltd. Annual Report 1986. 43 pp.
[4]Free on board-free into container depot.
[5]Values have been converted from Australian dollars (A$) to U.S. dollars (US$) at the yearend exchange rates of A$1.4652=US$1.00 for 1985, and A$1.5053=US$1.00 for 1986.
[6]Work cited in footnote 3.
[7]Work cited in footnote 3.
[8]Mining Journal (London). Industry in Action—West Coast in Brockman Deal. V. 306, No. 7854, Feb. 28, 1986, p. 153.
[9]Industrial Minerals (London). Westralian Sands—Cashing in on the Boom. No. 224, May 1986, p. 21.
[10]Roskill's Letter From Japan. Thorium: Last Year 600 Kg of Thorium Nitrate Imported From India. No. 122, June 1986, pp. 16-18.
[11]Japan Metal Journal. Agency Will Build Test Plant for Recovering Rare Metals in Thailand. Mar. 24, 1986, p. 6.
[12]Work cited in footnote 11.
[13]Palenzona, A. Th_2Hg: Another Representative of the $CuAl_2$-Type Structure. J. Less-Common Met., v. 125, Nov. 1986, pp. L5-L6.

Tin

By James F. Carlin, Jr.[1]

For the sixth consecutive year, there was a substantial world excess of tin, although world mine production declined and world consumption was estimated to have held steady. Repercussions from the exhaustion of International Tin Council (ITC) funds to support the tin price in late 1985 continued throughout 1986. On March 12, the London Metal Exchange (LME) settled all outstanding tin contracts, a move that effectively suspended the LME tin contract. Several LME tin dealers claimed large monetary losses due to that action and brought suit against the LME. Later in the year, numerous tin dealers and banks brought suit against the ITC for debts owed for past tin credit purchases. The tin price continued to be lowered in the first 9 months of the year, then by October, was raised modestly but still remained well below the levels of recent years. The substantially lower prices caused extensive restructuring of tin mining operations in most producing countries, with many mine closures and resultant unemployment.

Tin's unique combination of physical and chemical properties continued to make it a metal of interest to many researchers who developed new advanced material applications for it ranging from thin film devices to architectural glazing procedures.

Table 1.—Salient tin statistics

(Metric tons unless otherwise specified)

	1982	1983	1984	1985	1986
United States:					
Production:					
Mine	W	W	W	W	W
Smelter	3,500	2,500	4,000	[e]3,000	[1]3,213
Secondary	14,293	14,205	15,417	14,109	13,977
Exports[2]	5,769	1,340	1,429	1,478	1,547
Imports for consumption:					
Metal	27,939	34,048	41,224	33,830	35,768
Ore (tin content)	1,961	969	3,272	[r]1,616	3,936
Consumption:					
Primary	33,019	34,301	37,819	[r]37,187	32,548
Secondary	13,276	11,246	11,622	[r]12,580	10,975
Stocks, yearend U.S. industry	10,251	9,859	[r]9,901	[r]12,361	13,940
Prices, average cents per pound:					
New York market	586.85	601.28	567.80	525.90	294.12
Metals Week composite	653.91	654.78	623.80	[3]595.95	[3]369.91
London	580.50	589.19	556.55	[3]556.26	NA
Kuala Lumpur[4]	587.29	590.78	564.95	[3]540.70	[3]272.26
World: Production:					
Mine	[r]219,463	[r]196,641	198,422	[p]188,653	[e]180,237
Smelter	[r]221,032	[r]200,124	201,055	[p]196,633	[e]189,933

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data; U.S. mine production for 1982-86 was negligible.
[1]Reported figure.
[2]Exports (excluding reexports).
[3]Prices quoted for 10 months only.
[4]Beginning 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 six 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) continued the suspension of its daily fixed-price tin sale program until January 8, 1986, when it resumed sales for the balance of the year. A total of 5,490 metric tons of tin was sold in 1986, all of which represented payment material for GSA's Ferroalloy Upgrading Program, which started April 11, 1984.

At yearend, the National Defense Stockpile (NDS) inventory was 180,889 tons; the stockpile goal was 42,674 tons.

On November 14, 1986, the President signed the Department of Defense Authorization Act, 1987 (Public Law 99-661), which stated that no action could be taken before October 1, 1987, to make any change in a stockpile goal in effect on October 1, 1984, that results in a reduction in the quantity or quality of any strategic and critical material to be acquired for the NDS.

Federal laws provided a depletion allowance of 22% for domestic operations and 14% for U.S. companies producing in other countries.

On June 19, 1986, the Safe Drinking Water Act was amended, forbidding new pipes or patches to existing pipes in municipal water systems to have lead content exceeding 8% and prohibiting solder used for public water systems to contain more than 0.2% lead. The act was generally viewed by industry sources to be beneficial to future tin usage since lead use in such solder applications would be restricted and favor the other solder component, tin, or alternative joining materials.

The State of California passed a bottle deposit-redemption law, effective September 1, 1987, applying to all beverage containers. Ten States have now passed similar legislation in recent years. The State laws vary, and California's law was the most exacting, requiring an initial 1 cent deposit-redemption fee on all beverage containers. The fee would increase to 2 cents per container on December 31, 1989, and to 3 cents on December 31, 1992, if containers are not meeting a recycling rate of 65%. Designed to reduce litter, these State laws impact each type of container differently, but are generally considered to increase the availability of scrap material.

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, and owned by Gulf Chemical & Metallurgical Co., a subsidiary of Associated Metals & Minerals Corp., increased tin metal output slightly. The smelter primarily recovered tin 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.

SECONDARY TIN

The United States was believed to be the world's largest producer of secondary tin. 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 was established in Pittsburgh, PA, by five domestic tinplate producers to advance the collection, preparation, and transportation of can scrap.[2]

Table 2.—Secondary tin recovered from scrap processed at detinning and other plants in the United States

		1985[r]	1986
Tinplate scrap treated	metric tons	460,105	499,652
Tin recovered in the form of:			
Metal	do	1,302	1,134
Compounds (tin content)	do	186	W
Total	do	1,488	1,134
Weight of tin compounds produced	do	338	W
Average quantity of tin recovered per metric ton of tinplate scrap used	kilograms	3.23	2.27
Average delivered cost of tinplate scrap	per metric ton	$53.69	$44.76

[r]Revised. 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	1985	1986
Tin metal[1]	1,302	1,134
Bronze and brass[e] [2]	[r]8,045	7,996
Lead and tin alloys:		
Antimonial lead	791	891
Babbitt	88	66
Solder	3,565	3,676
Type metal	122	197
Other alloys[3]	10	17
Total	4,576	4,847
Tin content of chemical products	186	W
Grand total	14,109	13,977
Value (thousands)[e] [4]	$185,370	$113,984

[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
1985									
Copper-base scrap	11,970	131,220	13,159	120,361	133,520	9,670	653	4,555	5,208
Brass mills[2]	1,958	7,549	7,538	W	7,538	2,731	208	--	208
Foundries and other plants	3,450	19,301	4,934	15,277	20,211	2,540	230	647	877
Total tin from copper-base scrap	XX	XX	XX	XX	XX	XX	1,091	5,202	6,293
Lead-base scrap	40,502	727,297	57,245	671,053	728,298	39,501	1,497	4,729	6,226
Tin-base scrap[3]	27	110	W	116	116	21	1,484	106	1,590
Grand total	XX	XX	XX	XX	XX	XX	4,072	10,037	14,109
1986									
Copper-base scrap	9,670	134,251	10,194	123,456	133,650	10,271	416	4,758	5,174
Brass mills[2]	2,731	7,044	7,017	27	7,044	1,130	224	--	224
Foundries and other plants	2,540	3,143	1,536	3,315	4,851	832	71	122	193
Total tin from copper-base scrap	XX	XX	XX	XX	XX	XX	711	4,880	5,591

See footnotes at end of table.

Table 4.—U.S. stocks, receipts, and consumption of new and old scrap and tin recovered, by type of scrap —Continued

(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 —Continued									
Lead-base scrap	39,501	737,510	66,024	681,404	747,428	29,583	1,730	5,224	6,954
Tin-base scrap[3]	21	97	W	95	95	23	1,345	87	1,432
Grand total	XX	XX	XX	XX	XX	XX	3,786	10,191	13,977

[e]Estimated. 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 declined about 12% from that of 1985, mainly due to decreased industrial activity for some applications and a prolonged strike at a major steel company. Solder was the largest application of primary tin, with tinplate a distant second.

Tinplate continued to lose markets to aluminum in container applications. Of the 104.9 billion metal cans shipped, tinplated steel and tin-free steel accounted for 33% and aluminum accounted for 67%, compared with 101.9 billion metal cans shipped in 1985, when steel accounted for 34% and aluminum for 66%. Aluminum held an overwhelming segment of the beverage can market, while steel was still predominant in the food can and the general packaging markets.[3]

Table 5.—U.S. consumption of primary and secondary tin

(Metric tons)

	1982	1983	1984	1985[r]	1986
Stocks, Jan. 1[1]	8,717	7,549	7,740	8,130	9,438
Net receipts during year:					
Primary	35,843	36,494	39,388	38,939	35,906
Secondary	6,507	5,412	6,096	8,904	11,636
Scrap	7,830	7,435	7,323	7,909	7,125
Total receipts	50,180	49,341	52,807	55,752	54,667
Total available	58,897	56,890	60,547	63,882	64,105
Tin consumed in manufactured products:					
Primary	33,019	34,301	37,819	37,187	32,548
Secondary	13,276	11,246	11,622	12,580	10,975
Total	46,295	45,547	49,441	49,767	43,523
Intercompany transactions in scrap	274	245	318	214	309
Total processed	46,569	45,792	49,759	49,981	43,832
Stocks, Dec. 31 (total available less total processed)	12,328	11,098	10,788	13,901	20,273

[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)
1982	208,074	2,712,678	10,936	4.0
1983	166,186	2,586,810	9,328	3.6
1984	152,093	2,500,945	8,659	3.5
1985	146,041	2,215,042	[r]9,321	4.2
1986	122,963	2,071,023	8,660	4.2

[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	1985[r] Primary	1985[r] Secondary	1985[r] Total	1986 Primary	1986 Secondary	1986 Total
Alloys (miscellaneous)[1]	W	W	W	W	W	W
Babbitt	1,147	341	1,488	989	358	1,347
Bar tin	466	W	466	480	W	480
Bronze and brass	1,683	2,647	4,330	1,781	1,722	3,503
Chemicals	W	W	W	W	W	W
Collapsible tubes and foil	W	W	W	W	W	W
Solder	13,306	5,315	18,621	11,125	4,631	15,756
Tinning	1,511	W	1,511	1,422	W	1,422
Tinplate[2]	9,321	W	9,321	8,660	W	8,660
Tin powder	976	W	976	1,002	W	1,002
Type metal	7	W	7	W	W	W
White metal[3]	876	61	937	1,067	67	1,134
Other	7,894	4,216	12,110	6,022	4,197	10,219
Total	37,187	12,580	49,767	32,548	10,975	43,523

[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)

	1982	1983	1984[r]	1985[r]	1986
Plant raw materials:					
Pig tin:					
Virgin[1]	6,269	6,326	5,403	5,747	5,777
Secondary	265	732	1,586	2,342	3,021
In process[2]	1,015	682	1,141	1,349	1,437
Total	7,549	7,740	8,130	9,438	10,235
Additional pig tin:					
Jobbers-importers	1,386	608	761	1,642	1,272
Afloat to United States	1,316	1,511	1,010	1,281	2,433
Total	2,702	2,119	1,771	2,923	3,705
Grand total	10,251	9,859	9,901	12,361	13,940

[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, was lowered sharply during the first 9 months of 1986, continuing the decline that began in late 1985 when the funds used by the ITC to support the tin price were exhausted. Starting in September 1986, the price of tin increased modestly over the balance of the year.

Table 9.—Monthly composite price of Straits tin for delivery in New York

(Cents per pound)

Month	1985			1986		
	High	Low	Average	High	Low	Average
January	586.44	566.26	573.67	NA	NA	NA
February	568.27	552.37	562.62	NA	NA	NA
March	592.27	553.49	565.68	515.68	392.94	455.79
April	612.58	569.33	591.56	372.20	350.56	364.25
May	601.38	561.43	588.61	363.23	345.22	352.24
June	613.74	597.34	604.03	350.91	343.86	346.61
July	637.77	610.51	626.31	351.53	342.38	346.52
August	631.25	617.73	626.49	351.25	344.14	347.01
September	627.36	592.91	610.07	347.44	343.21	345.83
October	614.88	605.61	610.46	382.68	343.81	353.87
November	NA	NA	NA	395.05	374.16	384.22
December	NA	NA	NA	411.02	393.19	402.77
Average[1]	XX	XX	595.95	XX	XX	369.91

NA Not available. XX Not applicable.
[1]Prices quoted for 10 months only.

Source: Metals Week.

FOREIGN TRADE

Imports for consumption of tin concentrates increased, indicating the improved activity at the Tex Tin smelter. Imports of tin metal increased, with Brazil remaining the major source, followed by Malaysia, Bolivia, Indonesia, and China. China has emerged in recent years as an important supplier. Malaysia regained the prominent position as a supplier that it held for many years until recently. 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)		
1984	$3,292	1,211	$1,318	$12,494	838	$5,301
1985	3,290	877	2,804	18,357	827	5,164
1986	1,280	1,121	1,899	19,843	860	5,165

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: Exports: Quantity (metric tons)	Ingots, pigs, bars: Exports: Value (thousands)	Tinplate and terneplate: Exports[1]: Quantity (metric tons)	Tinplate and terneplate: Exports[1]: Value (thousands)	Tinplate and terneplate: Imports: Quantity (metric tons)	Tinplate and terneplate: Imports: Value (thousands)	Tinplate scrap: Imports: Quantity (metric tons)	Tinplate scrap: Imports: Value (thousands)
1984	1,429	$14,409	154,679	$93,033	338,630	$203,147	4,755	$480
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

[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	1985 Quantity (metric tons)	1985 Value (thousands)	1986 Quantity (metric tons)	1986 Value (thousands)
Concentrates (tin content):				
Australia	(1)	$22	--	--
Bolivia	22	97	259	$2,344
Canada	24	102	1	1
Mexico	32	102	--	--
Peru	1,506	9,966	3,676	11,348
South Africa, Republic of	32	351	--	--
Total	r1,616	r10,640	3,936	13,693
Metal:[2]				
Australia	266	3,060	94	691
Belize	--	--	99	505
Bolivia	1,815	21,187	4,893	28,943
Brazil	11,021	127,128	9,456	62,334
Canada	18	233	32	252
Chad	20	245	--	--
Chile	673	7,392	1,776	11,291
China	4,513	60,126	2,955	19,681
France	167	1,803	35	190
Germany, Federal Republic of	147	1,574	18	62
Hong Kong	258	2,954	422	2,593
India	450	5,012	850	6,006
Indonesia	4,586	53,753	4,149	27,973
Iran	--	--	60	365
Israel	--	--	2	20
Italy	--	--	75	630
Japan	188	2,131	100	651
Korea, Republic of	3	41	--	--
Malaysia	379	4,503	6,230	43,221
Mexico	--	--	432	2,075
Netherlands	45	499	471	2,578
Norway	149	1,838	--	--
Singapore	1,886	22,156	691	5,163
South Africa, Republic of	105	1,282	35	332
Sweden	280	2,948	--	--
Switzerland	50	589	--	--
Taiwan	120	1,423	135	851
Thailand	6,373	75,423	1,901	13,965
United Arab Emirates	129	1,225	--	--
United Kingdom	48	600	730	4,363
Zaire	--	--	5	98
Zimbabwe	140	1,283	123	669
Total[3]	33,830	400,408	35,768	235,506

rRevised.
[1]Less than 1/2 unit.
[2]Bars, blocks, pigs, or granulated.
[3]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

WORLD REVIEW

The Sixth International Tin Agreement (ITA), which commenced on July 1, 1982, continued in effect throughout 1986, although its operations were restricted. The United States was not a member of the agreement.

Repercussions from the exhaustion of ITC funds to support the tin price in late 1985 continued throughout 1986. On March 12, the LME settled all outstanding tin contracts, a move that effectively suspended the LME tin contract. Several LME tin dealers claimed large monetary losses due to that action and brought suit against the LME. Later in the year, numerous tin dealers and banks brought suit against the ITC for debts owed for past tin credit purchases.

In the early part of the year, the ITC continued to maintain export controls on producer member countries at a level of 39.6% of the levels of tin exports prevailing before July 1, 1982, which was the commencement date for the export control program. On April 1, 1986, the ITC ended all export controls for its member nations. Despite the existence of export controls for close to 4 years, industry sources estimated the world tin surplus at about 70,000 tons at yearend 1986.

Tin smuggling in Southeast Asia continued to be a problem, although it declined considerably during the year along with the sharp drop in tin prices. Industry sources continued to indicate that Singapore was the destination for considerable tonnage of smuggled tin concentrates from Indonesia, Malaysia, and Thailand. Tin smuggling was counterproductive to export control measures and was viewed as a contributing factor in the world tin surplus.

The Association of Tin Producing Countries (ATPC), comprised of seven major producer nations—Australia, Bolivia, Indonesia, Malaysia, Nigeria, Thailand, and Zaire—completed its third year as an organization. ATPC viewed itself as being complementary to, and supportive of, the activities of the ITC, and the organization attempted to persuade non-ITA member countries to restrain tin production.

Australia.—The island of Tasmania was the source of about two-thirds of Australia's tin mine production. The large Renison underground tin mine in western Tasmania accounted for about 40% of the country's total output of tin.

Central Murchison Gold Ltd. commenced trial operations at its tin-gold processing plant at Gowrie Creek in North Queensland.

Promin Holdings Ltd. and Laser-Tech Australia Ltd. announced plans to construct a new tin smelter in Cairns, North Queensland. The new smelter would be the first one ever in North Queensland and would enable tin miners to retain slag for resmelting, allowing byproducts such as tantalite, columbite, and gold to be recovered.

Australia's largest tin smelter, owned by Associated Tin Smelters Pty. Ltd. (ATS), in Sydney, closed in July. In recent years the smelter, which had a 7,400-ton-per-year capacity, had only been producing about 2,500 tons per year. The ATS smelter had been treating domestic tin ore from small miners, but with the depressed tin prices, that supply had been declining. Although Australia was a substantial tin ore producer, most of its concentrates were exported to Malaysia for smelting.

Greenbushes Ltd., the country's second tin smelter, operated in Western Australia and smelted the production from its own tin-tantalum mine.

Domestic tin usage was estimated at 2,500 tons, with the tinplate industry being the largest consumer.

Bolivia.—Tin mine production declined sharply as the Government attempted to institute major changes in the industry's structure and operations. The Government's reorganization was met with widespread public unrest, and a 90-day state of emergency was declared on August 28. The collapse of tin prices that began in late 1985 had a marked effect on Bolivia because of its status as the highest cost producer among the world's major tin mining countries. The work force of the Corporación Minera de Bolivia (COMIBOL), the country's largest tin producer, was reduced from 27,000 to 6,000. Under the reorganization, COMIBOL was split into five divisions, and the large Catavi-Siglo Mine and the Colavi Mine were closed. Some moderate-sized mines like Colquechaca, Japo, and Viloco were leased to worker cooperatives. COMIBOL planned to rehabilitate the Huanuni, Quechisla, and Bolivar Mines.

A significant proportion of mine output was from medium-sized mines, accounting for 28% of the total. There were also many small mines and some mining cooperatives, contributing 23% of the total. The three largest mines were Huanuni, Catavi, and Colquiri, in descending order. Bolivia was a high-cost tin producer, largely because its mines were the hard-rock underground type and its tin deposits were of relatively low grade. Most of the tin concentrates produced were beneficiated in mills adjoining the mines.

COMIBOL started to rescale its Vinto tin smelting complex in an attempt to bring it to profitability. The work was commenced by Klöckner AG of the Federal Republic of Germany. The Vinto complex, which was composed of a 20,000-ton-per-year-capacity high-grade smelter and a 10,000-ton-per-year-capacity low-grade tin smelter, had been operating at only 25% of capacity in recent years. With tin prices at depressed levels, the low-grade unit was effectively dormant as mines strove to produce higher grade ores and concentrates. The International Bank for Reconstruction and Development pledged $150 million for the project.

Brazil.—Brazil was not a member of the ITA, and Brazilian tin mines increased their output. Brazil ranked as the world's second largest tin producer. Tin mine and smelter production was predominantly owned by private enterprise, both domestic and foreign. The leading private tin mining companies in Brazil were Paranapanema S.A. Mineração Indústria e Construção, Brascan Recursos Naturais S.A. (BRN), and Mineração Brumadinho S.A. Although Brazil reportedly had the lowest cost tin mines in the world, all three major firms invested substantially during the year to lower costs further.

The leading producer, Paranapanema, accounted for more than one-half of Brazil's total tin output, operating at least seven tin mines. The firm experienced continued strong output from its relatively new Pitinga Mine in the Mapuere region in Amazonas State. The firm shipped the entire tin concentrate output of all its mines to its Mamoré smelter, near São Paulo, for conversion to refined metal.

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 Goiás 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.

Cia. Siderúrgica Nacional (CSN) of Volta Redonda, the State-owned Brazilian steel producer, produced about 575,000 tons of tinplate, almost twice the 1985 output. CSN had tinplate capacity of 600,000 tons per year, with plans to boost capacity by 1987 to over 1 million tons yearly.

Cookson Mamoré Tin Corp. was formed as a partnership of Cookson Group PLC and Paranapanema to market Paranapanema's tin metal on an exclusive basis to North America.

Burma.—Mining Corp. Two, based in Rangoon, is responsible for the country's entire production of tin, as well as tungsten, antimony, etc. The organization totaled about 6,000 people who operated various underground and opencast and gravel pump and dredge tin operations, as well as a tin concentrator at Tavoy. The country's tin ore was smelted at the Syriam smelter, with a capacity of 1,000 tons per year.

Canada.—Rio Algom Ltd., which had started production at its 4,500-ton-per-year-capacity open pit tin mine at East Kemptville, Nova Scotia, in 1985, ceased financial involvement in the mine owing to the sharp decline in tin prices. The project had been funded by a consortium of banks, which took as their collateral for the loans the assets of the East Kemptville Mine. Toward yearend, negotiations were held that would maintain Rio Algom as the operator of the tin mine on behalf of the banks. The mine shipped all tin concentrates to the Capper Pass tin smelter in North Ferriby, United Kingdom.

China.—The country's tin resources were located in the south, mostly in Guangdong, Guangxi, Hunan, Jiangxi, and Yunnan Provinces. Mine production from Gejiu in Yunnan and DaChang in Guangxi accounted for about 80% of the national total. The DaChang tinfields were noteworthy for their size, covering an area of about 170 square kilometers with a grade of about 1% tin. DaChang employed 5,000 people directly and produced about 6,000 tons of tin metal annually. Large-scale deposits of tin were reportedly discovered in the Ar Horqin grasslands section of the Inner Mongolia autonomous region. There were eight known tin smelters with a combined annual capacity of 25,000 tons.

India.—M. P. State Mining Corp. Ltd.

started a small-scale tin mining operation in the Bastar-Koraput tin belt, along the Orissa border. The London-based Caparo Group Ltd. announced plans to construct a tinplate plant with 1 million tons annual capacity near the Port of Goa.

Indonesia.—Most tin deposits were offshore. P.T. Tambang Timah (P.T. Timah), the State-owned mining firm, was the major producer. P.T. Timah announced plans to reduce its work force of 29,000 people by 2,000 annually over the next few years through attrition. The organization, which produced 80% of Indonesian tin, was reportedly encountering heavy losses.

P.T. Koba Tin was the second largest producer, with its largest mine on Bangka Island. Koba was jointly owned by Kajaura Mining Corp. (Pty.) Ltd., an Australian company, and by P.T. Timah. Koba announced plans to close its high-cost gravel pump mines owing to prevailing low tin prices. These closures were expected to amount to 20% of Koba's output.

P.T. Broken Hill Pty. Indonesia stopped mining operations and sold its lease to Preussag A.G. P.T. Riau Tin Mining closed its 700-ton-per-year mine on Bangka Island owing to low tin prices.

Billiton International B.V. sold the lease on its Bima dredge operating in Indonesia to Inspiration Mining Corp. The dredge, one of the largest employed anywhere in the world for tin mining, would reportedly be used in Alaska for precious metals mining.

The new P.T. Latinusa electrolytic tinplate plant in Cilegon, West Java, reportedly was operating smoothly and accounted for a doubling of Indonesia's tin metal consumption to 10% of the country's output.

Japan.—The country's only tin mine, the Akenobe Mine, in Hyogo Prefecture in south-central Japan, closed during the year after 120 years of operation. Mitsubishi Metal Corp., which purchased the mine in 1896, attributed the closure to the sharp decline in tin prices. The mine's tin concentrates had been shipped to the company's Naoshima refinery.

Malaysia.—Although Malaysia remained the world's leading tin producer, its tin mining activities continued the pattern of decline of recent years. The number of active mines declined to 185, down from 465 in 1985. The gravel pump mines, which traditionally accounted for as much as two-thirds of total output, were high-cost operations and were especially affected by closures. Total mine employment declined to a reported 15,000 people compared with 22,000 in 1985.

Two large tin smelters operated in Penang, refining all of Malaysia's tin concentrates and some imported concentrates.

Perusahaan Sadur Timah Malaysia Sdn. Bhd. (Perstima), the country's only tinplate producer, at Pasir Gudang, has progressed since its 1982 startup to be the primary supplier of tinplate to Malaysia. It accounted for 85% of the country's tinplate needs. Perstima obtained its blackplate steel for tinning from Japanese steel firms.

Mexico.—Tin mining was reported in the three adjoining States of Durango, Zacatecas, and San Luis Potosí in the north-central part of Mexico. The country's main 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 Estãno 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 processed mainly imported tin concentrates.

Namibia.—Most tin production came from the Uis Mine in the Brandberg area. 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 needs for use in making electrolytic tinplate.

Nigeria.—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. were the five tin mining companies. All tin concentrates were smelted domestically by Makeri Smelting Co. Ltd. at Jos in Plateau State.

Peru.—The San Rafael Mine, owned by Minsur S.A., was the only tin mine. Situated near Juliaca, the mine was within the northern extension of the Bolivian tin belt. The mine reported tin grades of 1.8%. Peru remained the major supplier of tin concentrates to the United States.

Saudi Arabia.—The Deputy Ministry for Mineral Resources (DMMR) announced discovery of the country's first tin deposit at Jabal near Silsilah. Initial exploration indicated 1 million tons of tin ore grading 0.18% tin, but the DMMR expected further exploration to reveal resources of 5 to 10 million tons.

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. Rooiberg suspended production at three of its four mines, while its fourth and largest mine, the C Mine, and its smelter remained open. The Union Tin operation was on a care and maintenance basis all year.

Spain.—The Minero Metalúrgica del Estãno S.A. tin smelter, which was forced into receivership in 1982, emerged from receivership but still needed a capital infusion. The plant produced about 600 tons yearly of tin alloys, a fraction of its 5,000-ton annual capacity.

Thailand.—Four major tin mining firms suspended work indefinitely, mostly due to depressed tin prices. Jootee Tin Dredging Co. Ltd. and Boonsoon Tin Dredging Co. Ltd. cut production in Pairl. Aokam Thai Co. Ltd. and Tongkah Harbour Tin Co. Ltd. suspended their southern operations. Thai Pioneer Enterprise Ltd. announced a plan to reopen its 3,600-ton-per-year-capacity tin smelter near Bangkok. The smelter had been closed since 1982.

U.S.S.R.—The U.S.S.R. ranked as the world's third leading tin ore producer, yet 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. Expansion of capacity occurred at the Deputatskiy tin mining and beneficiation complex in Yakutia. Placer mining had been conducted at Deputatskiy for over 40 years, and in 1979, development began of a lode mine and concentrator. In 1986, a new concentrator was commissioned at the Deputatskiy complex, with operation scheduled for 1988. With the commissioning of these new facilities, the Deputatskiy complex was facing a power shortage owing to delays in constructing the Adycha hydroelectric powerplant. The commissioning of the second stage 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. Currently, the country imported an estimated 35% of its tin requirements.

United Kingdom.—The Government provided the troubled Cornish tin mining industry with $22 million in interest-free loans and agreed to guarantee commercial loans totaling $14 million, to be used over a 5-year period to make the mines more competitive. The loans were awarded to the Wheal Jane and the South Crofty Mines, both owned by Rio Tinto Zinc Corp. PLC (RTZ). The Geevor and the Pendarves Mines, both in Cornwall, were unable to secure such loans and closed.

The Capper Pass tin smelter, owned by RTZ, started construction of a new tin processing circuit designed to more efficiently smelt the higher grades of tin concentrate now generally supplied as tin mines attempt to improve their output at a time of low tin prices. The new unit would raise the smelter's capacity to 20,000 tons annually of tin metal. Capper Pass treats tin ore from the East Kemptville, Nova Scotia, Canada, tin mine and from Peru's San Rafael Mine as well as other foreign sources and domestic production.

Zaire.—Société Minière et Industrielle de Kivu (Sominki) in Kivu was the major tin producer. 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. However, Geomines declared bankruptcy, and production at low levels was stockpiled at the minesite.

Zimbabwe.—Production was centered at the Kamativi Mine-concentrator-smelter complex in the northwest area near Hawange. The tin occurred as cassiterite, along with beryllium, lithium, and tantalite. In 1986, KHD Humboldt Wedag AG of the Federal Republic of Germany was awarded a contract to construct a new mineral processing facility at Kamativi.

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

(Metric tons)

Country	1982	1983	1984	1985[p]	1986[e]
Argentina	[r]342	291	274	454	260
Australia	12,126	[2]9,275	7,923	6,363	[3]8,631
Bolivia	26,773	25,278	19,911	16,136	11,900
Brazil	8,218	13,275	19,957	26,514	27,400
Burma	1,681	1,642	2,028	1,751	[3]1,495
Cameroon	15	NA	14	13	12
Canada	135	141	217	120	2,450
China[e]	15,000	15,000	15,000	15,000	15,000
Czechoslovakia[e]	200	250	250	250	250
German Democratic Republic[e]	1,700	1,800	1,800	1,800	1,600
Indonesia	33,806	26,553	23,223	21,759	[3]22,102
Japan	529	600	485	510	[3]500
Korea, Republic of	--	--	19	21	--
Laos	302	359	430	[e]540	550
Malaysia	52,342	41,367	41,307	36,884	[3]28,072
Mexico	27	[r]50	416	[e]400	400
Namibia	1,326	[e]1,400	906	984	1,000
Niger	36	40	76	[r e]100	60
Nigeria	2,355	1,560	1,700	[r e]990	1,090
Peru	1,672	[r]2,808	3,314	3,779	[3]4,817
Portugal	410	347	[r e]300	[r e]200	100
Rwanda	[r]1,159	[r]1,068	1,093	813	[3]29
South Africa, Republic of	3,035	2,668	2,301	2,153	2,100
Spain	518	444	438	637	400
Tanzania	[r]6	[r]4	[r e]4	[r e]4	4
Thailand	26,109	19,943	21,920	16,864	16,800
Uganda	[r]3	[r]18	[r e]18	[r e]18	18
U.S.S.R.[e]	21,000	22,000	23,000	23,000	23,500
United Kingdom	4,208	4,025	5,216	5,204	[3]4,594
United States	W	W	W	W	W
Vietnam[e]	500	550	500	600	650
Zaire[4]	2,320	2,163	2,708	3,100	2,800
Zambia	[e]10	[e]22	4	22	3
Zimbabwe[e]	1,600	[r]1,700	[r]1,670	[r]1,670	1,650
Total	[r]219,463	[r]196,641	198,422	188,653	180,237

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.
[1]Contained tin basis. Data derived in part from the Monthly Statistical Bulletin of the International Tin Council, London. Table includes data available through June 16, 1987.
[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	1982	1983	1984	1985[p]	1986[e]
Argentina[2]	216	254	292	135	365
Australia	3,105	2,913	2,899	2,683	[3]1,302
Bolivia	19,032	14,164	15,842	12,859	8,500
Brazil	9,298	12,950	18,887	24,701	25,500
China[e]	15,000	15,000	15,000	15,000	15,000
Czechoslovakia[2]	295	307	425	[e]430	430
German Democratic Republic[e]	2,000	2,000	2,000	[r]2,200	1,600
Germany, Federal Republic of	608	417	[r e]417	[e]400	350
Indonesia	29,755	28,390	22,467	20,909	22,000
Japan	1,296	1,260	1,354	1,391	[3]1,279
Malaysia[4]	62,836	53,338	46,911	45,500	44,000
Mexico[5]	944	1,216	1,531	1,492	1,500
Netherlands	2,800	5,398	6,517	6,033	5,000
Nigeria	2,754	1,190	1,400	1,020	1,000
Portugal	[r]416	[r]443	432	408	[3]194
Rwanda	908	1,110	[e]1,000	[e]800	--
South Africa, Republic of	2,884	2,685	1,592	1,366	1,850
Spain	3,700	3,700	4,400	3,900	3,500
Thailand	25,497	18,467	19,729	17,996	18,500
U.S.S.R.[e]	24,000	24,000	25,000	25,000	26,000
United Kingdom	8,164	6,467	7,105	7,548	7,000

See footnotes at end of table.

Table 14.—Tin: World smelter production, by country[1] —Continued

(Metric tons)

Country	1982	1983	1984	1985[p]	1986[e]
United States[6]	3,500	2,500	4,000	[e]3,000	[3]3,213
Vietnam	475	[3]520	475	570	600
Zaire	352	201	170	85	50
Zimbabwe	1,197	[r]1,234	1,210	1,207	1,200
Total	[r]221,032	[r]200,124	201,055	196,633	189,933

[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 16, 1987.
[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.

TECHNOLOGY

A Japanese firm developed an optical disk memory using a tin alloy for thin film, instead of tellurium. The new disk was made from a tin alloy as base material with molybdenum added. The alloy was then formed into a thin film on a polycarbonate base by vacuum evaporation. Reportedly, the new disk had improved reflection rates and carrier noise levels. Commercial production was planned for 1987.[4]

Several firms reported advances in the technology of application of tin oxide glazings to architectural glass to provide a form of transparent insulation, allowing the visible light through but controlling the flow of heat. Tin oxide coatings, competing with other semiconductors and metals like silver and copper, were deposited by a fast and inexpensive pyrolytic or "hard" coating process that was claimed to have substantial cost and quality advantages.[5]

Kawasaki Steel Corp. of Japan developed a nickel-diffused lightly tin-coated steel, trademarked as RIVERWELT. The product was intended for fabrication into welded food and beverage cans and featured a four-layer coating that consisted of a middle layer of iron-nickel-tin alloy, and an undermost layer of diffused nickel, both sandwiched between an upper layer of metallic tin and the base steel, with the product surface covered by a thin film of special chromate. Reportedly, the product afforded cost savings on tin and insured good paint adhesion, while keeping conventional tinplate's weldability and good resistance to corrosion.[6]

Several U.S. steel companies developed techniques for remelting steel can scrap, a process earlier jeopardized by the presence of aluminum, lead, and tin. Mill-generated scrap as well as purchased and customer scrap, including cans, was used in recharging basic oxygen furnaces. The scrap mix typically constituted 23% of the total charge. The key to effective can scrap use was its dilution with other materials. Steel industry estimates indicated about 18 million steel cans were retrieved daily at resource recovery facilities.

Vulcan Materials Corp. PLC opened a detinning plant in Hartlepool, United Kingdom, that reportedly was the first in the world for treating domestic refuse. Because tinplate in metal cans is about 99% steel, it could be extracted magnetically from collected domestic waste. Prior to this plant, the contamination in the cans such as lacquers and food particles had made detinning uneconomical. This plant reportedly utilized a new shredder that eliminated virtually all contaminated materials by means of cyclonic air extraction, magnets, and screening. The plant converted used cans at a rate of 15,000 tons yearly into ferrous scrap and tin.[7]

The International Tin Research Institute opened its new headquarters and laboratory premises at Uxbridge, near London, United Kingdom. Since its start in 1932, the Institute, which is funded by leading world tin producing nations, has been a leader in developing new tin applications.[8]

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[1]Physical scientist, Division of Nonferrous Metals.
[2]American Metal Market. V. 94, No. 119, June 19, 1986, p. 9.
[3]Can Manufacturer's Institute. Metal Can Shipments Report 1986. Washington, DC, 1986, p. 5.
[4]American Metal Market. V. 94, No. 247, Dec. 22, 1986, p. 15.
[5]Solar Age. V. 11, Feb. 1986, pp. 21-26.
[6]Iron and Steel Engineer. V. 63, No. 1, Jan. 1986, p. 70.
[7]Tinplate World. No. 5, 1986, p. 7.
[8]Tin and Its Uses. No. 151, 1987, pp. 1-2.

Titanium

By Langtry E. Lynd[1] and Ruth A. Hough[2]

U.S. consumption of titanium concentrates increased in 1986, and production and consumption of titanium dioxide (TiO_2) pigment again reached new record-high levels, in line with continued expansion of the domestic economy, particularly in the homebuilding industry. U.S. production of ilmenite, rutile, and synthetic rutile increased slightly in 1986, as did imports of titanium concentrates. Domestic production of titanium sponge declined 25%; consumption of sponge and ingot and net shipments of mill products were down about 10% from 1985 levels. The relatively slow market for titanium metal and low capacity utilization rate led to intense price competition and the shutdown of one sponge plant, reducing operating U.S. sponge capacity by 8%. The continued high demand for TiO_2 pigment led to substantial increases in the price of rutile concentrates. TiO_2 pigment prices increased to record-high levels by yearend.

Domestic Data Coverage.—Consumption data for titanium raw materials are developed by the Bureau of Mines from a voluntary domestic survey. Of the 35 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 7. Consumption for the one nonrespondent was estimated using reported prior year consumption levels.

Table 1.—Salient titanium statistics

(Short tons unless otherwise specified)

	1982	1983	1984	1985	1986
United States:					
Ilmenite concentrate:					
Mine shipments	233,063	W	W	W	W
Value ... thousands	$19,093	W	W	W	W
Imports for consumption	348,366	259,328	409,605	506,804	465,617
Consumption	583,250	730,578	783,391	756,071	806,270
Titanium slag:					
Imports for consumption	247,845	138,708	209,839	291,828	361,872
Consumption	225,541	166,401	200,858	252,027	276,324
Rutile concentrate, natural and synthetic:					
Imports for consumption	163,325	111,578	180,508	179,663	174,820
Consumption	238,937	265,558	317,902	305,278	329,151
Sponge metal:					
Imports for consumption	1,354	1,199	[1]2,667	[1]1,717	1,626
Consumption[e]	17,328	16,072	24,713	21,606	19,489
Price, Dec. 31, per pound	$5.55	$5.55	$5.55	$3.50-$4.00	$3.90-$4.30
Titanium dioxide pigment:					
Production	659,710	760,385	834,889	[r]860,443	917,305
Imports for consumption	138,922	174,857	193,501	196,213	202,674
Consumption, apparent[2]	741,065	853,008	916,198	[r]981,479	987,612
Price, Dec. 31, cents per pound:					
Anatase	69.0	69.0	69.0	72.0	77.0
Rutile	75.0	75.0	75.0	78.0	82.0
World: Production:					
Ilmenite concentrate	[r]3,338,549	[3]2,948,100	[3]3,794,598	[p] [3]3,792,966	[e] [3]3,749,838
Rutile concentrate, natural[3]	373,449	342,081	375,684	[p]414,153	[e]438,693
Titaniferous slag	1,157,445	1,160,000	1,260,000	[p]1,410,000	[e]1,417,000

[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]Apparent consumption equals 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.

The Department of Defense Authorization Act, 1987 (Public Law 99-661), signed by the President on November 14, 1986, stated that no action may be taken before October 1, 1987, to implement or administer any change in a stockpile goal in effect on October 1, 1984, that results in a reduction in the quality or quantity of any strategic and critical material to be acquired for the NDS.

Antidumping and countervailing duties will be waived on imports of material for the NDS and for certain other defense-related purposes, as a result of a decision by the U.S. Department of Commerce, International Trade Administration (ITA). The ITA decided, after a review period of almost 2 years, that the waiver policy has the sanction of law even though opponents, including some representatives of the U.S. titanium industry, have said the policy disadvantages U.S. producers. The review of the waiver policy's legitimacy had been prompted by complaints from the titanium industry when certain imports of titanium sponge for the NDS were excluded from antidumping and countervailing duties. In 1984, the ITA set final dumping margins on Japanese sponge imported for the NDS, but also decided that imports to fulfill the 1983 purchase contracts for titanium for the stockpile would not be subject to duties.

Acting on an appeal by Japanese titanium sponge producers, the U.S. Court of International Trade in New York, on July 17, 1986, upheld a 1984 ITA finding that imports of titanium sponge from Osaka Titanium Co. Ltd., Toho Titanium Co. Ltd., and Nippon Soda Co. Ltd. threatened material injury to domestic producers. In November 1986, following its annual review of Japanese sponge imports, for the period November 15, 1984, to October 31, 1985, the ITA set preliminary antidumping margins of zero for Osaka Titanium and less than 1% for Toho Titanium, compared with previous margins of 14.59% and 34.25%, respectively. U.S. sponge producer RMI Co., Niles, OH, opposed the new margins at an ITA hearing on December 5, 1986, that had been requested by RMI on a basis of pricing and cost issues.

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 1985, AMU was the only domestic producer of natural rutile concentrate. Kerr-McGee Chemical Corp. was the sole producer of synthetic rutile, at Mobile, AL.

AMU received permits from the U.S. Minerals Management Service to explore a 954-square-mile offshore area for heavy minerals, starting at Georgia's 3-mile limit and extending 10 miles offshore from south of Jekyll Island near Brunswick to north of Tybee Island near Savannah. AMU's exploration activity, to begin on April 1, was to be within the area where sampling by the U.S. Geological Survey in 1985 indicated large concentrations of ilmenite, rutile, and other heavy minerals.

P. W. Gillibrand Co., a producer of construction materials and industrial sands, was separating and stockpiling heavy minerals containing ilmenite at a rock, sand, and gravel operation in the Soledad Canyon area, Los Angeles County, CA. Gillibrand planned to install additional gravity, electrostatic, and magnetic separation equipment to allow production of 50,000 to 100,000 tons per year of concentrates, of which about 33% would be ilmenite (containing about 50% TiO_2), 20% magnetite, 27% apatite, and 4.5% zircon. Gillibrand estimated available reserves at over 100 million tons of TiO_2 content in alluvial sand, titaniferous magnetite, and gabbro.

Ferrotitanium.—Ferrotitanium was produced by Ashland Chemical Co., Columbus, OH; Reactive Metals and Alloys Corp., West Pittsburg, PA; and Shieldalloy Corp., Newfield, NJ. Most of the production consisted of the 70% titanium grades.

Metal.—The TIMET Div. of Titanium Metals Corp. of America reportedly concluded a 10-year agreement with Nippon

Steel Corp. of Japan to sell Nippon Steel titanium alloy ingot and to supply Nippon Steel with titanium rolling technology for use with new facilities to be completed in 1987. Under the agreement, Nippon Steel was to become TIMET's exclusive sales agent in Japan for aerospace-grade titanium mill products. Nippon Steel officials said they believe there is a growing potential demand for titanium alloy products in Japan for aircraft, marine, and other industrial areas.

McDonnell Aircraft Co., St. Louis, MO, a division of McDonnell Douglas Corp., doubled its capacity for using superplastic forming (SPF) and diffusion bonding to produce aircraft parts from titanium. A new $2.5 million, 1,000-ton press was installed in April and was to serve 10 molding units, 7 of which were already operational. The new press saves manufacturing time by moving along a 100-foot platform to 1 of 10 different work stations while parts at other stations are being heated. The SPF process involves heating sheets of titanium to about 1,650° F under inert gas pressure that allows controlled expansion of the sheets into shapes up to several times their original size. Diffusion bonding allows parts to be joined by atomic diffusion, without melting. These processes are being used by McDonnell to make engine bays and other parts for the F-15E fighter aircraft.

Elettrochimica Marco Ginatta (EMG) of Italy reportedly signed a $20 million contract to supply its electrolytic technology to produce ultrapure titanium sponge and powder to a U.S. titanium producer. The name of the U.S. licensee was not released, but U.S. industry sources said RMI had shown interest in the EMG process in the past few years. According to EMG, the U.S. licensee would use the technology in a new 10,000-ton-per-year plant, with construction to start in 1987. Potential savings of 40% of the cost of existing titanium metal production processes were claimed. The future of a 1,200-ton-per-year plant that EMG was to have built in Trieste, Italy, seemed to be in doubt, but EMG was negotiating with prospective Western European partners to build a second plant with a 5,000-ton-per-year capacity.

Albany Titanium Inc. (ALTi), Albany, OR, planned to begin construction in 1987 of a commercial plant to produce titanium from ilmenite, at a site in the Southern United States. Startup of the proposed 5,000-ton-per-year sponge and powder plant would probably be about 18 months after beginning construction. ALTi's pilot plant at Albany was being operated by a team of two Fluor Corp. companies, Daniel International and St. Joe Minerals Corp., using ALTi employees to gather data to help justify financing for the commercial plant. Late in 1986, ALTi signed an agreement with the Aircraft Engine Business Group of General Electric Co. (GE) to jointly develop powdered titanium alloys for jet engines, with GE to take as much as a 20% share in ALTi.

In June, operations by ALS Metals Co., a joint venture formed in 1982 between Allegheny Ludlum Steel Corp., Sumitomo Metal Industries Ltd., Sumitomo Corp., and Sumitomo U.S., were terminated. ALS imported Sumitomo's semifinished titanium mill products into the United States from Japan, and converted them into sheet, strip, plate, and welded tubing at Allegheny Ludlum steel mills in Oklahoma and Pennsylvania. The increased value of the Japanese yen relative to the U.S. dollar was a major factor in the decision to terminate the ALS operations.

At yearend, Wyman-Gordon Co., Worcester, MA, announced plans to close its 80%-owned International Titanium Inc. (ITI) titanium sponge plant at Moses Lake, WA, and one of its forging plants, Reisner Metals Inc., South Gate, CA. The ITI plant was to be shut down over an 8-week period, and the Reisner Metals operation was to be phased out over a considerably longer period. Reisner's market, mainly forgings for gas turbine engines, will continue to be served by Wyman-Gordon's Eastern U.S. plants. The annual capacity of active U.S. sponge producers in 1987 will drop 8% to about 28,000 tons.

Table 2.—Production and mine shipments of ilmenite concentrate[1] from domestic ores in the United States

Year	Production, gross weight (short tons)	Shipments		
		Gross weight (short tons)	TiO_2 content (short tons)	Value (thousands)
1982	263,391	233,063	145,725	$19,093
1983	W	W	W	W
1984	W	W	W	W
1985	W	W	W	W
1986	W	W	W	W

W Withheld to avoid disclosing company proprietary data.
[1]Includes a mixed product containing rutile, leucoxene, and altered ilmenite.

Table 3.—U.S. titanium metal production capacity in 1986

Company	Ownership	Plant location	Capacity (short tons)	
			Sponge	Ingot
Howmet Corp., Titanium Ingot Div.	Pechiney, France	Whitehall, MI	--	5,000
International Light Metals Corp	Martin Marietta Corp., 60%; Nippon Kokan K.K., 40%.	Torrance, CA	--	6,000
International Titanium Inc	Wyman-Gordon Co., 80%; Mitsui & Co. Ltd., Japan, nearly 20%.	Moses Lake, WA	2,500	--
A. Johnson Metals Corp	Axel Johnson Group, Stockholm, Sweden.	Lionville, PA	--	[1]1,500
Lawrence Aviation Industries Inc.	Self	Port Jefferson, NY	--	1,500
Oregon Metallurgical Corp	Owens-Corning Fiberglas Corp., 80%; public, 20%.	Albany, OR	4,500	8,000
RMI Co	USX Corp., 50%; National Distillers & Chemical Corp., 50%.	Ashtabula, OH	9,500	--
		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	17,000
Viking Metallurgical Corp	Quanex Corp	Verdi, NV	--	[1]5,000
Wyman-Gordon Co	Self	Worcester, MA	--	2,500
Total			30,500	69,500

[1]Single melt only; commercially pure ingot and slab.

Pigment.—Production of TiO_2 pigment increased for the fourth consecutive year, and in 1986, was 917,000 tons, about 98% of nominal capacity. Modifications of existing plants were continued to maximize capacity utilization.

Kerr-McGee announced plans to expand its TiO_2 facility at Hamilton, MS, from 72,000 to 93,000 tons per year. The $25 million program was scheduled to begin early in 1987 with completion by late 1988. This is the third expansion at the facility since 1983. Synthetic rutile produced at Kerr-McGee's plant in Mobile, AL, is the main feedstock for the Hamilton plant.

The merger of SCM Corp. into Hanson Industries U.S.A., a subsidiary of Hanson Trust PLC of the United Kingdom, was completed on April 1, 1986. SCM Chemicals Inc. is the world's third largest producer of TiO_2 pigments, after DuPont and Tioxide Group PLC, and has plants in the United States, the United Kingdom, and Australia, with a total capacity of 378,000 tons per year.

Table 4.—Components of U.S. titanium metal supply and demand

(Short tons)

Component	1982	1983	1984	1985	1986
Production:					
Sponge	[1]15,600	13,966	24,326	23,257	17,402
Ingot	26,536	26,439	39,964	[r]35,387	35,093
Exports:					
Sponge	36	39	171	51	69
Other unwrought	173	258	204	[r]181	207
Scrap	4,287	5,379	4,109	6,760	6,403
Ingot, slab, sheet bar, etc	2,196	1,371	2,071	2,248	2,119
Other wrought	1,404	783	778	[r]1,147	1,132
Total	8,096	7,830	7,333	[r]10,387	9,930
Imports:					
Sponge	1,354	1,199	[2]2,667	[2]1,717	1,626
Scrap	1,277	1,572	1,850	2,134	2,375
Ingot and billet	212	81	176	179	106
Mill products	870	936	840	1,449	1,239
Total	3,713	3,788	5,533	5,479	5,346
Stocks, yearend:					
Government: Sponge (total inventory)	32,331	32,331	32,470	36,831	36,831
Industry:					
Sponge	3,350	3,136	3,147	4,755	3,180
Scrap	11,073	12,635	12,489	11,686	11,558
Ingot	2,534	3,273	4,526	4,000	4,100
Other	3	22	18	34	33
Total industry	16,960	19,066	20,180	20,475	18,871
Reported consumption:					
Sponge	17,328	16,072	24,713	21,606	19,489
Scrap	8,528	10,467	15,549	14,720	16,487
Ingot	27,580	26,232	39,062	[r]35,020	33,801
Mill products (net shipments)[3]	18,281	15,949	22,808	[r]22,760	20,842
Castings (shipments)[3]	260	240	268	411	454

[r]Revised.
[1]Calculated sponge metal production equals sponge consumption plus sponge exports minus sponge imports and adjustments for Government and industry stock changes.
[2]Excludes sponge imported by the General Services Administration (GSA) for the national stockpile.
[3]Bureau of the Census, Current Industrial Reports, Ser. ITA-991.

Table 5.—Capacities of U.S. titanium dioxide pigment plants on December 31, 1986

Company and plant location	Pigment capacity (short tons per year)	
	Sulfate process	Chloride process
E. I. du Pont de Nemours & Co. Inc.:		
Antioch, CA	--	35,000
De Lisle, MS	--	150,000
Edge Moor, DE	--	110,000
New Johnsonville, TN	--	240,000
Kemira Inc., Savannah, GA	64,000	46,000
Kerr-McGee Chemical Corp., Hamilton, MS	--	72,000
SCM Chemicals Inc., Hanson Industries U.S.A.:		
Ashtabula, OH	--	102,000
Baltimore, MD	66,000	50,000
Total	130,000	805,000

Table 6.—Components of U.S. titanium dioxide pigment supply and demand

(Short tons unless otherwise specified)

Component	1982 (gross weight)	1983		1984		1985		1986[1]	
		Gross weight	TiO_2 content	Gross weight	TiO_2 content	Gross weight	TiO_2 content	Gross weight	TiO_2 content
Production	659,710	760,385	707,158	834,889	777,031	r860,443	r788,957	917,305	852,773
Shipments:[2]									
Quantity	707,075	813,958	762,818	905,383	844,901	950,637	884,758	1,085,084	1,013,079
Value thousands	$927,517	$950,515	$950,515	$1,106,898	$1,106,898	$1,275,131	$1,275,131	$1,530,225	$1,530,225
Exports	72,823	91,702	83,372	106,124	96,740	101,954	92,434	112,227	102,506
Imports for consumption	138,922	174,857	e162,600	193,501	e180,091	196,213	r179,912	202,674	188,416
Stocks, yearend	86,933	77,465	e72,035	83,533	e77,744	56,756	r e52,041	76,896	e71,486
Consumption, apparent[3]	741,065	853,008	e791,816	916,198	e854,673	r981,479	r e902,138	987,612	e919,238

[e]Estimated. [r]Revised.

[1]Data coverage beginning in 1986 was extended to include additional major importers.

[2]Includes interplant transfers.

[3]Apparent consumption equals 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 about 8%, reflecting the increased production of TiO_2 pigment.

Ferrotitanium.—Consumption of ferrotitanium and titanium scrap in steel and other alloys increased slightly over 1985 levels.

Metal.—Consumption of sponge and ingot and net mill product shipments each decreased about 10%. Consumption of scrap increased 12%, because of the rise in the proportion of scrap in ingot feedstock to 47% in 1986, compared with 42% in 1985. The higher scrap utilization stemmed mainly from increased production of ingot using the electron beam melting process, which employs a 100% scrap charge, and greater availability of high-quality chips and turnings that have been processed to remove high-density inclusions and other impurities.

Castings shipments increased 10% in 1986, and since 1984 have increased 69%. These increases resulted from growing acceptance of the use of castings, particularly investment castings, treated by hot isostatic pressing, instead of forgings and welded structures in a wide variety of nonrotating jet engine components.[3]

An example of a new titanium castings application is Howmet Turbine Components Corp.'s completion of production qualification of a main rotor damper bracket, cast from Ti-6Al-4V alloy, for the UH-GOA *Black Hawk* helicopter. This was the first investment-cast dynamic structural rotorcraft component to be qualified. The qualification program was conducted by Sikorsky Aircraft Div., United Technologies Corp., and was sponsored by the U.S. Army Aviation Systems Command, St. Louis, MO. The program demonstrated that investment casting of near net shapes, followed by hot isostatic pressing, can achieve significant overall savings in material costs and machining time, with component properties equivalent to those of a forging.[4]

Mill product shipments in 1986 were 50% in the form of billet; 34% sheet, strip, plate, tubing, pipe, extrusions, and other; and 16% 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 75% for aerospace and 25% for other industrial applications.

Current use of titanium in large commercial aircraft represents about 6% of empty aircraft weight. Titanium is utilized where high-strength toughness, heat resistance, and high structural efficiency are required. Typical military aircraft uses are for A-10 ballistic armament; 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.

The Navy Ships Parts Control Center, Mechanicsburg, PA, awarded a contract for production of 675 fire fighting pumps made from titanium for use in surface vessels. The contract was estimated to be worth up to $40 million. The Navy considered the $25,000 potential cost for each 750- to 1,000-gallon-per-minute pump to be cost effective, compared with a $40,000-per-unit estimate it received for an overhaul of existing brass and stainless steel pumps.

The Navy was reportedly considering increased use of titanium components in such equipment as the propulsion systems of torpedos, shipboard piping systems, heat exchangers, and a variety of structural shapes. Advantages of using titanium in a marine environment, instead of steel or brass, include its high strength, low density, and superior resistance to saltwater corrosion.

Pigment.—Consumption of TiO_2 pigments rose to a new peak for the fourth consecutive year, mainly because of continued expansion in the homebuilding industry. Data on shipments (tables 6 and 8) was extended in 1986 to include additional major importers who supply the domestic TiO_2 market. This additional data coverage results in better agreement between domestic shipments (total shipments less exports) and apparent consumption (table 7), and improves the accuracy of end-use data (table 8). The percentage changes resulting from inclusion of the additional data sources are the largest for rubber, printing ink, and ceramics, which would each have decreased slightly if the new data had not been used.

Table 7.—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]
1982	583,250	352,393	225,541	168,433	238,937	225,113
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:						
Alloys and carbide	(3)	(3)	(4)	(4)	--	--
Pigments	747,897	474,561	252,027	199,610	254,837	239,893
Welding-rod coatings and fluxes	(3)	(3)	--	--	5,192	4,881
Miscellaneous[5]	8,174	6,450	--	--	45,249	41,714
Total	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

[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, glass fibers, and titanium metal.

Table 8.—U.S. distribution of titanium pigment shipments, titanium dioxide content, by industry[1]

(Percent)

Industry	1982	1983	1984	1985	1986
Paint, varnish, lacquer	48.1	48.9	54.8	54.3	52.6
Paper	27.4	27.3	19.9	20.5	20.7
Plastics (except floor covering and vinyl-coated fabrics and textiles)	12.7	13.2	15.4	16.2	15.8
Ceramics	1.2	1.0	1.0	.7	2.2
Rubber	2.6	1.8	2.0	1.7	2.0
Printing ink	1.0	1.1	1.2	1.0	1.4
Other	7.0	6.7	5.7	5.6	5.3
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 9.—U.S. consumption of titanium products[1] in steel and other alloys

(Short tons)

	1982	1983	1984	1985	1986
Carbon steel	420	744	659	483	732
Stainless and heat-resisting steel	1,289	1,748	1,851	2,104	2,185
Other alloy steel (includes HSLA)	664	749	677	491	297
Tool steel	W	W	W	W	W
Total steel	2,373	3,241	3,187	3,078	3,214
Cast irons	47	38	62	23	65
Superalloys	409	535	622	657	630
Alloys, other than above	200	252	473	357	322
Miscellaneous and unspecified	10	12	18	18	35
Total consumption	3,039	4,078	4,362	4,133	4,266

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 total TiO_2 content of industry stocks of concentrates increased slightly in 1986. Decreases in stocks of slag and rutile were more than offset by increases in stocks of ilmenite.

Table 10.—U.S. stocks of titanium concentrates and pigment, December 31

(Short tons)

	Gross weight	TiO_2 content
Ilmenite:[1]		
1984	201,091	128,507
1985	237,430	147,357
1986	279,106	169,723
Titanium slag:[1]		
1984	66,599	52,397
1985[r]	106,062	83,821
1986	97,917	77,476
Rutile:[1]		
1984	102,128	96,186
1985	115,973	109,319
1986	109,068	102,938
Titanium pigment:[2]		
1984	83,533	[r] [e]77,744
1985	56,756	[r] [e]52,041
1986	76,896	[e]71,486

[e]Estimated. [r]Revised.
[1]Producer, consumer, and dealer stocks.
[2]Bureau of the Census. Producer stocks only.

PRICES

Concentrates.—The continued high demand for TiO_2 pigments in 1986 drove prices for Australian rutile concentrates 15% to 20% above those of 1985. Prices for Sierra Leone rutile were reportedly at similar levels.

Metal.—Reported sales prices on sponge firmed somewhat during the year. Mill product prices were generally somewhat lower than in 1985.

Pigment.—List and sales prices for TiO_2 pigments were increased about 3 cents per pound in October and remained at the higher level for the rest of the year.

Table 11.—Published prices of titanium concentrates and products

		1985[1]	1986[1]
Concentrates:			
Ilmenite, f.o.b. eastern U.S. ports	per metric ton	([2])	([2])
Ilmenite, f.o.b. Australian ports	do	$38.00-$42.00	$47.00-$53.00
Ilmenite, large lots, bulk, f.o.b. U.S. east coast	do	50.00- 56.00	50.00- 56.00
Rutile, f.o.b. eastern U.S. ports	per short ton	([2])	([2])
Rutile, bagged, f.o.b. Australian ports	do	371.00-386.00	398.00-422.00
Rutile, bulk, f.o.b. Australian ports	do	315.00-328.00	374.00-386.00
Rutile, large lots, bulk, f.o.b. U.S. east coast	do	350.00-360.00	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	196.00	210.00-215.00
Titanium slag, 85% TiO_2, f.o.b. Richards Bay, Republic of South Africa[e]	do	212.00	225.00-230.00
Metal:			
Sponge, reported sales	per pound	3.50- 4.00	3.90- 4.30
Sponge, Japanese, under contract, c.i.f. U.S. ports, including import duty	do	No quotation	No quotation
Mill products:			
Bar	do	9.77	9.25- 10.04
Billet	do	8.35	7.10- 7.76
Plate	do	10.64	8.00- 9.53
Sheet	do	12.73	9.50- 10.00
Strip	do	13.45	10.10- 10.60
Pigment:			
Titanium dioxide pigment, f.o.b. U.S. plants, anatase	do	.72- .73	.75- .77
Titanium dioxide pigment, f.o.b. U.S. plants, rutile	do	.78	.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 TiO_2 pigments resumed the annual increase that was interrupted in 1985. Both exports and imports of these pigments reached new record-high levels in 1986.

Exports of most titanium metal categories decreased during the year. Exports of sponge and other unwrought titanium increased but were still at rather low levels.

Imports for consumption of titanium slag increased 24%, which more than offset decreases in imports of ilmenite, rutile, and synthetic rutile.

Table 12.—U.S. exports of titanium products, by class

Class	1984 Quantity (short tons)	1984 Value (thousands)	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)
Concentrates:						
Ilmenite	3,807	$151	--	--	2,006	$286
Rutile	4,844	1,784	27,759	$6,953	3,308	1,128
Total	8,651	[1]1,936	27,759	6,953	5,314	1,414
Metal:						
Sponge	171	967	51	338	69	461
Other unwrought	204	1,224	181	2,604	207	1,757
Scrap	4,109	7,168	6,760	14,533	6,403	10,652
Ingots, billets, slabs, etc	2,071	40,993	2,248	40,942	2,119	38,754
Other wrought	778	20,509	1,147	29,481	1,132	31,413
Total	7,333	70,861	[1]10,388	87,898	9,930	83,037
Pigment and oxides:						
Titanium dioxide pigments	106,124	97,804	101,954	108,384	112,227	145,920
Titanium compounds, except pigment-grade	2,123	5,024	1,247	4,486	3,220	10,415
Total	108,247	102,828	103,201	112,870	115,447	156,335

[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 titanium concentrates, by country

Concentrate and country	1984 Quantity (short tons)	1984 Value (thousands)	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)
Ilmenite:						
Australia	409,605	$11,063	506,539	$14,060	427,453	$13,846
India	--	--	--	--	18,783	1,831
Indonesia	--	--	265	530	--	--
Sri Lanka	--	--	--	--	19,381	1,160
Total	409,605	11,063	506,804	14,590	465,617	16,837
Titanium slag:						
Canada	160,155	25,081	195,230	36,350	194,058	35,696
South Africa, Republic of	49,685	7,702	96,598	15,881	167,814	29,030
Total[1]	209,839	32,783	291,828	52,231	361,872	64,726
Rutile, natural:						
Australia	93,871	25,046	r66,054	19,062	73,844	25,222
Brazil	--	--	3,121	481	1,126	214
Namibia	--	--	--	--	11,052	3,852
Sierra Leone	48,436	13,326	32,994	10,822	19,439	7,039
South Africa, Republic of	15,939	2,674	44,146	10,094	37,124	9,521
Other	r219	r55	r286	r50	90	16
Total[1]	158,465	41,100	146,602	40,509	142,675	45,865

See footnotes at end of table.

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

Concentrate and country	1984 Quantity (short tons)	1984 Value (thousands)	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)
Rutile, synthetic:						
Australia	22,043	$3,810	33,061	$3,458	32,035	$6,315
China	--	--	--	--	110	34
Total	22,043	3,810	33,061	3,458	32,145	6,349
Titaniferous iron ore:[2]						
Canada	1,966	77	858	38	710	23

[r]Revised.
[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. Data adjusted by the Bureau of Mines.

Table 14.—U.S. imports for consumption of titanium dioxide pigments, by country

Country	1984 Quantity (short tons)	1984 Value (thousands)	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)
Australia	5,277	$5,398	5,285	$5,967	5,271	$6,604
Belgium-Luxembourg	10,840	9,824	16,459	15,508	18,009	20,649
Canada	26,212	29,388	26,658	30,019	24,509	28,476
Finland	6,079	5,954	5,799	6,200	5,930	6,995
France	47,801	45,107	39,379	42,167	36,818	44,719
Germany, Federal Republic of	34,980	34,156	39,723	38,955	48,867	57,902
Italy	1,078	1,032	1,520	1,855	3,239	4,338
Japan	4,546	4,900	5,378	6,267	5,083	5,586
Mexico	1,668	1,201	3,289	4,050	1,424	1,595
Netherlands	189	198	1,238	1,120	2,760	3,307
Norway	6,931	6,304	6,978	5,968	7,495	8,282
South Africa, Republic of	--	--	551	634	1,708	2,160
Spain	22,129	20,863	21,283	23,659	17,292	20,965
United Kingdom	22,847	20,857	21,242	22,880	21,876	25,885
Yugoslavia	2,597	1,447	516	508	412	631
Other[1]	329	322	913	1,054	1,981	1,964
Total[2]	193,501	186,952	196,213	206,809	202,674	240,058

[1]Includes Algeria, Austria, Brazil, China, Denmark, Dominican Republic, Greece, Hong Kong, Ireland, the Republic of Korea, Macao, Mali, New Zealand, Poland, 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 15.—U.S. imports for consumption of titanium metal, by class and country

Class and country	1984 Quantity (short tons)	1984 Value (thousands)	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)
Unwrought: Sponge:						
China	--	--	--	--	20	$77
Japan	[1]2,662	$15,789	[1]1,689	$10,007	1,606	9,504
Korea, Republic of	--	--	28	156	--	--
United Kingdom	[1]5	26	([2])	1	--	--
Total[3]	[1]2,667	15,815	[1]1,717	10,164	1,626	9,583
Ingot and billet:						
Canada	6	62	29	247	8	83
France	38	162	([2])	15	--	--
Germany, Federal Republic of	30	561	46	844	47	778
Israel	--	--	([2])	6	8	232
Japan	77	1,327	101	950	40	590
United Kingdom	26	328	2	49	3	56
Other	([2])	[r]6	([2])	[r]20	([2])	8
Total[3]	176	2,447	179	2,131	106	1,747

See footnotes at end of table.

Table 15.—U.S. imports for consumption of titanium metal, by class and country —Continued

Class and country	1984 Quantity (short tons)	1984 Value (thousands)	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)
Waste and scrap:						
Austria	217	$390	--	--	236	$512
Belgium-Luxembourg	28	11	47	$61	52	50
Canada	190	320	117	155	260	461
China	68	168	372	839	54	90
France	149	451	122	498	205	630
Germany, Federal Republic of	294	851	87	316	110	327
Japan	117	522	352	1,175	338	1,112
Sweden	100	301	90	311	51	149
Switzerland	--	--	162	318	238	470
U.S.S.R	90	270	78	194	149	311
United Kingdom	544	2,215	595	2,001	584	1,567
Other	53	202	111	207	96	246
Total[3]	1,850	5,703	2,134	6,075	2,375	5,927
Wrought titanium:						
Canada	212	3,701	390	6,293	399	6,284
Germany, Federal Republic of	6	140	([2])	18	44	554
Japan	529	6,091	987	13,128	741	10,309
United Kingdom	68	1,130	55	1,254	45	1,386
Other	25	441	18	345	10	307
Total[3]	840	11,504	1,449	21,038	1,239	18,840

[r]Revised.
[1]Excludes sponge imported by GSA for the national stockpile.
[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 production of titanium concentrates was about the same as in 1985. World production and demand for TiO_2 pigments were again at record-high levels, with demand estimated at about 2.65 million tons. Prices of concentrates and pigment increased in response to the high demand. Pigment producers were adding to existing plant capacity and were building or planning to build new pigment plants in Brazil, Canada, the Republic of Korea, Saudi Arabia, Singapore, and Taiwan.

Titanium sponge metal production in the market economy countries fell nearly 30% to 35,000 tons because of substantial production decreases in both Japan and the United States.

Argentina.—Indupa, a privately owned Argentine company, was reportedly negotiating to obtain process engineering and construction services from the U.S.S.R. for a 27,500-ton-per-year TiO_2 plant in Newquen Province. The proposed chloride-process plant reportedly could obtain chlorine from an Indupa vinyl chloride unit for processing imported ilmenite that would be used as feedstock.

Australia.—As in previous years, Australia was the largest producer of titanium minerals, with exports of ilmenite—in order of decreasing quantity, mainly to the United States, the United Kingdom, Japan, Spain, and France—and exports of rutile, in order of decreasing volume, mainly to the United States, the United Kingdom, Japan, and the Netherlands.

Associated Minerals Consolidated Ltd. (AMC), Mineral Sands Div. of Renison Goldfields Consolidated Ltd., was on schedule with construction of its new 124,000-ton-per-year synthetic rutile plant at Narngulu, near Geraldton in Western Australia. The new plant, estimated to cost about $40 million, was to be completed during the second quarter of 1987 and will bring AMC's total synthetic rutile production capacity to 190,000 tons per year.

Westralian Sands Ltd. reportedly was also on schedule with construction of its 110,000-ton-per-year synthetic rutile plant at Capel, Western Australia. The plant was to be completed by mid-1987 and will bring Australia's total synthetic rutile capacity to 300,000 tons per year.

TiO_2 Corp. was carrying out a feasibility study of the Cooljarloo dune sand deposit and remnant stockpiles at Jurien Bay about 160 miles north of Perth in Western Australia. Production was expected to start in late 1987, with initial production of about 50,000 tons per year of rutile and 225,000 tons per year of ilmenite.[5] Reserves were revised upward to about 13 million tons of heavy minerals.[6]

CRA Ltd. was investigating the potential of heavy mineral deposits in the Wimmera area, about 12 miles southeast of Horsham, Victoria. Drilling and sampling indicated the presence of rutile, leucoxene, and zircon.

SCM Chemicals Ltd. decided to convert its sulfate-process TiO_2 plant at Bunbury, Western Australia, to the more environmentally acceptable chloride process. Assistance of about \$5.4 million was to be received from the government of Western Australia to carry out the \$44 million conversion. The government has been responsible for disposal of the effluent from this plant, but under terms of the new agreement with SCM Chemicals, this obligation will cease by December 1989. The converted plant will have a design capacity of over 50,000 tons per year compared with the current 40,000 tons per year.[7]

Brazil.—Early in the year, the Government of Brazil authorized construction of a \$150 million, 440,000-ton-per-year anatase concentrate plant in the Tapira region of the State of Minas Gerais, with plant startup planned for 1988. The plant was to be operated by the Government-owned mining company Cia. Vale do Rio Doce (CVRD). This decision followed earlier planning that included proposed building of a 66,000-ton-per-year TiO_2 pigment plant nearby that would use part of the Tapira anatase concentrate as feed, the remainder to be available for export. Plans for DuPont to build the TiO_2 plant and purchase much of the concentrate to be exported were still under way. Rhône-Poulenc S.A. of France reportedly agreed to test the CVRD concentrate in Rhône-Poulenc's TiO_2 processing plant in São Paulo. An agreement between International Minerals & Chemical Corp. (IMC), Northbrook, IL, and the State of Goiás was still in effect, under which IMC was to invest in a \$200 million anatase concentrate plant in Catalao, Goiás. The plant was to have a capacity of 330,000 tons per year of concentrate, mainly for export. Plant startup was reportedly planned for 1989.[8]

Canada.—QIT-Fer et Titane Inc. has converted one of its electric smelting furnaces at its Sorel, Quebec, plant for smelting beach sand concentrates to make low-alkali, high-titanium slag suitable for chlorination. This furnace has been equipped with advanced control systems that will be proved out over the next 1 to 2 years in preparation for commercial smelting of ilmenite from beach sands. The slag preparation plant was modified to produce a dry, sized fraction of currently produced Sorelslag that can be used as a partial feed to fluid bed chlorinators. Slag production was planned for output of 990,000 tons in 1987, and additional plant modifications were scheduled to raise annual production capacity to over 1,100,000 tons by mid-1988.

NL Chem Canada Ltd., a subsidiary of NL Chemicals Inc., was scheduled to complete construction and start up its new 42,000-ton-per-year chloride-process TiO_2 plant at Varennes, Quebec, in mid-1987. NL Chem Canada will continue to operate a 40,000-ton-per-year sulfate-process TiO_2 plant at the same location.

China.—SCM Corp. planned to extend its TiO_2 operations into China. SCM, International Enertech (Houston, TX), and China's Sichuan Nonferrous Metals Industrial Corp. (SNMIC) were launching a venture to produce, near Zygong, Sichuan Province, 132,000 tons per year of synthetic rutile, pending successful results from pilot plant tests that had been started by SNMIC. Feed for the synthetic rutile plant would be byproduct ilmenite from iron mining near Dukou. About 55,000 tons per year of synthetic rutile would go to a Chinese TiO_2 pigment plant that would use SCM technology and would be China's first chloride-process TiO_2 plant, and 55,000 tons per year would go to SCM.[9]

India.—Indian Rare Earths Ltd. (IREL) reportedly began limited production of ilmenite and rutile at the Orissa Sands Complex and made trial runs at its 100,000-ton-per-year synthetic rutile plant at that location. Annual production capacity of the mine and mill was to include 240,000 tons of ilmenite and 11,000 tons of rutile.

Japan.—Nippon Kokan K.K. reportedly developed a new titanium-clad steel plate for sale to manufacturers of chemical tankers, pressure vessels, and other offshore structural equipment where high corrosion resistance is needed. The titanium-clad steel is economical because it can replace titanium plate and would be 75% less costly than pure titanium plate if made with 10% titanium and 50% less costly if made with 20% titanium. The titanium cladding is applied with a hot-rolling process, rather than the explosive-bonding process commonly used for bonding titanium to steel.

The Japanese titanium industry was expected to benefit from two new commercial aircraft projects to which the Government of Japan was to allocate special funding. One of these is a program to develop a 150-seat aircraft being undertaken by three large Japanese firms and the Boeing Co. The other aircraft project, code-named the V2500, is a high-thrust turbofan engine being designed by an international consortium, including a Japanese subconsortium, Japanese Aeroengines Corp., to power the new Airbus A320 series aircraft after 1988.[10]

The Japanese titanium sponge and mill products industry was suffering from declining exports and domestic demand, with total mill products shipments estimated at 4,960 tons in 1986, down 23% from 6,460 tons in 1985. Domestic demand from the power industry, the largest user of titanium mill products in Japan, showed the steepest drop, reportedly because the Japanese industry in general was using less power as a result of production cuts. Exports were hurt by the strong Japanese yen. Japanese sponge production in 1986 was estimated at 16,000 tons compared with 24,800 tons in 1985.

Korea, Republic of.—Lucky Advanced Materials Inc. (LAM) began construction of a facility at Samilmyon to produce titanium tetrachloride from imported rutile. The titanium tetrachloride was to be used initially to produce 30,000 tons per year of TiO_2 pigment. LAM also planned in the future to use part of the output of titanium tetrachloride for the production of titanium metal. Under a licensing agreement concluded in December 1985, LAM will use titanium tetrachloride production technology provided by Kerr-McGee of the United States.

Madagascar.—QIT of Montreal, Canada, announced that it had entered into a joint-venture partnership with the Government of Madagascar to develop beach sand deposits in Madagascar. The development program indicates that a mine to produce 330,000 tons of ilmenite concentrate per year could be in operation before the end of 1989. The ilmenite from the mine would be exported to QIT's Canadian operations, where it would be converted into 220,000 tons per year of 90% TiO_2 slag, and a high-purity iron byproduct. The 90% TiO_2 slag would be suitable for use in either the chloride process or the sulfate process for the manufacture of TiO_2 pigment.[11]

Mozambique.—Edlow Resources Limited, Hamilton, Bermuda, was awarded a contract to explore and develop titanium deposits in the coastal Zambesia area, near the Port of Pebane. Initial reconnaissance for rutile and ilmenite was to begin in January 1987. The titanium-bearing sands are found along a 125-mile stretch of coastline centered on Pebane.

Norway.—Construction of the K/S Ilmenittsmelteverket A/S (KSI) plant to smelt ilmenite in Tyssedal was expected to be completed by yearend. Planned annual production capacity is about 220,000 tons of 75% TiO_2 slag. The KSI plant was to use as feed about 385,000 tons per year of ilmenite from the Titania A/S Tellnes Mine near Hauge i Dalane in southwestern Norway.

Saudi Arabia.—Kerr-McGee and Sha'ir Co. for Trading, Industry, and Contracting (Shairco) reportedly formed a new company called Crystal Pigment Co. The new firm was to build a 50,000-ton-per-year TiO_2 pigment plant at Yanbu by mid-1989 at an estimated cost of $120 million. The plant would use imported feedstock and export the pigment produced. Kerr-McGee and Shairco each owned 25% of the new company.

Sierra Leone.—Sierra Rutile Ltd., owned by Nord Resources Corp., Dayton, OH, made major capital improvements to its dredge and wet separation plant in 1986, increasing production 20% over the 1975 level. An additional 30% expansion to about 140,000 tons per year of rutile concentrate was planned for 1987, and was to include construction of a supplemental bucket-wheel dredge, to be operating in the second quarter of 1987.[12]

Singapore.—Ishihara Sangyo Kaisha Ltd. of Osaka announced plans to build a 72,000-ton-per-year TiO_2 chloride-process plant in Jurong at a cost of about $176 million. Construction was to be in two phases, with the first 36,000 tons of annual capacity due to be completed in mid-1989 and the second phase to be built when justified by economic conditions. The Singapore site was chosen because of its location in the fast-growing Southeast Asian market and to offset the effects of the rising value of the Japanese yen. The company has access to a long-term supply of TiO_2 concentrates through its part ownership of Westralian Sands.

South Africa, Republic of.—In the third quarter of 1986, Richards Bay Minerals put into operation a new dredge and floating concentrator. A third 60-megawatt smelting furnace was operational by yearend, bringing smelting capacity to at least 660,000 tons per year of 85% TiO_2 slag. The slag preparation facility was modified to increase the proportion of slag sized for the chloride pigment process from 45% to at least 65%.

U.S.S.R.—Production of titanium sponge metal was estimated to be 48,000 tons. Annual production capacity was estimated to be about 54,000 tons. There were no reported imports of ilmenite from Australia, following 3 years in which such imports were 115,000 tons, 114,000 tons, and 69,000 tons.

Table 16.—Titanium: World production of concentrates (ilmenite, leucoxene, rutile, and titaniferous slag), by country[1]

(Short tons)

Concentrate type and country	1982	1983	1984	1985[p]	1986[e]
Ilmenite and leucoxene:[2]					
Australia:					
Ilmenite	1,266,788	987,900	1,645,937	1,564,031	[3]1,423,467
Leucoxene	21,758	14,725	35,395	15,222	[3]17,930
Brazil	12,480	33,568	45,134	[e]50,000	50,000
China[e]	150,000	154,000	154,000	154,000	160,000
Finland	184,968	180,669	[e]184,000	[e]150,000	--
India[4]	168,585	148,234	154,323	157,630	154,000
Malaysia[5]	111,556	245,509	259,025	272,512	[3]438,384
Norway	608,215	612,826	718,523	811,080	[3]884,053
Portugal	[r]520	298	181	[e]160	[3]256
Sri Lanka	75,268	90,145	112,489	126,605	110,000
Thailand	20	226	591	1,726	15,748
U.S.S.R.[e]	475,000	480,000	485,000	490,000	496,000
United States[6]	263,391	W	W	W	W
Total	[r]3,338,549	2,948,100	3,794,598	3,792,966	3,749,838
Rutile:					
Australia	243,277	174,404	187,860	233,265	[3]242,559
Brazil	258	510	454	[e]3,100	1,100
India[4]	6,374	[e]6,100	[e]6,600	7,496	8,000
Sierra Leone[7]	52,590	79,146	100,641	88,858	[3]107,034
South Africa, Republic of[e]	52,000	62,000	62,000	61,000	61,000
Sri Lanka	7,950	8,921	7,129	9,434	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	373,449	342,081	375,684	414,153	438,693
Titaniferous slag:					
Canada[8]	737,445	700,000	800,000	[e]930,000	937,000
South Africa, Republic of[e 9]	420,000	460,000	460,000	480,000	480,000
Total	1,157,445	1,160,000	1,260,000	1,410,000	1,417,000

[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: 1982—3,136,054; 1983—2,610,028; 1984—2,943,538; 1985—3,000,000 (estimated); and 1986—3,000,000 (estimated). This material reportedly contains 20% TiO_2. Table includes data available through June 23, 1987.
[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]Reported figure.
[4]Data are for fiscal year beginning Apr. 1 of year stated.
[5]Exports.
[6]Includes a mixed product containing ilmenite, leucoxene, and rutile.
[7]Contains 96% TiO_2.
[8]Contains 80% TiO_2.
[9]Contains 85% TiO_2.

TECHNOLOGY

The Bureau of Mines investigated the conversion, at both laboratory and pilot plant scale, of a 46.6% TiO_2 ilmenite concentrate to chlorination-grade feedstock that could serve as a substitute for imported rutile used to produce titanium tetrachloride ($TiCl_4$). The concentrate was derived from the Tahawus, NY, ilmenite-magnetite lode deposit, and was carbothermically reduced in an electric furnace with soda ash flux to separate iron and yield a high-titanium slag. Calcium, magnesium, and manganese, which are harmful in the slag-chlorination process, were removed from the slag by grinding, pelletizing, sulfation with sulfur dioxide and air at 700° to 900° C, and leaching with water or dilute hydrochloric acid. Pilot-plant-leached slags averaged 85.5% TiO_2 with combined contents of the above impurities of 1.86%, and were successfully chlorinated in a laboratory fluid bed reactor at 950° C to extract titanium as $TiCl_4$.[13]

Relative enthalpies of high-purity disodium hexatitanate ($Na_2Ti_6O_{13}$) were measured at the Bureau of Mines to provide new thermodynamic data needed to advance the technology of materials. Measurements from 298.15 to 1,478 K were made by drop calorimetry with a copper block. Tabulated values are listed for the standard relative enthalpy, heat capacity, entropy, and Gibbs energy function in that temperature range.[14]

The solubility of anhydrous aluminum chloride in solutions of $TiCl_4$ and vanadium tetrachloride was determined as part of a research project by the Bureau of Mines to make a homogeneous alloy sponge of titanium, vanadium, and aluminum. Solubility curves were determined using an autoclave at 75°, 100°, 125°, and 150° C.[15]

An outside paper by Bureau research staff described processing and problems involved in the chlorination of ilmenite and the recovery of iron from the large quantities of ferric chloride obtained as a byproduct in the production of $TiCl_4$. Pelletizing of the ferric chloride reduced its tendency to pick up moisture, improved handling behavior, and allowed the incorporation of reaction promoters and fuels within the material. Bench-scale studies in fluidized-bed oxidation reactors are described and discussed.[16]

As part of an investigation of the possibility of using domestic clay to produce aluminum via an energy-saving chloride process, the Bureau determined vapor-liquid equilibria for the system aluminum chloride-$TiCl_4$. Results indicated two azeotropes of approximately 20% and 95% aluminum chloride, suggesting difficulties in distillation separation of these two products of clay chlorination.[17]

The Bureau completed an analysis of the availability of titanium minerals in the market economy nations, which indicated that supplies of rutile will decline over the next decade, forcing producers of titanium metal and pigment to depend on more abundant, but lower grade sources. The existence of large ilmenite supplies and the availability of economical processing methods suggest that synthetic rutile and high-titanium slags, made from ilmenite, will be increasingly important forms of high-grade titanium concentrates for both metal and pigment manufacture. The development of anatase deposits, and the mining of less economical rutile deposits may also help meet the demand for high-grade titanium concentrates.[18]

The Bureau also investigated a procedure to produce fine-sized titanium nitride, carbide, and carbonitride powders. Titanium nitride was produced by reducing $TiCl_4$ with magnesium or sodium vapor in a nitrogen atmosphere at temperatures between 750° and 1,050° C. Titanium carbide and titanium carbonitride can be formed by adding methane to the nitrogen atmosphere. Uniformly fine-sized powders, suitable for industrial applications, were produced.[19]

The Titanium Development Association hosted the 1986 International Conference on Titanium Products and Applications, held in San Francisco, CA, October 19-22, 1986. This conference was the first of its kind in North America to explore the major facets of titanium applications technology. Papers were presented in nine categories: aerospace, environmental behavior, forming, industrial applications, joining, medical applications, powder metallurgy, raw material (melting, casting, and recycling), and superplastic forming.[20] The conference was cosponsored by technical and trade associations from France, the Federal Republic of Germany, Japan, the U.S.S.R., the United Kingdom, and the United States.

A comprehensive review of nonaerospace applications of titanium was presented at the Institute of Metals Conference on Designing with Titanium, held at Bristol, United Kingdom, July 7-9, 1986. The review indicated that prospects were favorable for continued growth of the industrial market for titanium mill products.[21]

Investigation by the Duriron Co. of the use of the induction-slag process for production of small- and medium-sized titanium and zirconium castings was described. A scaled-up modification of the original Bureau of Mines process was developed that enhanced the quality of cast titanium alloys. A key feature of this process modification was the elimination of calcium fluoride that had been a source of nonmetallic inclusions, and a possible cause of gas porosity in the solidifying metal. Induction skull melting is very flexible with regard to the variety of shapes and sizes of scrap material that may be melted, and provides a high level of superheat throughout the melt, facilitating the filling of molds with deep cavities and thin sections.[22]

Electron beam cold hearth refining (EBCHR) was described as an effective process to provide highly refined titanium and superalloys with cleanliness levels superior to those produced by more conventional melting processes, such as vacuum arc melting, vacuum induction melting, and electroslag refining. Major advantages were EBCHR's ability to remove the high-density inclusions that may be present in recycled titanium chips, and its recently discovered potential for removing low-density inclusions, composed primarily of titanium oxynitrides.[23]

The achievement of wrought-equivalent fatigue properties in reduced chloride powder metallurgy (P/M) Ti-6Al-4V alloys was reported. The ability to cold consolidate blended elemental titanium alloy powders into near-net shapes offers a considerable advantage over the alternate titanium P/M method utilizing prealloyed powders.[24]

A review of current developments in titanium alloy technology was published. Although conventional wrought products supply the bulk of the titanium market, there is still great interest in near-net-shape technology. Research efforts on castings were being directed toward hot isostatic pressing (HIP) and heat treatment to improve fatigue strength and other properties to match those of wrought alloys. Suppliers of powder metallurgy parts were also using HIP and heat treatments to improve properties. There is also a strong interest in developing very high-strength, high-hardenability alloys for forgings with strengths up to 180,000 pounds per square inch.[25]

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

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Tungsten

By Gerald R. Smith[1]

Reported consumption of tungsten concentrate decreased by 30% as the demand for carbides and mill products decreased significantly. Mine production and shipments continued to decline in relation to this lower demand as well as to the lower market prices for tungsten products. The average price per metric ton unit of WO_3 in concentrate shipped from domestic mines was $56.04 in 1986, down $17.73 from that of 1985.

All domestic production came from three mining operations in California and Colorado. Each of the mines and associated mills was operated on a below-capacity, intermittent basis during the year. By yearend there were no domestic tungsten mines in operation.

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 40 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)

	1982	1983	1984	1985	1986
United States:					
Concentrate:					
Mine production	1,521	980	1,203	996	780
Mine shipments	1,575	1,016	1,173	983	817
Value thousands	$22,062	$10,528	$13,409	$9,143	$5,774
Consumption	4,506	5,181	8,577	6,838	4,804
Shipments from Government stocks	344	259	1,368	902	301
Exports	305	1	129	124	34
Imports for consumption	3,528	2,861	5,807	4,746	2,522
Stocks, Dec. 31:					
Producer	54	47	46	60	21
Consumer	1,765	1,085	959	1,077	502
Ammonium paratungstate:					
Production	4,914	5,021	7,339	6,527	5,604
Consumption	5,873	5,655	8,808	7,941	6,475
Stocks, Dec. 31: Producer and consumer	748	970	1,191	1,056	468
Primary products:					
Production	6,441	6,020	9,799	8,219	6,408
Consumption	6,349	6,523	10,216	8,096	7,214
Stocks, Dec. 31:					
Producer	1,477	1,433	1,850	1,968	1,484
Consumer	933	1,446	1,585	1,206	860
World: Concentrate:					
Production	r47,027	r40,925	46,172	p46,535	e42,474
Consumption	r42,158	r42,727	50,181	p48,327	e45,086

eEstimated. pPreliminary. rRevised.

Legislation and Government Programs.—The sale of tungsten ores and concentrates, acquired under the Defense Production Act of 1950 for the National Defense Stockpile (NDS), was resumed by the General Services Administration (GSA) on June 5, 1986. All sales of tungsten in the stockpile, excluding those used as payment material in support of the ferroalloy upgrading program, had been discontinued since October 1, 1985, when the stockpile transaction fund reached its legal ceiling of $250 million. GSA also included a halt in the sale of the Defense Production Act material at that time, even though the revenue from the sale of this material was unrelated to the transaction fund and thus was not counted against the legal ceiling. Of the 46,017 kilograms of tungsten remaining in the Defense Production Act inventory, a total of 40,708 kilograms was sold to two bidders after a second offering was made by GSA on July 3, 1986. No additional sales of this inventory were made during 1986. In November 1986, however, GSA added 7,979 kilograms of tungsten for release in accordance with the Defense Production Act. This wolframite concentrate contained 0.36% bismuth but was considered to be of much higher quality than the 5,309 kilograms of tungsten still remaining from the original inventory.

In addition to the sale of the Defense Production Act material, GSA released 261,211 kilograms of tungsten in ores and concentrates during 1986 as part of the ferroalloy upgrading program. The Defense Authorization Bill, passed by the Congress in October 1986, authorized an additional 861,827 kilograms of tungsten for release in this program, leaving a total of 927,203 kilograms in the program at the end of 1986. Only the ferroalloy upgraders—Elkem Metals Co. or Macalloy Corp. or their agents—are eligible to receive this tungsten, which is being released either as wolframite or as scheelite. Its use is also limited to 75% for domestic and 25% for export.

The Environmental Protection Agency (EPA) entered into an agreement on June 26, 1986, with AMAX Inc. and an intervenor, GTE Products Corp., resolving a petition filed against EPA's proposed amendment to a regulation affecting primary tungsten processors. The regulation, subcategory 40 CFR Part 421 of regulation 49 FR 8742, originally promulgated by EPA on March 8, 1984, limits effluent discharges to U.S. waters and limits the introduction of pollutants into publicly owned treatment works by existing and new sources that conduct primary tungsten operations. As part of the June 26 agreement, the parties jointly requested the U.S. Court of Appeals for the Fourth Circuit to stay the effectiveness of those portions of 40 CFR Part 421 that EPA is proposing to amend, pending final action by EPA on the proposed amendments. The court granted this request on July 9.

Table 2.—U.S. Government tungsten stockpile material inventories and goals

(Metric tons of tungsten content)

Material	Goals	Inventory by program, Dec. 31, 1986		
		National stockpile	DPA[1] inventory	Total
Tungsten concentrate:				
Stockpile grade	25,152	24,623	88	24,711
Nonstockpile grade	--	11,609	13	11,622
Total	25,152	36,232	101	36,333
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

Mine production and shipments decreased 22% and 17%, respectively, compared with those of 1985. Three mines in California and Colorado were each operated during part of 1986. Two were closed indefinitely by midyear, and the other was closed permanently at yearend. Of the total 780 metric tons of contained tungsten concentrate produced domestically, 93% was recovered at two of the operating mines.

The Pine Creek Mine and ammonium paratungstate (APT) plant of Umetco Minerals Corp., a subsidiary of Union Carbide Corp., near Bishop, CA, were operated at a reduced capacity during the first 5 months of the year. On May 13, the company sold its holdings in these operations to a group of nine former employees, thus becoming U.S. Tungsten Corp., a division of Strategic Minerals Corp. The APT facility was either closed or operated at a reduced capacity for the remainder of the year, and the mine was not reopened.

The Climax Mine and mill of Climax Molybdenum Co., a division of AMAX, at Climax, CO, produced tungsten concentrate as a byproduct of its operation during the first 5 months of the year. After a summer shutdown, the company announced its decision to discontinue production of tungsten concentrate. Open pit mining was stopped at the facility, and underground mining of molybdenum was performed at reduced capacity.

Teledyne Tungsten, a subsidiary of Teledyne Inc., operated its Strawberry Mine and mill near North Fork, CA, for about 9 months of the year; the facility was permanently closed in December.

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
1982	198,652	1,575	$22,062	$111.06	$14.00
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

[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.

Table 4.—Major producers of tungsten concentrate and principal tungsten processors in the United States in 1986

Company	Location of mine, mill, or processing plant
Producers of tungsten concentrate:	
Climax Molybdenum Co., a division of AMAX Inc	Climax, CO.
Teledyne Tungsten	North Fork, CA.
U.S. Tungsten Corp., a division of Strategic Minerals Corp	Bishop, CA.
Processors of tungsten:	
AMAX Inc., AMAX Metals Group	Fort Madison, IA.
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 decreased 11% from that of 1985. The major end use, 61% of the total, continued to be cutting and wear-resistant materials, primarily as tungsten carbide powder. Other end uses were mill products, 23%; specialty steels, 6%; and miscellaneous, including superalloys, welding and hard-facing rods, chemical and ceramic uses, and other tungsten materials, 10%.

Consumption of tungsten products used directly to make end-use items was distributed as follows: tungsten carbide powder, 61%; tungsten metal powder, 25%; scheelite, 4%; tungsten scrap, 4%; ferrotungsten, 3%; and other, 3%.

During 1986, there was some increase in demand for tungsten used in cutting tools, particularly from automobile makers and appliance manufacturers. However, the decline in domestic oil drilling, a result of the drop in world crude prices, had a negative impact on tungsten demand. In addition, demand for tungsten used in drill bits suffered from the shutdowns and curtailments at domestic mines.

Table 5.—Production, disposition, and stocks of tungsten products in the United States in 1986

(Metric tons of tungsten content)

	Hydrogen-reduced metal powder	Tungsten carbide powder		Chemicals	Other[1]	Total
		Made from metal powder	Crushed and crystalline			
Gross production during year	6,124	2,906	486	2,018	58	11,592
Used to make other products listed here	3,197	4	71	1,911	--	5,183
Net production	2,927	2,902	415	106	58	6,408
Producer stocks, Dec. 31	734	443	264	43	--	1,484

[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 1986, by end use

(Metric tons of tungsten content)

End use	Ferrotungsten	Tungsten metal powder	Tungsten carbide powder	Scheelite (natural, synthetic)	Tungsten scrap[1]	Other tungsten materials[2]	Total
Steel:							
Stainless and heat-resisting	35	--	--	34	4	W	73
Alloy	24	--	--	W	--	W	24
Tool	102	--	--	201	W	W	303
Superalloys	W	W	W	W	176	W	176
Alloys (excludes steels and superalloys):							
Cutting and wear-resistant materials	--	94	4,337	--	W	W	4,431
Other alloys[3]	W	W	W	--	W	W	W
Mill products made from metal powder	--	1,669	W	--	--	W	1,669
Chemical and ceramic uses	--	--	W	--	--	28	28
Miscellaneous and unspecified	27	24	87	57	134	181	510
Total	188	1,787	4,424	292	314	209	7,214
Consumer stocks, Dec. 31, 1986	26	18	683	32	83	18	860

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

The average value of tungsten concentrate shipped from domestic mines and mills, as reported to the Bureau of Mines, decreased to \$56.04 per metric ton unit of WO_3, a 24% decrease compared with the 1985 value. Wolframite and scheelite concentrate prices decreased steadily throughout most of the year, according to the Metal Bulletin (London) quotations, reaching lows of \$30 and \$38, respectively, during the last quarter.

Since 1977, wolframite prices have decreased from approximately \$180 per metric ton unit to the excessively low 1986 levels. Much of this decline has been attributed to factors such as overexpansion in mining capacity, high levels of production in economically developing countries, and reduced demand for new tungsten products. The latter occurred because greater quantities of material were recycled, longer life of wear-resistant parts was achieved through use of coating technology, and the number of substitute materials being used increased. Since 1977, tungsten has been sold from the NDS. During this time, volatile movements in the tungsten market have occurred, and there have been significant adjustments in world trade patterns. Also during this period, expansion of downstream production by China has been a strong influence on world tungsten prices.

Domestic APT sales were quoted at \$84 to \$88 per metric ton unit at the end of the first quarter, during which time wolframite concentrate was quoted at \$47 to \$55 per metric ton unit. The strong interdependence of APT and concentrate prices decreased the APT selling price to about \$66 per metric ton unit during the final quarter, when concentrate prices reached their yearly low. The domestic transaction price in effect throughout the year for tungsten carbide powder was about \$9.35 per pound. The price of hydrogen-reduced tungsten powder (99.9% pure) ranged from \$9.53 to \$9.85 per pound.

Table 7.—Monthly price quotations of tungsten concentrate in 1986

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	Dollars per metric ton unit	Dollars per short ton unit
	Low	High	Average	Average	Low	High	Average	Average	Low	High	Average	Average		
January	62.00	70.00	66.00	59.87	54.00	62.22	58.11	52.72	48.00	56.00	52.00	57.32	65.62	59.52
February	62.00	70.00	66.00	59.87	55.00	63.00	59.00	53.52	48.00	56.00	52.00	57.32	64.29	58.32
March	59.50	67.13	63.31	57.43	52.38	59.38	55.88	50.69	46.00	54.25	50.12	55.25	64.98	58.95
April	55.13	63.13	59.13	53.64	48.50	55.75	52.13	47.29	43.75	51.50	47.62	52.49	61.04	55.37
May	52.13	61.00	56.57	51.32	47.00	56.00	51.50	46.72	43.00	50.00	46.50	51.26	59.09	53.61
June	51.25	59.88	55.57	50.41	47.00	56.00	51.50	46.72	42.25	50.00	46.12	50.84	56.41	51.17
July	47.78	56.67	52.23	47.38	45.00	54.00	49.50	44.91	39.75	46.25	43.00	47.40	53.87	48.87
August	43.13	53.25	48.19	43.72	39.00	48.88	43.94	39.86	33.80	38.80	36.30	40.01	54.61	49.54
September	38.55	52.44	45.50	41.28	33.00	43.44	38.22	34.67	30.25	35.00	32.62	35.96	50.97	46.24
October	43.11	55.00	49.06	44.51	31.11	41.89	36.50	31.11	31.80	37.60	34.70	38.25	47.68	43.25
November	45.38	54.38	49.88	45.25	30.38	42.38	36.38	33.00	29.00	35.50	32.25	35.55	46.38	42.08
December	46.00	55.00	50.50	45.81	30.71	45.00	37.86	34.35	29.00	36.00	32.50	35.83	41.80	37.92

[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 $55.16 for 1986. The average equivalent price per short ton unit of WO_3 was $50.04 for 1986.
[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 $47.54 for 1986. The average equivalent price per short ton unit of WO_3 was $43.13 for 1986.
[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 $42.14 for 1986. The average equivalent price per metric ton unit of WO_3 was $46.46 for 1986.
[4]Weighted average price per metric ton unit of WO_3 was $55.56 for 1986. The equivalent weighted average price per short ton unit of WO_3 was $50.40 for 1986.

FOREIGN TRADE

Exports of tungsten in concentrate and primary products decreased 44% compared with those of 1985. The decrease was observed throughout all types of exported tungsten materials, reflecting the general decline in production capacity utilization in the domestic tungsten industry. Imports for consumption also decreased significantly, by 33% over the same period, reflecting the overall decrease in domestic demand for tungsten materials. The decrease was most evident in the quantity of concentrates imported. Whereas imports of concentrates declined 47% in 1986 compared with those of 1985, APT imports declined only 14%. Net import reliance as a percent of apparent consumption of tungsten material was 70%, approximately the same as in 1985.

An Omnibus Trade Bill (H.R. 4800) that included an amendment to suspend for 3 years the current $0.17 per pound contained tungsten duty on imported ores and concentrates was passed by the House of Representatives in October but failed to progress from the Senate Finance Committee. The duty suspension would have applied to imports of tungsten ore and concentrate from developing countries with most-favored-nation status. The tungsten amendment was introduced because U.S. processors of concentrate increasingly depend upon supplies of concentrate from these countries and remain less competitive with foreign processors because of the present tariff. The original bill (H.R. 2360) to suspend the duty was also included in a miscellaneous tariff bill (H.R. 5686), but this legislation also failed to be passed. The Omnibus Trade Bill, again including the duty-suspension amendment, was reintroduced in the 100th Congress.

In response to a petition filed by the Refractory Metals Association (RMA), informal talks were conducted with the Government of China by the Office of the United States Trade Representative (USTR) in March 1986 in an attempt to decrease the exporting of inexpensive APT and tungstic acid to the United States. The RMA claimed that these imports were causing market disruption and material injury to the domestic tungsten industry. In December 1986, the RMA requested a decision from USTR on its original petition, citing that the informal talks had not successfully curbed the flow of these tungsten materials into the United States. The petition, filed under Section 406(d)(1) of the Trade Act of 1974, requested that formal consultations be carried out under a bilateral trade treaty with China, that the International Trade Commission conduct an investigation into the effects of such imported materials on the U.S. tungsten industry, and that emergency import quotas be imposed on those materials.

Table 8.—U.S. exports of tungsten ore and concentrate, by country

	1985		1986	
	Tungsten content (metric tons)	Value (thousands)	Tungsten content (metric tons)	Value (thousands)
Austria	1	$15	--	--
France	--	--	28	$187
Germany, Federal Republic of	10	85	6	53
India	--	--	([1])	2
Japan	40	290	--	--
Mexico	18	108	--	--
Netherlands	54	323	--	--
U.S.S.R.	1	9	--	--
United Kingdom	([1])	1	--	--
Total	124	831	34	242

[1]Less than 1/2 unit.

Source: Bureau of the Census.

Table 9.—U.S. exports of ammonium paratungstate, by country

Country	1985 Gross weight (metric tons)	1985 Tungsten content[1] (metric tons)	1985 Value (thousands)	1986 Gross weight (metric tons)	1986 Tungsten content[1] (metric tons)	1986 Value (thousands)
Belgium-Luxembourg	37	26	$411	(²)	(²)	$6
Canada	12	8	133	--	--	--
France	1	1	9	3	2	22
Germany, Federal Republic of	1	1	25	2	2	47
Mexico	5	4	51	4	2	31
Netherlands	22	15	251	--	--	--
Singapore	(²)	(²)	1	--	--	--
United Kingdom	24	17	278	1	1	21
Total	102	72	1,159	10	7	127

[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	1985 Tungsten content (metric tons)	1985 Value (thousands)	1986 Tungsten content (metric tons)	1986 Value (thousands)
Argentina	(¹)	$11	(¹)	$1
Australia	3	87	1	37
Austria	32	787	18	473
Belgium-Luxembourg	25	511	22	714
Brazil	14	451	15	584
Canada	143	3,437	54	1,598
Denmark	8	297	11	221
Finland	10	174	5	61
Germany, Federal Republic of	71	1,629	45	1,444
India	5	117	4	119
Ireland	5	337	--	--
Israel	135	2,246	(¹)	10
Italy	40	1,524	10	400
Japan	18	346	10	213
Mexico	17	627	7	158
Netherlands	15	640	19	933
Peru	1	15	(¹)	10
Singapore	1	23	1	47
South Africa, Republic of	19	428	6	256
Sweden	3	38	2	19
Switzerland	10	189	8	220
United Kingdom	63	1,299	72	908
Venezuela	1	17	3	86
Other	r22	504	36	756
Total	661	15,734	349	9,268

rRevised.
[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	1985 Gross weight (metric tons)	1985 Tungsten content[1] (metric tons)	1985 Value (thousands)	1986 Gross weight (metric tons)	1986 Tungsten content[1] (metric tons)	1986 Value (thousands)
Australia	--	--	--	3	2	$106
Austria	23	19	$525	21	17	431
Belgium-Luxembourg	6	5	135	4	3	95
Brazil	5	4	129	10	8	254
Canada	17	14	486	38	31	1,222
Finland	6	5	112	23	18	358
Germany, Federal Republic of	121	97	3,071	110	88	2,665
Ireland	1	1	27	11	9	311
Israel	1,172	937	21,567	256	205	4,430
Italy	4	3	260	39	31	825
Japan	12	10	496	3	2	138
Mexico	7	5	179	6	4	122
Netherlands	338	270	4,443	467	374	5,142
Singapore	6	4	101	1	1	19
Switzerland	21	17	222	76	61	1430
United Kingdom	15	12	385	25	20	514
Other	57	46	1,193	96	77	1,717
Total	1,811	1,449	33,331	1,189	951	19,779

[1]Tungsten content estimated by multiplying gross weight by 0.80.

Source: Bureau of the Census.

Table 12.—U.S. exports of miscellaneous tungsten-bearing materials

Product and country	1985 Tungsten content (metric tons)	1985 Value (thousands)	1986 Tungsten content (metric tons)	1986 Value (thousands)
Tungsten and tungsten alloy wire:				
Argentina	([1])	$209	1	$353
Brazil	5	879	6	924
Canada	22	3,561	13	2,871
France	1	238	2	246
Germany, Federal Republic of	6	1,601	9	2,436
Hong Kong	1	209	2	179
India	3	355	9	883
Italy	2	339	3	381
Japan	4	916	3	912
Korea, Republic of	3	339	5	649
Mexico	6	1,248	3	350
Poland	1	118	([1])	31
Taiwan	2	181	4	445
United Kingdom	3	689	4	792
Other	3	1,106	6	2,077
Total	62	11,988	70	13,529
Unwrought tungsten and alloy in crude form, waste, and scrap:				
Australia	--	--	([1])	10
Austria	61	487	57	308
Belgium-Luxembourg	56	451	15	88
Canada	33	550	18	329
Finland	([1])	4	([1])	2
Germany, Federal Republic of	287	2,099	404	1,478
Israel	1	20	--	--
Italy	2	44	--	--
Japan	13	16	5	80
Mexico	([1])	18	1	29
Netherlands	37	303	3	19
Saudi Arabia	1	21	--	--
South Africa, Republic of	--	--	1	15
Sweden	3	83	1	7
United Kingdom	19	222	36	276
Other	1	12	1	13
Total	514	4,330	542	2,654

See footnotes at end of table.

Table 12.—U.S. exports of miscellaneous tungsten-bearing materials —Continued

Product and country	1985 Tungsten content (metric tons)	1985 Value (thousands)	1986 Tungsten content (metric tons)	1986 Value (thousands)
Other tungsten metal:				
Australia	1	$183	2	$138
Austria	([1])	9	8	612
Canada	29	2,008	27	2,945
France	2	668	4	686
Germany, Federal Republic of	15	1,275	26	1,162
Italy	([1])	89	2	89
Japan	9	2,584	19	2,779
Mexico	4	627	3	256
Netherlands	9	177	1	220
Singapore	([1])	6	([1])	28
South Africa, Republic of	8	41	([1])	7
Sweden	([1])	4	1	34
Switzerland	1	207	4	241
Taiwan	1	103	5	291
United Kingdom	9	1,273	17	1,299
Venezuela	([1])	3	1	32
Other	1	536	10	604
Total	89	9,793	130	11,423
Other tungsten compounds:				
Austria	([1])	21	1	13
Belgium-Luxembourg	3	68	([1])	2
Brazil	4	185	4	107
Canada	7	280	4	444
China	4	52	([1])	1
France	21	148	1	36
Germany, Federal Republic of	2	126	5	222
Hong Kong	1	42	1	33
Ireland	2	87	2	83
Israel	1	52	([1])	28
Italy	2	107	1	42
Japan	5	179	6	263
Korea, Republic of	54	117	([1])	373
Mexico	84	605	25	237
Netherlands	33	548	1	42
Singapore	8	299	2	51
Sweden	--	--	1	29
United Kingdom	1	172	2	87
Venezuela	--	--	([1])	14
Other	3	110	5	127
Total	235	3,198	61	2,234

[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	1985		1986	
	Tungsten content (metric tons)	Value (thousands)	Tungsten content (metric tons)	Value (thousands)
Australia	414	$3,107	192	$946
Bolivia	627	5,270	609	3,231
Brazil	69	503	8	44
Burma	55	643	85	470
Canada	1,371	10,364	61	425
Chile	--	--	104	472
China	558	3,391	302	1,840
France	4	36	--	--
Germany, Federal Republic of	24	213	(1)	4
Japan	--	--	44	279
Malaysia	12	167	--	--
Mexico	183	1,325	173	879
Peru	282	2,093	436	2,029
Portugal	555	4,525	202	1,520
Rwanda	9	76	--	--
Singapore	87	797	12	67
Spain	11	124	--	--
Thailand	472	3,948	264	1,415
Turkey	--	--	30	219
Zaire	13	124	--	--
Total	4,746	36,706	2,522	13,840

[1]Less than 1/2 unit.

Source: Bureau of the Census.

Table 14.—U.S. imports for consumption of ammonium tungstate, by country

Country	1985		1986	
	Tungsten content (metric tons)	Value (thousands)	Tungsten content (metric tons)	Value (thousands)
China	1,126	$13,229	971	$8,894
Germany, Federal Republic of	33	449	131	1,618
Hong Kong	63	1,240	5	44
Japan	--	--	(1)	2
Korea, Republic of	116	1,391	48	491
Switzerland	--	--	1	9
Taiwan	12	132	--	--
United Kingdom	1	19	--	--
Total	1,351	16,460	1,156	11,058

[1]Less than 1/2 unit.

Source: Bureau of the Census.

Table 15.—U.S. imports for consumption of ferrotungsten, by country

Country	1985		1986	
	Tungsten content (metric tons)	Value (thousands)	Tungsten content (metric tons)	Value (thousands)
Austria	27	$263	85	$770
Brazil	--	--	4	22
China	22	219	75	443
Germany, Federal Republic of	1	12	(1)	2
Netherlands	--	--	4	21
Portugal	41	435	14	141
Sweden	2	22	--	--
United Kingdom	--	--	3	19
Total	93	951	185	1,418

[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	1985 Tungsten content (metric tons)	1985 Value (thousands)	1986 Tungsten content (metric tons)	1986 Value (thousands)
Other metal-bearing materials in chief value of tungsten:				
Austria	--	--	13	$104
Brazil	4	$24	8	49
China	32	220	43	226
South Africa, Republic of	--	--	7	39
Total	36	244	71	418
Waste and scrap containing not over 50% tungsten:				
Canada	1	5	1	15
France	(1)	8	--	--
Other	1	7	35	205
Total	2	20	36	220
Waste and scrap containing over 50% tungsten:				
Australia	(1)	5	--	--
Belgium-Luxembourg	2	24	--	--
Canada	23	253	30	864
China	21	231	15	152
France	5	44	5	34
Germany, Federal Republic of	27	378	15	186
Hong Kong	--	--	1	9
Israel	331	3,550	69	610
Italy	--	--	1	15
Japan	15	237	16	251
Mexico	10	106	5	46
Netherlands	125	617	228	1,416
Singapore	19	394	28	752
South Africa, Republic of	15	166	8	62
Sweden	12	142	--	--
Switzerland	6	82	9	85
United Kingdom	20	242	5	125
Total	631	6,471	435	4,607
Unwrought tungsten, except alloys, in lumps, grains, and powders:				
Belgium-Luxembourg	1	42	3	93
China	5	45	--	--
Germany, Federal Republic of	17	461	29	609
Japan	3	122	2	109
Korea, Republic of	9	174	17	256
United Kingdom	5	37	--	--
Other	2	44	3	37
Total	42	925	54	1,104
Unwrought tungsten, ingots, and shot	2	45	1	46
Unwrought tungsten, other[2]	1	45	(1)	15
Unwrought tungsten, alloys:				
Austria	(1)	17	(1)	31
Canada	2	149	3	283
China	7	184	--	--
Germany, Federal Republic of	17	365	7	158
Other	(1)	12	4	186
Total	26	727	14	658
Wrought tungsten:[2]				
Austria	9	987	1	43
Belgium-Luxembourg	6	501	10	845
France	(1)	110	--	--
Israel	11	390	--	--
Japan	25	2,853	32	3,337
United Kingdom	2	171	3	107
Other	3	222	2	227
Total	56	5,234	48	4,559
Tungstic acid:				
China	158	1,148	156	1,167
Other	(1)	1	--	--
Total	158	1,149	156	1,167

See footnotes at end of table.

Table 16.—U.S. imports for consumption of miscellaneous tungsten-bearing materials —Continued

Product and country	1985 Tungsten content (metric tons)	1985 Value (thousands)	1986 Tungsten content (metric tons)	1986 Value (thousands)
Calcium tungstate:				
Germany, Federal Republic of	5	$155	9	$328
Japan	(1)	27	1	29
Total	5	182	10	357
Potassium tungstate	2	4	--	--
Sodium tungstate:				
China	131	1,181	129	734
Germany, Federal Republic of	2	24	1	17
Japan	17	26	--	--
Total	150	1,231	130	751
Tungsten carbide:				
Australia	(1)	7	--	--
Austria	4	115	2	53
Belgium-Luxembourg	37	1,075	34	1,207
Canada	1	29	--	--
China	50	1,020	35	657
Germany, Federal Republic of	257	5,726	238	4,710
Japan	(1)	6	(1)	33
Korea, Republic of	39	707	41	734
United Kingdom	31	495	23	232
Other	3	75	2	63
Total	422	9,255	375	7,689
Other tungsten compounds:				
Canada	(1)	13	8	209
China	20	256	(1)	1
Other	(1)	33	11	125
Total	20	302	19	335
Mixtures, organic compounds, chief value in tungsten: Other	7	227	10	226

[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, 1986: Most favored nation (MFN)	Rate of duty effective Jan. 1, 1986: 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	6.2% ad valorem	35% ad valorem.
629.25	Waste and scrap containing by weight not over 50% tungsten.	5.2% 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.	11.3% ad valorem	58% ad valorem.
629.29	Unwrought tungsten, ingots, and shot	6.8% ad valorem	50% ad valorem.
629.30	Unwrought tungsten, other	7.6% ad valorem	60% ad valorem.
629.32	Unwrought tungsten, alloys, containing by weight not over 50% tungsten.	5.0% ad valorem	35.5% ad valorem.
629.33	Unwrought tungsten, alloys, containing by weight over 50% tungsten.	7.6% ad valorem	60% ad valorem.
629.35	Wrought tungsten	7.3% ad valorem	Do.
416.40	Tungstic acid	11.1% ad valorem	55% ad valorem.
417.40	Ammonium tungstate	10.4% ad valorem	49.5% ad valorem.
418.30	Calcium tungstate	10.2% ad valorem	43.5% ad valorem.
420.32	Potassium tungstate	11.9% ad valorem	50.5% ad valorem.
421.56	Sodium tungstate	10.3% ad valorem	46.5% ad valorem.
422.40	Tungsten carbide	11.0% ad valorem	55.5% ad valorem.
422.42	Other tungsten compounds	10.2% 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 18th session in Geneva, Switzerland, in November 1986. Discussions focused on the current tungsten market situation and future outlook. Earlier forecasts of foreign consumption had to be revised downward in some countries in light of developments in their national economies. The evolution of consumption in these countries varied greatly from sector to sector. Some consuming countries reported improved consumption in a number of sectors, including wire production, electronics, and hard metal. However, consumption declined or stagnated in such sectors as gas and oil, mining, and steel. The views on future consumption were generally not optimistic. Several representatives also drew attention to the difficulties faced by mining operations in their countries as a result of the depressed conditions in the tungsten market. Because of mounting losses, more mines were shut down or were facing the threat of closure in many producing countries.

Several points were considered to be of particular importance in influencing the future of the world tungsten industry. These included the question of whether China would establish a centralized market policy, what effect mine closures would have on the market once stocks were exhausted, what producers' reaction would be to any future price increases, and the possibility of alternatives to the existing pricing system.

The COT agreed that the UNCTAD secretariat should include several items for study in the documentation for the 19th session. These consisted of (1) characterization of the current crisis of the market and of the primary tungsten and intermediate products industry, (2) indepth analysis of the origins of the crisis, (3) changing patterns of production, trade, and marketing of intermediate products, (4) structural and technological change, particularly in the area of substitution and reduced use of tungsten, including related research and development and market promotion, and (5) the relationship of exchange-rate variations and local currency prices to supply and demand trends.

Australia.—Production of tungsten concentrates in 1986 decreased by 34% compared with that of 1985. About 54% of the total production came from the King Island scheelite mine of Peko-Wallsend Ltd. and 40% from the Mount Carbine wolframite mine of Queensland Wolfram Pty. Ltd. Almost all of the concentrate was exported to major buyers, such as the Federal Republic of Germany, the U.S.S.R., and the United States. Peko-Wallsend operated at about 50% of capacity for most of the year, and operations at the Mount Carbine Mine were reduced by over 40% in June. In November, the Mount Carbine opencut mine was placed on care-and-maintenance status for an indefinite period; underground development at the newly proposed 900,000-ton-per-year ore mine was also halted.

Bolivia.—Tungsten concentrate production decreased to 1,160 tons per year of contained tungsten in 1986, down significantly from the average production of nearly 2,300 tons per year in the first half of the decade. The decrease reflects the closure of 7 of the country's 10 mines as a result of extremely low prices. Corporación Minera de Bolivia, traditionally the country's largest producer, ceased production in December 1985, after its marketing arrangement with the Bolsa Negra and Kami mining cooperatives ended. These two cooperatives now market their own concentrate, accounting for nearly two-thirds of the total Bolivian production. International Mining Co., the country's only privately owned tungsten concentrate producer, is still producing about 450 tons per year from its Chojlla wolframite mine, although its two other operations, Enramada and Chambillaya, have been closed and are unlikely to be reopened unless there is a substantial increase in international prices.

Brazil.—Establishment of a national tungsten stockpile was considered to provide an assured outlet for domestic production at a time when market prices have been extremely low. Under the scheme, proposed by the Departmento Nacional de Produção Mineral, tungsten from the stockpile would be exported only when market prices merited such sales. Major producers of tungsten concentrate in 1986 were Termoligas Metalúrgicas S.A. and Mineração Tomas Salustino S.A.

Canada.—The Canada Tungsten Mining Corp. Ltd. (Cantung), a subsidiary of AMAX, was idled by a strike in May 1986 at its mine in Tungsten, Northwest Territories. This mine, the last operating in Canada, subsequently remained closed indefinitely, owing to the weak tungsten market. During the year, Cantung acquired all tungsten interests that were held by AMAX, including those in the Cantung Mine, the Mactung deposit north of this mine, and the Hemerdon Mine near Plymouth, Devon, United Kingdom. A long-term lease was arranged with AMAX to operate the APT plant in Fort Madison, IA. The Cantung Mine was placed under caretaker status in hope of a return to production in a reasonably short time should favorable market conditions return.

Finland.—Rautaruukki Oy, a mining and quarrying company, announced the discovery of a tungsten deposit. The discovery was made as a result of a tungsten prospecting venture concluded in 1986 in southern Häme (central Finland).

France.—Société Minière d'Anglade permanently closed its Salau Mine, the only operating French mine, in December 1986 because of low prices and declining reserves. Efforts by the company to obtain state or local government aid to avoid closure were ultimately unsuccessful.

Peru.—The Pasto Bueno Mine of Fermín Málaga Santolalla Hijos Negociacíon Minera S.A. was closed in January, owing to a labor strike that continued throughout the remainder of the year and prevented the resumption of operation. In February, the company declared a force majeure termination of all tungsten exports. High-purity hubnerite concentrate was shipped from this mine primarily to Japan, the United States, and Western Europe. With the shutdown in January, Málaga Santolalla as a whole was effectively shut down and needed financing as well as an agreement with its workers before it could reopen.

Sweden.—The Economic Defense Board of Sweden agreed to provide governmental support to AB Statsgruvor, its sole miner of tungsten, by giving the company a "strategic preparedness loan" to keep its Yxsjoeberg Mine open at least 4 more years. Part of the debt was to be written off each year the mine was kept open. In addition, Sandvik AB, Sweden's largest tungsten consumer, agreed to buy most of the ore produced.

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

(Metric tons of tungsten content)

Country	1982	1983	1984	1985[p]	1986[e]
Argentina	17	41	37	17	25
Australia	2,618	2,015	1,733	1,970	1,300
Austria	1,465	1,408	1,632	1,481	1,500
Bolivia	2,534	2,449	1,893	1,643	1,160
Brazil	1,524	1,026	1,037	1,090	800
Burma	844	930	1,096	945	[2]715
Canada	2,842	328	3,715	3,197	1,416
China[e]	12,500	12,500	13,500	15,000	15,000
Czechoslovakia[e]	50	50	50	50	50
France	727	832	796	735	[2]982
Guatemala	40	--	--	6	20
India	25	15	21	28	30
Japan	604	475	477	568	[2]511
Korea, North[e]	2,200	500	1,000	1,000	1,000
Korea, Republic of	2,420	2,480	2,702	2,579	2,500
Malaysia	43	31	25	[e]20	25
Mexico	194	186	274	282	294
Mongolia[e]	1,500	1,500	1,500	1,500	1,500
New Zealand	7	6	6	5	5
Peru	[r]682	[r]762	699	723	742
Portugal	[r]1,353	1,183	1,509	1,755	[2]1,637
Rwanda	324	231	260	167	[2]13
Spain	545	517	565	458	[2]447
Sweden	[r]349	365	385	402	[2]390
Thailand	855	562	741	586	361
Turkey[e]	150	[r]390	[r]153	[r]100	50
Uganda	4	4	[e]4	[e]4	4
U.S.S.R.[e]	9,000	9,100	9,100	9,200	9,200
United States	1,521	980	1,203	996	[2]780
Zaire	38	44	30	18	15
Zimbabwe	52	15	29	10	2
Total	[r]47,027	[r]40,925	46,172	46,535	42,474

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through June 23, 1987.
[2]Reported figure.

Table 19.—Tungsten: World concentrate consumption, by country[1]

(Metric tons of tungsten content)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Reported consumption:					
Australia[e 3]	145	[r]200	[r]175	[r]150	125
Austria	1,304	1,629	2,096	[e]2,000	2,000
Canada[e 3]	18	15	12	12	12
France	653	520	815	808	850
Japan	1,826	1,977	2,302	2,616	2,200
Korea, Republic of	1,742	1,555	2,070	2,048	1,950
Mexico	19	22	77	79	70
Portugal	183	174	159	133	100
Sweden	994	774	765	820	1,220
United Kingdom	660	560	610	600	600
United States	4,506	5,181	8,577	6,838	[4]4,804
Apparent consumption:[5]					
Argentina	[r]17	[r]23	37	17	25
Belgium-Luxembourg	[e]9	[e]10	142	341	200
Brazil	454	450	538	1,269	860
Bulgaria[e 3]	100	100	100	100	100
China[e 3]	6,000	6,500	7,000	7,500	7,500
Czechoslovakia[e]	1,300	1,300	1,300	1,300	1,300
German Democratic Republic[e]	270	250	270	270	270
Germany, Federal Republic of	1,541	2,030	3,934	2,073	1,600
Hungary[e]	400	400	500	500	500
India	454	[e]400	[e]400	[e]400	350
Italy	[e]40	27	78	[e]100	100
Korea, North[e 3]	1,600	1,000	1,000	1,000	1,000
Netherlands[e]	300	300	300	400	400
Poland	1,312	1,073	594	603	600
South Africa, Republic of[e]	250	250	250	250	250
Spain	161	107	80	[e]100	100
U.S.S.R.[e 3]	15,900	15,900	16,000	16,000	16,000
Total	[r]42,158	[r]42,727	50,181	48,327	45,086

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Source, unless otherwise specified, is the Quarterly Bulletin of the UNCTAD Committee on Tungsten: Tungsten Statistics. V. 21, No. 1, Jan. 1987.
[2]In addition to the countries listed, Denmark, Finland, Israel, Norway, Romania, Switzerland, and Yugoslavia may consume small amounts of 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

International Carbide of Canada will pilot-test the Bureau of Mines' patented process for producing tungsten carbide.[2] The process, developed by the Bureau's Reno (NV) Research Center, uses an energy-efficient molten salt, solvent-extraction process with methane sparging to prepare tungsten carbide directly from tungsten minerals. It promises to be simpler and less expensive than the conventional process for producing tungsten carbide using the intermediate APT method. The pilot plant being built in Vancouver, British Columbia, Canada, was expected to produce tungsten carbide material for evaluation early in 1987.

Westinghouse Electric Corp., Pittsburgh, PA, began fabricating test specimens of a new columbium-tungsten alloy filament composite that was expected to be used for components of a nuclear-powered reactor in space.[3] This new composite could prove to be the strongest possible material for an all-metallic system that would operate in a temperature range of 1,800° to 3,000° F. It was being developed for use in the ST-100, a program by the National Aeronautics and Space Administration, the U.S. Department of Energy, and the Defense Advanced Research Projects Agency to put a minimum of 100 kilowatts of electricity in space by 1991. The composite would not be suitable for reactors on Earth since its oxidation resistance is poor at elevated temperatures. The filament could also be used in a nickel alloy matrix for space shuttle engine components, which could increase the potential life of an engine from the present 3 or 4 missions to as many as 40 or 50.

The Coating Applications Group of Perkin-Elmer Corp.'s Metco Div. developed two new tungsten-containing plasma spray powder alloys.[4] These 700 and 700F alloys are fully alloyed nickel-base powders containing amorphous tungsten as well as other elements. They have been described as all-purpose materials suitable for protecting aerospace and automotive parts in corrosive, high-temperature environments. They may also be useful as materials for coating diesel engine piston rings and valves where corrosion and wear resistance is required.

In addition to the traditional uses of tungsten carbide for its wear-resistant properties, recent studies have shown that the material may find further application as a component of composite alloy coatings.[5] A plasma transferred arc process similar to the gas tungsten arc process has been used to apply nickel-base tungsten carbide composite alloy coatings to carbon steels, effectively enhancing the wear resistance of these normally corrosion-, heat-, or wear-resistant alloy coatings. Tests results suggest that a solid tool steel part could be replaced, for example, by a composite-alloy-coated 1020 carbon steel.

Plasma spraying techniques involving tungsten carbide powder have also been demonstrated for use in certain military applications.[6] A cobalt-bonded tungsten carbide coating containing 12% cobalt has been applied onto midspan stiffeners of turbofan blades, yielding a part that is stronger and more wear-resistant than the original. This particular plasma-spraying process produces a coating of low porosity (0.09%) and high hardness (1,200 Knoop under a 500-gram load).

New nickel-based superalloys containing 5.8 to 12.6 weight percent tungsten have been used successfully in automotive applications.[7] Turbine blade and casing material made of these superalloys has exhibited excellent stability when tested in newly designed turbocharged engines that operate at higher exhaust gas temperatures.

During 1986, materials continued to be developed with a goal of either extending the life of tungsten carbide components or replacing them in cutting and wear-resistant applications. Automotive engineers achieved significant tool-life improvements in machining certain aluminum components using polycrystalline diamond inserts in place of normal carbide tools.[8] The inserts consisted of cobalt-bonded tungsten-carbide-base material onto which fused synthetic diamond blanks were brazed. A similar combination of materials was used to prepare cutting elements for rotary drilling applications.[9] In this instance, the part was made by sintering (at 1,500° C) micrometer-sized synthetic diamond particles onto a cobalt-bonded tungsten carbide base at high pressure. Prior deficiencies in polycrystalline diamond inserts that had limited their widespread use in drilling were overcome. The inserts were unable to withstand high-impact loadings in hard-rock drilling and were unstable at temperatures above 700° C, reached either during the brazing step in the manufacturing process or when frictional heating occurred during the drilling procedure.

In at least one instance, the development of polycrystalline diamond technology has provided a potential new application for tungsten carbide. Using a layer of polycrystalline diamond on a sintered tungsten carbide substrate, an efficient chain saw for use in cutting stone was developed. Marble quarrying was one possible application.[10] This new saw, replacing the conventional steel helicoidal saw, has shown the capability to reduce tool costs by as much as 60%.

Whisker-reinforced ceramics have been given serious consideration as high-speed cutting tool materials.[11] With the advent of superalloys and the need for faster, more efficient cutting methods, the new alumina-silicon carbide whisker ceramics appear to be particularly applicable in the aerospace industry. The whisker-ceramic tools have been used to machine nickel-based superalloys at speeds up to 10 times faster than previously possible with traditional carbide inserts.

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[1]Physical scientist, Division of Ferrous Metals.

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Vanadium

By Henry E. Hilliard[1]

The world vanadium industry was mostly stagnant in 1986 with a virtual standstill in both production and demand. However, developments in the last quarter of 1986 may have consolidated the carefully balanced stability established since the recovery from the recession and low prices in 1983. In the United States, coproduction of uranium and vanadium has been temporarily discontinued. The loss from this source was partially offset by increased production from low-cost oil residues, spent catalysts, and slags. Finland's Rautaruukki Oy closed permanently both of its vanadiferous magnetite mines in 1985 and produced only from stocks in 1986. China, recently an important world supplier, was behind in shipments for most of the year owing to a shortage of raw materials. Highveld Steel and Vanadium Corp. Ltd. of the Republic of South Africa reported record-high profits and sales in the first half of 1986 despite a reduction in the production of steel due to antiapartheid sentiments. Highveld, which enjoyed a bumper year in 1985 owing to the rand-dollar exchange rate, experienced a slight decline in profits and sales during the second half of the year.

In May 1986, Strategic Minerals Corp. (STRATCOR) finalized the takeover of the tungsten and vanadium assets of Umetco Minerals Corp., a subsidiary of Union Carbide Corp. In January, Umetco sold its chromium assets in the Republic of South Africa to General Mining Union Corp. Ltd. Umetco retained only two uranium mines and concentrators in Uravan, CO, and Gas Hills, WY. Union Carbide's Zimbabwe Mining and Smelting Co., which operated three mines and a large smelter to produce high-carbon ferrochrome in Zimbabwe, was not a part of Umetco and was not for sale.

Table 1.—Salient vanadium statistics

(Short tons of contained vanadium unless otherwise specified)

	1982	1983	1984	1985	1986
United States:					
Production:					
Ore and concentrate:					
Recoverable vanadium[1]	4,098	2,171	1,617	W	W
Value thousands	$52,577	$30,675	$24,551	W	W
Vanadium oxides recovered from ore[2]	4,867	2,433	2,620	W	W
Vanadium oxides recovered from petroleum residue[3]	1,513	893	1,701	2,695	2,330
Consumption	3,496	3,277	4,761	4,883	4,308
Exports:					
Ferrovanadium (gross weight)	326	775	469	454	513
Ore and concentrate	57	59	12	3	86
Vanadium pentoxide, anhydride (gross weight)	1,582	2,648	3,712	1,527	1,544
Other compounds (gross weight)	361	95	305	322	343
Imports (general):					
Ferrovanadium (gross weight)	855	846	1,461	977	747
Ores, slags, residues	1,112	58	633	303	2,013
Vanadium pentoxide, anhydride	129	408	149	63	443
World: Production from ores, concentrates, slags	36,124	30,924	34,291	[p] [4]33,299	[e] [4]32,800

[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.

STRATCOR also purchased a 100% interest in Vametco Minerals Co., whose major asset is a vanadium mine and mill in Brits, Republic of South Africa. The Brits plant sold vanadium products primarily in Western Europe and Japan. STRATCOR also operated a tungsten mine and mill in Bishop, CA, a tungsten and vanadium processing plant in Niagara Falls, NY, and a sales office in Pittsburgh, PA.

Domestic Data Coverage.—Domestic production data for vanadium are developed by the Bureau of Mines from four voluntary surveys of U.S. mills and processing facilities. Of the 18 plants or mills canvassed in 1986, 16 responded with complete data, representing more than 90% of total production. Supplemental information was provided by two power-generating stations. Data on uranium-vanadium mining operations are obtained from an independent survey conducted by the U.S. Department of Energy. When efforts to obtain a response to a Bureau survey fails, it becomes necessary to use estimation techniques to account for the missing data. Production for the two nonrespondents was estimated using reported prior year production levels adjusted by trends in employment and other guidelines.

Legislation and Government Programs.—The National Defense Stockpile (NDS) goal of 1,000 short tons of vanadium contained in vanadium pentoxide (V_2O_5) remained in effect throughout the year. This goal was established by the General Services Administration (GSA) on May 1, 1980. However, the program undertaken by GSA to upgrade and increase the stocks of vanadium materials held in the NDS continued to be slowed by growing budgetary restrictions. The inventory consisted entirely of V_2O_5 that represents about 721 short tons of contained vanadium. About 75% of the vanadium inventory was acquired between 1947 and 1955; the balance was acquired in 1984 and 1985.

An Interagency Working Group was established in 1982 to undertake quality assessment studies mandated by the National Materials and Minerals Policy, Research and Development Act of 1980. The group was advised by a panel of industry experts assembled by the American Society for Metals (ASM). The assessment was based on comparison of the composition and form of the stockpiled vanadium to that currently used by industry to produce the materials required for critical applications. Emphasis was on the technical requirements of these applications, the degree of obsolescence of the stockpiled vanadium, and recommended actions to be taken to assure timely availability and reliability during a national emergency. The panel issued its final report in June 1986. The panel concluded that the quality of the original V_2O_5 acquired in the 1947-55 period was not suitable for producing vanadium-aluminum master alloys for use in aircraft titanium alloys containing vanadium. Likewise, the panel determined that the V_2O_5 was not usable in catalytic applications. The lack of controls on residuals and undesirable elements, the low V_2O_5 content, the absence of data on chemical analysis, and potential problems related to radioactivity are factors that contributed to the inability of the NDS material to meet requirements for titanium alloys and catalysts. The V_2O_5 purchased in 1984 was determined not to be usable in titanium alloys or in catalyst applications because the molybdenum content is higher than allowable for these applications. The panel determined that all of the V_2O_5 in the NDS, including the 1947-55 material and the more recent acquisitions, was suitable for the production of ferrovanadium. Exceptions would be those lots having levels of radioactivity that exceed permissible limits for transportation and industrial processability. Among the panel's recommendations were to (1) procure grade 1 V_2O_5 as the first priority of an acquisition program for vanadium; (2) consider converting a portion of the stockpiled V_2O_5 to ferrovanadium for use by the steel industry; and (3) evaluate the potential constraints in the availability of aluminum powder in an emergency to determine the feasibility of stockpiling vanadium-aluminum master alloys and ferrovanadium.

A significant fraction of the vanadium produced in the United States since 1950 has been a coproduct of uranium milled in the Colorado Plateau. For the second year in a row, the Secretary of Energy determined that the United States does not have a viable uranium mining and milling industry. The 1986 finding covers the 1985 calendar year. The industry lost $349 million in 1985 and $307 million in 1984. Some analysts have warned that if the uranium industry continues on its present course, the United States could become totally dependent on foreign sources for its uranium and vanadium supply, a possibility with unfavorable consequences not only for the goal of energy independence, but also for national security. In conjunction with its finding that the domestic uranium industry was not viable, the U.S. Department of Energy proposed new enrichment criteria designed to spur domestic uranium oxide (U_3O_8) sales. At the same time, the Department of Energy opposed suggestions that restrictions be placed on the enrichment of foreign source uranium for use in domestic reactors. The Uranium Producers of America stated that the new enrichment criteria violate the explicit legal requirements of the Atomic Energy Act of 1963. Section 161(v) of the act requires the Department of Energy to restrict enrichment of foreign source uranium to the extent necessary to preserve the viability of the domestic uranium industry. Litigation, initiated by several uranium producers in 1984, resulted in a ruling by a Federal judge in Denver, CO, that ordered the Department of Energy to restrict enrichment of foreign uranium for domestic use. The Department of Energy appealed the ruling, and a three-judge panel will decide whether to uphold the lower court's decision. Most producers and consumers felt that the future of the entire industry could turn on this decision by the Tenth Circuit Court of Appeals in Denver, CO.

The Senate Energy and Natural Resources Committee approved and sent an amendment to Senate bill 1004 to the Senate that calls for restrictions on the use of foreign uranium in the United States and establishes a $900 million fund to reclaim uranium-vanadium millsites. The Federal Government would be required to purchase only domestic-origin uranium in the future. Nuclear power facilities would be required to purchase at least 50% of domestic uranium for their future needs. The Uranium-Vanadium Mill Tailings Fund would be created out of contributions from mill owners, nuclear utilities, and the Federal Government. States with active mills would contribute 10 cents per ton of active tailings within their borders. Approximately 193 million tons of mill tailings in 10 Western States would be covered by this fund. Meanwhile, the State of Colorado and Union Carbide agreed on a $40 million plan to reclaim the Uravan uranium-vanadium mill in southwestern Colorado. Under the agreement, which will settle a lawsuit brought by the State of Colorado against Union Carbide and its subsidiary Umetco, Union Carbide will cover the tailings with 10 feet of soil. Contaminated water in storage ponds will be evaporated and solid material removed to a safer site. Continuous testing of the soil will be conducted on 4 square miles around the mill. The Uravan mill began operations in 1917 and had left 10 million tons of tailings.

DOMESTIC PRODUCTION

Domestic production, expressed in terms of recovered vanadium, continued the modest recovery from the depressed levels of 1983, the worst year for vanadium mining and milling since 1951. Recoverable production, which represents receipts of ore and vanadium-bearing ferrophosphorus, continued the decline that began after the 1981 high of more than 5,000 tons. Idaho was the leading producing State, followed by Colorado and Utah. Four of the five mills in Colorado and Utah that have coproduct vanadium recovery circuits were on standby in 1986 because of the continuing depressed price for U_3O_8 and imports of uranium both natural and enriched. Recovery of vanadium from low-cost petroleum residues, utility ash, and spent refinery catalysts increased significantly, partially offsetting the low level of domestic mine production.

STRATCOR completed the buy out of Umetco's tungsten and vanadium operations and reopened the Hot Springs, AR, vanadium oxides mill. The mill had an annual capacity of about 7,500 tons of V_2O_5. Traditionally, the Hot Springs mill has used vanadiferous micaceous clays as feed material. The clays were mined from four open pits in the Wilson Springs carbonatite-alkalic igneous complex. In September 1985, Umetco laid off 150 employees at the facility and suspended operations for about 1 year. Seventy-five employees were retained to perform maintenance and modernize the mill. Before reopening the mill in September 1986, STRATCOR completed the installation of new solvent extraction equipment that enabled the plant to use low-cost vanadium-bearing residues from oil refineries as feedstock. The modernized mill was expected to produce 2,500 tons per year of V_2O_5 and vanadium trioxide (V_2O_3) for the U.S. market. Some material was shipped to STRATCOR's ferrovanadium plant in Niagara Falls, NY. The remainder of the material was to be shipped to consumers. With the modernization and the ability to process a wide range of feedstocks, Hot Springs will be one of the lowest cost vanadium producers in the world.

Recently, vanadium-bearing feed materials of foreign origin have become a popular source of vanadium. These materials include iron slags from Chile, China, and the Republic of South Africa, as well as utility ashes, spent catalysts from petroleum refineries, and a variety of petroleum residues. One plant recovering vanadium from spent catalysts is in Freeport, TX. Another, operated by AMAX Nickel Inc., is in Braithwaite, LA. The Freeport, TX, plant is operated by Gulf Chemical Corp. and was recently a supplier of V_2O_5 to the NDS. The facility has the capacity to process about 30,000 tons of catalysts per year and has 130 employees. Management planned to double the plant's capacity by 1990 and eventually recover several million pounds of cobalt and nickel left in the stockpiled catalyst residues after vanadium and molybdenum extraction.

At Freeport, the spent catalyst is first roasted with sodium carbonate (Na_2CO_3) in a multiple-hearth furnace for about 2 hours. The roasting is carried out under oxidizing conditions at 650° to 850° C. During roasting, the vanadium and molybdenum react with Na_2CO_3 to form soluble salts. The resulting calcine is then quenched in water, ground, and leached. Next, the insolubles are separated from the pregnant leach liquor in a countercurrent decantation circuit. Finally, the vanadium is precipitated as ammonium metavanadate (NH_4VO_3) with ammonium chloride. The NH_4VO_3 precipitate is calcined and fused to produce V_2O_5. Molybdenum is precipitated as molybdic acid ($H_2MoO_4 \cdot H_2O$) by acidifying the filtrate and heating to 80° to 85° C. The $H_2MoO_4 \cdot H_2O$ is calcined to produce molybdenum trioxide.

AMAX Nickel was using a newly developed process to recover vanadium, molybdenum, cobalt, nickel, and alumina from spent petroleum refinery catalysts. The process developed by AMAX Inc. and CRI Ventures Inc., partners in the venture known as CRI-MET, fully utilizes the spent catalysts. Previous methods recycled only 20% of the material with the remainder going to landfill. The CRI-MET process uses a two-stage leach, one for solubilization of vanadium and molybdenum values and the other for solubilization of alumina. It separates the spent catalyst components into four products. They are molybdenum trisulfide, vanadium pentoxide, alumina trihydrate, and nickel-cobalt concentrate.

Upon receipt of the spent catalysts, it is first fed to a ball mill, along with caustic soda. There it is finely ground and partially leached. The slurry is then pumped to the first stage leach autoclave where it is oxidized at high temperature and pressure. Sulfur is converted to sulfate, hydrocarbons are mostly destroyed, and the molybdenum and vanadium are dissolved. A liquid solid separation is performed by filtration. The solution becomes the feed for molybdenum and vanadium recovery. The solids, along with recycled caustic, make up the feed for the second stage alumina leach autoclave.

Molybdenum recovery from the first stage leach solution involves the precipitation of molybdenum trisulfide with sulfuric acid and a suitable sulfide. The precipitate is washed and dried; it is further processed at another location into oxide and other molybdenum products.

Vanadium recovery from the leach solution follows molybdenum precipitation. The vanadium is precipitated with caustic. It is washed, centrifuged, dried, oxidized, and granulated. The product is a granular vanadium pentoxide that is converted at another location into ferrovanadium.

Solids from the first stage leach, which are high in alumina, are leached a second time at high temperature and pressure with strong caustic to solubilize the alumina. Following the autoclave leach, the solids are separated and washed with the use of centrifuges. They are dried and then smelted at another location into a nickel-cobalt matte from which the nickel and cobalt are recovered as pure metals.

The alumina solution, after separation of the nickel cobalt solids, goes through alumina precipitators. By cooling and contact with seed material, alumina trihydrate is precipitated. It is separated from the solution and washed with the use of centrifuges. The washed solids are dried and sold as pure alumina trihydrate. The process does not generate solid waste. The wastewater is processed through a treatment system before discharge.

The Long Island Lighting Co. (LILCO) began recovering V_2O_5 from boiler ash when it changed from coal- to oil-fired boilers in 1963. The residual fuel oils used contain from 50 to 200 parts per million vanadium. When fired, vanadium in the oil formed acidic deposits on heat transfer surfaces causing overheating and severe corrosion. LILCO solved this problem by injecting magnesium oxide into the oil before firing in a reduced oxygen atmosphere. The injection resulted in less deposit formation, better fuel economy, and produced an ash containing up to 39% V_2O_5. The New York-based LILCO operates oil-fired power stations at Northport and Port Jefferson, NY, both in Suffolk County. Production from high-grade ash totaled 724 tons (revised) V_2O_5 in 1984, 463 tons (revised) in 1985, and 411 tons in 1986. LILCO also produced low-grade sludges, containing 3% to 15% V_2O_5, from wastewater treatment plants. Production from low-grade sludges totaled 366 tons (revised) in 1985 and 234 tons in 1986.

Foote Mineral Co., Exton, PA; Globe Metallurgical Inc., Beverly, OH; and the industrial group of International Minerals & Chemical Corp. (IMC), Northbrook, IL, all were put up for sale in July, indicating a further restructuring of the ferroalloys industry. The industry continued to suffer from weak demand and imports in 1986. Of the three companies for sale, only IMC had a buyer. IMC was being purchased by a New York investment firm and the former chief executive officer of Susquehanna Corp. Foote, a majority-owned subsidiary of Newmont Mining Corp., produces lithium, electrolytic manganese dioxide, and ferroalloys. Foote executives said the company would consider the sale of all of its assets, or a merger. Globe's facilities include a silicon, magnesium, ferrosilicon, and other ferroalloys plant in Beverly, OH, and a silicon plant in Selma, AL. Pechiney Électrométallurgie of France showed an interest in Globe's assets.

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]
1982	4,093	4,098
1983	W	2,171
1984	W	1,617
1985	W	W
1986	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]
1982	8,850	8,689
1983	4,590	4,344
1984	4,688	4,678
1985	W	W
1986	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 domestic consumption of vanadium in 1986 was about 12% less than that of 1985. This decrease in consumption indicated that the slowing of the recovery from the 20-year low of 1983, which began in 1985, continued into 1986. The primary cause of the recovery was increased domestic production of high-strength, low-alloy (HSLA) steels for the automotive and construction industries. Historically, the automobile and construction industries have used mild steels, but since the early 1970's a variety of factors, such as safety and weight reduction, caused the increased use of alternative materials, including HSLA steels. Ford Motor Co. estimated that the use of HSLA steels increased from 100 pounds per automobile to 270 pounds per automobile between 1975 and 1985. However, the steel industry as a whole showed an overall decline of about 8% in raw steel output in 1986 and remained in an uphill battle against imports of major iron and steel products.

More than 80% of domestic consumption of vanadium was by the domestic iron and steel industry as ferrovanadium and proprietary carbon or nitrogen derivatives of V_2O_5. This dependence on the depressed iron and steel industry continued to create marketing problems for domestic producers of ferrovanadium. Ferrovanadium imports decreased substantially from the record-high level of 1984, but remained a problem for producers. Canada regained the share of the U.S. market lost to Austria and

Belgium-Luxembourg in 1985. The Republic of South Africa, which made no shipments for 7 years prior to 1985, rebounded to become the third largest supplier in 1986.

Vanadium pentoxide is the principal intermediate material from which producers manufacture ferrovanadium and other vanadium compounds. Some ferrovanadium, e.g., the low vanadium grades produced by Foote and Shieldalloy Corp., is produced directly from vanadium-bearing slags. Most V_2O_5 for ferrovanadium production is sold as "fused flake" or "technical" grade containing a minimum of 98% V_2O_5. Higher grades, usually granular, are the raw materials for the production of catalysts and other vanadium-bearing specialty chemicals.

Every year, about 10,000 tons of ferrovanadium enters the international market, being exported by a relatively small number of producer countries to consumers all over the world. Domestic demand for vanadium grew at an average rate of about 4.5% per year from 1976 to 1981. Forecasts that this growth rate would continue through 1990 had to be revised downward. The collapse in demand, which reached its lowest point in 1983, was brought on by the worldwide recession during this period. One factor affecting recovery from the 1983 slump has been the emergence of low-cost steel producers such as Brazil, the Republic of Korea, and Taiwan. Although these new producers do not in themselves influence total world demand for ferrovanadium and other alloy additives, they do have modern plants exploiting the latest steelmaking technology. This forced established producers in the United States and other industrialized countries to invest in new plants and equipment in order to remain competitive. Such new high-technology plants and processes have allowed reductions in the proportions of ferroalloys added to steel by reducing wastage and by imparting to steel, by other means, properties previously achieved with ferroalloys.

The largest market for vanadium outside the steel industry, titanium alloys, is also the most promising. An alloy containing 4% vanadium was the most widely used titanium alloy in the aerospace industry. New alloys being developed to facilitate the use of titanium in more airframe components may contain up to 15% vanadium.

Vanadium has been the subject of considerable research on superconductors but faced strong competition from other materials such as columbium. Moreover, recent research has produced new superconductors made from rare earths and copper that operate at much higher temperatures. These materials allowed the use of liquid nitrogen cooling systems, which are less expensive than the liquid helium systems required for vanadium and columbium superconductors. When fully developed, rare-earth and copper superconductors will make the continued use of substantial quantities of vanadium unlikely. Research projects and prototypes for applications in the field of nuclear energy will provide an occasional boost to demand, but the demand for large tonnages of vanadium alloys in nuclear fusion reactors will not develop for many years, if ever.

Vanadium compounds have many uses in catalyst and other specialty chemicals. However, the tonnages for these end uses have steadily declined over the last 10 years as more efficient vanadium catalysts and alternative catalysts containing no vanadium have been developed. The relatively secure market for V_2O_5 catalysts in the manufacture of sulfuric acid continued to be strong in 1986 and catalysts with higher vanadium content were being adopted for maleic anhydride production. In the rapidly expanding market for desulfurization and other pollution control processes, there was strong competition from other catalysts, and demand for vanadium did not benefit significantly.

In addition to the consumers' stocks, and producers' stocks of vanadium as fused oxide, precipitated oxide, vanadates, metal, alloys, and chemicals totaled 1,842 tons of contained vanadium at yearend 1986, compared with 2,849 tons at yearend 1985.

Table 4.—Producers of vanadium alloys or metal in the United States in 1986

Producer	Plant location	Products[1]
Affiliated Metals and Minerals Inc	New Castle, PA	FeV.
Cabot Corp., Engineered Products Group	Henderson, KY	VAl and ZrVAl.
Do	Wenatchee, WA	Do.
Foote Mineral Co., Ferroalloys Div	Cambridge, OH	FeV and Ferovan.[2]
Metallurg Inc., Shieldalloy Corp	Newfield, NJ	FeV.
Reading Alloys Inc	Robesonia, PA	FeV and VAl.
Strategic Minerals Corp	Niagara Falls, NY	Do.
Teledyne Inc., Teledyne Wah Chang Albany Div	Albany, OR	V.
Union Carbide Corp., Umetco Minerals Corp	Marietta, OH[3]	Carvan[2] and Nitrovan.[2]

[1]FeV, ferrovanadium; V, vanadium metal; VAl, vanadium aluminum; ZrVAl, zirconium vanadium aluminum.
[2]Registered trademarks for proprietary products.
[3]Elkem Metals Co. has been toll converting vanadium oxide at Marietta for Union Carbide since 1981.

Table 5.—U.S. consumption and consumer stocks of vanadium materials, by type

(Short tons of contained vanadium)

Type	1985		1986	
	Consumption	Ending stocks	Consumption	Ending stocks
Ferrovanadium[1]	4,071	248	3,617	252
Oxide	18	5	11	W
Ammonium metavanadate	W	W	W	W
Other[2]	794	107	680	62
Total	4,883	360	4,308	314

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 1986, by end use

(Short tons of contained vanadium)

End use	Quantity
Steel:	
Carbon	1,026
Stainless and heat-resisting	41
Full alloy	856
High-strength, low-alloy	1,136
Tool	510
Unspecified	W
Total	3,569
Cast irons	24
Superalloys	12
Alloys (excluding steels and superalloys):	
Cutting and wear-resistant materials	W
Welding and alloy hard-facing rods and materials	6
Nonferrous alloys	652
Other alloys[1]	W
Chemicals and ceramics:	
Catalysts	11
Other[2]	W
Miscellaneous and unspecified	34
Grand total	4,308

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 1986 was $3.65 per pound of V_2O_5, f.o.b. mill. This price spread was established on May 15, 1981, and remained in effect throughout all of 1986. In April, Highveld increased its prices for metallurgical-grade pentoxide in Japan and Europe to $2.65 per pound, an increase of 10% from its first quarter price of $2.41 per pound. The move followed a highly successful sales trip in which Highveld found a strong demand for its product. As a result, Highveld ran its Witbank vanadium-bearing slag operations and its Vantra pentoxide plant at full capacity through the remainder of the year. Highveld pointed to the 21-million-pound production loss to the market by the permanent closure of Rautaruukki and the temporary shutdown of the Umetco facility in Hot Springs, AR, as the reasons for the price increase. The price increase was also influenced by the inability of China to deliver as expected.

In February, Foote and Shieldalloy raised prices for ferrovanadium by 50 cents per pound, 1 week after Umetco made a similar move. Foote raised its price of 70% to 80% ferrovanadium to $6.00 per pound and its price for standard 60% ferrovanadium to $5.80 per pound, f.o.b. Newfield, NJ. Umetco's new price for 80% ferrovanadium was $6.50 per pound. The price on Nitrovan was increased $1.25 to $6.50, reflecting higher costs for vanadium and nitrogen. The price for Vanox was increased to $5.00 per pound from $4.50. Umetco's prices are all f.o.b. Niagara Falls, NY. In October, STRATCOR (formerly a part of Umetco) increased the price of vanadium-oxytrichloride by 50 cents to $5.25 per pound. At the same time, the price of vanadium tetrachloride was increased by 55 cents to $6.20 per pound, f.o.b. Niagara Falls, NY.

FOREIGN TRADE

The U.S. trade pattern for vanadium products changed dramatically over the 1981-85 period. However, the 1986 trade pattern was virtually unchanged from that of 1985. One notable exception was the marked increase in imports of V_2O_5. Exports of ferrovanadium totaled 513 tons gross weight compared with 454 tons in 1985 and 775 tons in 1983. The average declared value of the ferrovanadium was $4.69 per pound of alloy, a 7% decrease from the $5.03 value for 1985. Exports of V_2O_5 and catalysts containing V_2O_5 totaled 1,544 tons gross weight, essentially unchanged from that of 1985, but substantially less than the 3,712 tons for 1984. According to the Bureau of the Census, vanadium tetrachloride was one of the principal unspecified chemicals exported in 1985.

U.S. imports for consumption of ferrovanadium totaled 596 tons of contained vanadium, down from 779 tons in 1985 and a historic high of 1,171 tons in 1984. The material averaged about 81% vanadium and had a mean Customs value of $5.39 per pound of contained vanadium. Canada was the largest supplier of ferrovanadium, with 266 tons gross weight, followed by Austria, the Republic of South Africa, and the Federal Republic of Germany. Pentoxide imports totaled 735 tons gross weight with 464 tons coming from the Republic of South Africa. China was the next largest supplier with 218 tons, followed by the Federal Republic of Germany, Belgium-Luxembourg, and France.

Imports of vanadium contained in ores, slags, and residues totaled 3,594 tons as V_2O_5 compared with 541 tons in 1985. About 60% of this vanadium was in the form of vanadiferous iron slag from Highveld's Witbank steelworks in the Transvaal, Republic of South Africa. The remaining 40% was contained in other assorted petroleum refinery residues and utility ash from, in order of decreasing tonnage, Mexico, Italy, the Dominican Republic, Venezuela, the United Kingdom, and Canada.

Potassium vanadate imports totaled 57 tons gross weight, the same as those of 1985. The Republic of South Africa was the source of 38 tons, with the remainder coming from the Federal Republic of Germany. Imports of vanadium carbide, unwrought vanadium metal, and imports classified as "Other vanadium compounds" were less than 1 ton each. Imports classified as "Mixtures of inorganic compounds" totaled 6 tons gross weight compared with 64 tons in 1985.

Table 7.—U.S. exports of vanadium in 1986, by country

(Thousand pounds and thousand dollars)

Country	Ferrovanadium (gross weight)		Vanadium ore and concentrate (vanadium content)		Vanadium compounds (gross weight): Pentoxide (anhydride)[1]		Vanadium compounds (gross weight): Other[2]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Argentina	--	--	--	--	6	10	--	--
Australia	--	--	--	--	24	28	(3)	5
Austria	--	--	--	--	--	--	35	109
Belgium-Luxembourg	--	--	--	--	294	422	36	140
Brazil	--	--	--	--	427	807	--	--
Canada	176	903	--	--	128	229	317	3,378
Chile	--	--	--	--	36	45	17	30
Denmark	3	10	--	--	3	5	--	--
Ecuador	--	--	--	--	2	3	--	--
France	--	--	--	--	630	933	179	9,877
Germany, Federal Republic of	6	25	--	--	--	--	7	44
India	--	--	--	--	48	142	--	--
Indonesia	79	300	--	--	14	24	--	--
Israel	--	--	--	--	1	180	--	--
Italy	--	--	--	--	60	73	--	--
Japan	--	--	--	--	476	1,118	(3)	4
Korea, Republic of	--	--	--	--	242	300	--	--
Malaysia	1	5	--	--	--	--	--	--
Mexico	70	360	10	25	289	825	88	149
Netherlands	58	234	--	--	--	--	--	--
New Zealand	--	--	--	--	1	1	--	--
Nigeria	--	--	--	--	12	29	--	--
Pakistan	--	--	--	--	9	34	--	--
Philippines	1	5	--	--	18	32	--	--
Singapore	--	--	--	--	8	13	(3)	3
South Africa, Republic of	--	--	--	--	34	506	--	--
Sweden	--	--	--	--	(3)	2	--	--
Switzerland	--	--	--	--	120	250	--	--
Taiwan	--	--	--	--	19	31	3	16
Thailand	(3)	1	--	--	--	--	--	--
Trinidad and Tobago	43	178	--	--	--	--	--	--
Venezuela	588	2,626	167	747	167	746	3	11
Zimbabwe	--	--	--	--	19	22	--	--
Total[4]	1,025	4,647	177	772	3,088	6,810	685	13,765

[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	1985 Gross weight	1985 Vanadium content	1985 Value	1986 Gross weight	1986 Vanadium content	1986 Value
General imports:						
Austria	461	380	1,994	311	255	1,459
Belgium-Luxembourg	487	400	1,887	37	30	139
Brazil	(1)	(1)	5	--	--	--
Canada	418	339	1,775	532	430	2,495
China	44	36	199	22	18	105
Germany, Federal Republic of	334	252	1,238	249	194	1,006
South Africa, Republic of	168	137	614	303	248	1,135
United Kingdom	40	31	149	40	32	188
Total[2]	1,953	1,574	7,861	1,494	1,207	6,527

See footnotes at end of table.

Table 8.—U.S. imports of ferrovanadium, by country —Continued

(Thousand pounds and thousand dollars)

Country	1985 Gross weight	1985 Vanadium content	1985 Value	1986 Gross weight	1986 Vanadium content	1986 Value
Imports for consumption:						
Austria	461	380	1,994	311	255	1,459
Belgium-Luxembourg	509	418	1,982	37	30	139
Brazil	(1)	(1)	5	--	--	--
Canada	418	339	1,775	532	430	2,495
Germany, Federal Republic of	334	252	1,238	249	194	1,006
South Africa, Republic of	168	137	614	303	248	1,135
United Kingdom	40	31	149	40	32	188
Total[2]	1,931	1,557	7,757	1,472	1,189	6,423

[1]Less than 1/2 unit.
[2]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	1985 Gross weight (pounds)	1985 Vanadium content (pounds)	1985 Value	1986 Gross weight (pounds)	1986 Vanadium content (pounds)	1986 Value
General imports:						
Belgium-Luxembourg	--	--	--	37,479	20,996	$89,061
China	--	--	--	435,398	243,910	1,042,694
France	--	--	--	2,863	1,604	16,172
Germany, Federal Republic of	35,554	r19,917	$169,721	22,430	12,565	98,310
Japan	1,200	672	5,829	--	--	--
Netherlands Antilles	2,641	1,479	3,960	--	--	--
South Africa, Republic of	186,285	r104,357	396,683	1,084,566	607,574	2,547,157
Total	225,680	r 1126,426	576,193	1,582,736	886,649	3,793,394
Imports for consumption:						
Belgium-Luxembourg	--	--	--	37,479	20,996	89,061
China	--	--	--	435,398	243,910	1,042,694
France	--	--	--	2,863	1,604	16,172
Germany, Federal Republic of	35,554	r19,917	169,721	22,430	12,565	98,310
Japan	1,200	672	5,829	--	--	--
Netherlands Antilles	2,641	1,479	3,960	--	--	--
South Africa, Republic of	--	--	--	972,132	544,588	2,317,482
Total	39,395	r 122,069	179,510	1,470,302	823,663	3,563,719

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

Source: Bureau of the Census.

WORLD REVIEW

Brazil.—The Brazilian ferroalloys industry continued its systematic increase in the production of ferrovanadium, ferrocolumbium, and other specialty ferroalloys in 1986. Production of ferrovanadium reached 1,052 tons gross weight compared with 998 tons in 1985. Installed capacity was about 3,000 tons per year and was divided between Centroligas-Produtos Siderúrgicos Ltda. and four other producers: Cia. Paulista de Ferro-Ligas, Electrometalur S.A. Indústria e Comércio, Polisinter Indústria e Comércio Ltda., and Termoligas Mineração e Metalurgia S.A.

Brazil is not known to possess significant reserves of vanadium. However, a recent study by the Companhia Baiana de Pesquisa Minetal (CBPM) has shown promising deposits in Campo Alegre de Lourdes, Bahia State. CBPM, an agency of Brazil's Bahia State government, has been conducting exploratory work in this area for about 10 years. The CBPM was also developing magnetite ore deposits in the municipal district of Maracas, Bahia State, and is in the planning stages of building a plant to process the ores. The plant, expected to cost about $40 million, will use feed from ore deposits at Maracas and Campo Alegre de Lourdes. The Bahia deposits are estimated to contain 7 million tons of ore with an average of 1.3% V_2O_5. Production, the first ever in Brazil, will be used to supply domestic markets and reduction of imports. Brazil imported more than 1,000 tons of V_2O_5 in 1986. Brazil's largest supplier of V_2O_5 was the Federal Republic of Germany, followed by the Republic of South Africa, the United Kingdom, the United States, and China. Meanwhile, the Brazilian House of Representatives approved a measure that limits foreign ownership of its newly defined strategic minerals reserves. The legislation was being considered by the Senate. If passed and signed by the President, numerous joint ventures between foreign and Brazilian mining firms would be invalidated. Mining ventures covered by the bill would be given a grace period to allow Brazilian firms to increase their Brazilian ownership to 51%. Foreign companies would be able to maintain 49% holdings in ventures if they wish. The bill's author defined strategic minerals as those abundant in Brazil but scarce outside of Brazil such as columbium, of which Brazil has over 80% of the world's known reserves. The so-called strategic minerals include beryllium, chromium, cobalt, manganese, molybdenum, nickel, potassium, titanium, tungsten, vanadium, and uranium.

China.—China was expanding its iron and steel complexes at Panzhihua near Dukou in Suchuan Province and at Maanshan in Anhui as part of its seventh 5-year plan (1986-90). Construction of new steelmaking facilities and modernization of existing plants began in early 1985 at the two sites and are expected to be completed by 1995. Panzhihua and Maanshan both have their own magnetite mines and are major producers of vanadiferous slags. These slags average about 17% V_2O_5.

The Panzhihua plant has a pig iron capacity of 1.5 million tons per year. In 1986, slag from the plant was preferentially supplied to the Jinzhou and Emei ferroalloy plants where it was converted to V_2O_5 and ferrovanadium. Both plants were under the control of the Metallurgical Industry Ministry. The Changde and Nanyang (Hanan) plants, both under the control of the Ministry of Chemical Industry, on the other hand, were usually short of slag. The Nanyang plant has a capacity of about 1,000 tons per year of V_2O_5. The Jinzhou plant was the country's largest producer through which the National Chemicals Import and Export Corp. exports V_2O_5 to the rest of the world. China's production of V_2O_5 was estimated at 8,000 tons with 3,000 tons for domestic use and the remainder exported. About 1,000 tons of V_2O_5 was produced from Soviet slag bringing China's total production to 9,000 tons. The country's production capacity was estimated at 13,000 to 14,000 tons per year. With this large surplus in capacity, China was actively seeking to make deals with foreign customers to process their raw material on commission.

France.—Pechiney announced in late December 1985 that it will no longer produce ferrovanadium and ferrotitanium in France. A planned 2-year retrenchment will result in the layoff of 560 of the 3,000 employees of Pechiney Électrométallurgie, the ferroalloy subsidiary. Pechiney planned to concentrate on the production of standard ferrosilicon at its modern Dunkirk plant, gradually shutting down older facilities at Saint-Beronand Laudon beginning in the fall of 1987.

Japan.—In an effort to assure a stable supply of rare metals to the Japanese metals industry, the Metal Mining Agency under the control of the Japanese Ministry of International Trade and Industry was expected to launch a joint exploration and development project in China in 1987. The Metal Mining Agency planned to explore the coast of Zhongsha in Guangdong Province for zirconium, titanium, columbium, tantalum, and vanadium. The other area of exploration is near Dayangqi in Hiliongjiang Province. This area will be explored for nickel, molybdenum, cobalt, chromium, and vanadium, along with lead and zinc. The project was expected to begin in April 1987 and to cost $16 million for fiscal year 1987.

In 1986, the steel industry was the major consumer of vanadium in Japan for the manufacture of high-strength steel. Although some vanadium was recovered from spent catalysts and petroleum residues in Japan, ferrovanadium production was dependent on imported sources of V_2O_5 and the domestic facilities were geared to processing V_2O_5 rather than vanadium-bearing slags.

South Africa, Republic of.—Highveld announced that, for the first time, and as a direct result of the imposition of sanctions by the United States, the European Economic Community (EEC), and Hong Kong, no statistics regarding the company's production or sales of iron and steel, vanadium, or ferroalloys would be released for 1986. According to a company spokesman, the annual report, scheduled to be published in March 1987, will contain only statistics that relate to profits and dividends. As a result, the only production figures available cover the first 6 months of 1986.

Highveld produced 63,207 tons gross weight of slag containing about 25% V_2O_5 in calendar year 1985.[2] The 1986 production was estimated at about 76,000 tons. The vanadium slag is a byproduct of pig iron production at the company's integrated steelworks in the Transvaal. Highveld's totally computerized No. 2 plant, which was brought on-line in July 1985 and which was running at full capacity in 1986, has effectively increased total capacity by 30% to about 960,000 tons of ore. The new No. 2 plant, which has three 60-meter-long kilns that carry out partial reduction of the ore prior to feeding to the electric arc furnace to produce pig iron, was reported to be 10% more efficient in terms of power consumption than the No. 1 plant. Its rated capacity was estimated by the manufacturer at 500 tons per day but under optimum conditions can be increased to about 660 tons per day. Higher pig iron production levels resulted in increased steel and vanadium slag output during the last quarter of 1986. The addition of scrap metal to the steelmaking process has led to 1.1 tons of steel being produced for each ton of iron fed into the plant.

Sanctions imposed by the United States and EEC countries were not believed to have been a problem for Highveld owing to the fact that Highveld exports to some 80 countries worldwide. A stronger rand was expected to be more of a threat to Highveld's profitability than sanctions. However, Highveld was moving toward long-term contracts in an effort to avoid the possibility of short-term contracts being summarily canceled. Highveld is also developing new export markets for some of its steel products to offset the loss of markets in the United States and EEC countries. Another result of sanctions has been to effectively unify the steel industry in the Republic of South Africa. It has become extremely difficult to obtain up-to-date statistical information regarding production and exports. Virtually all steel producers refuse to divulge any information that potentially could be used against them. However, according to the Steel and Engineering Industries Federation, output of primary steel products in 1986 was estimated at 8.8 million tons, compared with 8.5 million tons in 1985. As in previous years, the bulk of the Republic of South Africa's steel production was from the South African Iron and Steel Industrial Corp. Ltd., which reported that in the fiscal year ending June 30, 1986, a total of 7,183,700 tons of raw steel was produced compared with 6,532,400 tons in 1985. Pig iron production rose to 5,752,800 tons compared with 5,457,000 tons in the 1985 fiscal year.

In September, Rand Mines Ltd. completed the merger of its Winterveld Chrome Mines with Vansa Vanadium S.A. Ltd. Rand Mines acquired a 42% stake in that company and at the same time control of a potential new platinum development that Vansa controls through its wholly owned subsidiary, Rhodium Reefs.[3] In the eastern Transvaal, Vansa was developing a new vanadium mine on Kennedy's Vale, which is also underlain by the platinum-bearing Merensky and UG2 Reefs. Development of the mine was expected to cost $13 to $14 million and was expected to start production within 2 years. The mining operations and recovery plant will be located near Steelpoort in the Lyndenberg District. The ore body forms a plug in one of the hills in the district. The ore, assaying an average 1.2% V_2O_5 by weight, will be mined using opencast methods, and use will be made of the ore passes and adits that were installed in 1966 when operations were previously carried out.[4] The ore will be crushed in the pit before being conveyed to the crushing and screening plant. Here the ore is further reduced and classified to give a product of less than 0.5 inch in diameter, which forms the feedstock for the milling plant. The feed is further milled to less than 300 micrometers by means of a ball mill and a cyclone classification unit. Next, the magnetite is separated from nonmagnetic tailings with magnetic separators. The milled magnetite is then mixed with sodium salts and roasted in large rotary kilns. The roasting step takes about 6 hours and converts the vanadium present into water-soluble sodium metavanadate, which is subsequently treated in the leaching circuit. The pregnant liquor from this process is treated with ammonium sulfate to precipitate vanadium as ammonium metavanadate. Finally, the precipitate is filtered, deammoniated in a calcine furnace, and drummed in flake form as V_2O_5. The mine is expected to produce 3,000 tons of V_2O_5 per year.

Table 10.—Vanadium: World production, by country[1]

(Short tons of contained vanadium)

Country	1982	1983	1984	1985[p]	1986[e]
Production from ores, concentrates, slags:[2]					
Australia (in vanadium pentoxide product)[3]	25	--	--	--	--
China (in vanadiferous slag product)[e]	5,000	5,000	5,000	5,000	5,000
Finland (in vanadium pentoxide product)	3,470	3,516	3,376	2,350	--
Norway[e]	120	--	--	--	--
South Africa, Republic of:[4]					
Content of pentoxide and vanadate products[e]	3,981	4,117	6,633	[r]6,537	6,620
Content of vanadiferous slag product[e 5]	8,930	5,620	7,165	[r]8,912	10,580
Total	12,911	9,737	13,798	15,449	17,200
U.S.S.R.[e]	10,500	10,500	10,500	10,500	10,600
United States (recoverable vanadium)	4,098	2,171	1,617	W	W
Total	36,124	30,924	34,291	[6]33,299	[6]32,800
Production from petroleum residues, ashes, spent catalysts:[7]					
Japan (in vanadium pentoxide product)[e]	754	778	770	840	840
United States (in vanadium pentoxide and ferrovanadium products)	1,513	893	1,701	2,695	3,452
Total	2,267	1,671	2,471	3,535	4,292
Grand total	38,391	32,595	36,762	[6]36,834	37,092

[e]Estimated. [p]Preliminary. [r]Revised. 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 14, 1987.

[2]Production in this section is credited to the country that was the origin of the vanadiferous raw material.

[3]Reported output for export.

[4]Includes production for Bophuthatswana.

[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

The aerospace plane, hypersonic vehicles, and strategic defense initiative (SDI) requirements are putting unparalleled pressure on material development for use in these systems. Most of the pressure is to produce materials that can operate at temperatures above 950° F and still maintain their toughness. One leading candidate to solve this problem appears to be titanium aluminide and at least two companies have announced that they will move from the laboratory to limited production of this material in 1987.[5] Titanium aluminides, and titanium alloys in general, have the disadvantage of having to be hot formed into final configurations, a process that drives up manufacturing cost. To overcome this disadvantage, several new high-strength alloys are now being developed that can be cold formed just like pure titanium. The two most notable of these alloys are 15-3-3-3 (15% vanadium-3% aluminum-3% chrome-3% tin), and 3-8-6-4-4 (3% aluminum-8% vanadium-6% chrome-4% zirconium-4% molybdenum). Another new titanium alloy, 10-2-3 (10% vanadium-2% iron-3% aluminum) can be forged at temperatures much lower than conventional alloys.

Scientists at Allied-Signal Corp. were developing a family of aluminum-base alloys for use in high-temperature applications.[6] Work at the company's Corporate Technical Center in Morristown, NJ, has identified missile fins, airframe sheets, aircraft wheel forgings, and gas turbine engine components as potential applications. The aluminum-base alloys contain 6% to 12% iron, 1% to 3% vanadium, 1% to 3% silicon, and 0% to 3% zirconium. Depending on the percentage of alloying elements, these alloys may be used in applications requiring fracture toughness, corrosion resistance, fatigue strength, or high-temperature resistance.

W. R. Grace & Co. has begun trial production of a catalyst based on titanium dioxide, V_2O_5, and tungsten trioxide.[7] Trial production runs were being conducted at Grace's recently completed catalyst plant in Bergish-Galbach, Federal Republic of Germany. The plant, which has a catalyst capacity of about 2,000 cubic meters per year, was scheduled to start production in January 1987. The plant will be operated by Feldmuehle Grace Noxeram GmbH, a joint venture between Grace and Feldmuehle A.G. The catalyst system reduces smokestack emissions by converting flue gas and injected ammonia into nitrogen and water.

Vanadium is classified as a strategic and critical material because of its import dependence and its use in equipment essential to the defense and commercial well-being of the Nation. Over 80% of U.S. consumption is by the iron and steel industry as ferrovanadium or related vanadium-carbon alloys. When used as an alloying element, vanadium increases strength and improves toughness and ductility of carbon steels. Vanadium is also used as an additive to titanium-base alloys that are used in jet engines and other aircraft parts, and as catalysts, which are used in the manufacture of sulfuric acid (H_2SO_4) and other chemicals.

In the United States, particularly in the Colorado Plateau, vanadium is found in uranium-bearing minerals and certain phosphatic shales and phosphate rocks. One of these phosphate deposits, located in Idaho, represents a large domestic vanadium reserve. The phosphorite beds, 3 to 20 feet thick, average 20% to 30% P_2O_5 and 0.14% V_2O_5.[8] At least 125,000 tons of coproduct V_2O_5 is contained in these deposits. The Bureau of Mines investigated the recovery of vanadium, uranium, and phosphorus from these ores and concentrates by leaching with H_2SO_4.[9] Samples containing 0.12% to 0.23% V_2O_5, 0.009% to 0.012% U_3O_8, and 18% to 30% P_2O_5 were treated by batch agitation leaching, roasting followed by acid leaching, salt-roasting followed by acid leaching, and leaching under pressure. Maximum recoveries from leaching alone ranged from 78% to 98% of the vanadium and 74% to 88% of the uranium. Leaching under pressure extracted 88% to 95% of the vanadium and 86% to 91% of the uranium. Phosphate extractions ranged from 89% to 99%. Solvent extraction laboratory tests were conducted to selectively recover vanadium and uranium values from the acid leach solutions. An average of 95% of the uranium could be recovered using di(2-ethylhexyl) phosphoric acid, plus trioctylphosphinic oxide. Essentially all of the vanadium was recovered as the pentoxide with octylphenyl acid phosphate plus isodecanol; phosphate remained in the raffinate.

Pentavalent vanadium forms anionic chelates with 4-(2-pyridylazo)-resorcinol at pH 5.0 to 7.8, which can be quantitatively extracted into nitrobenzene as an ion pair with xylometazolonium cation. The ternary system has an absorption maximum at 540 nanometers and obeys Beer's law in the range from 0 to 1.8 micrograms of vanadium per milliliter. Researchers in the Department of Chemistry at Nagarjuna University in India have determined that in the presence of 1,2-diaminocyclohexanetetracetic acid (CyDTA) as a masking agent, the extraction becomes highly selective and can be applied for the determination of vanadium, in the presence of various metal ions in steels and titanium-base alloys.[10] The method has the advantage, over other spectrophotometric methods for vanadium, of having high sensitivity, and the interference from many diverse ions can be completely masked with CyDTA.

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[1]Physical scientist, Division of Ferrous Metals.

[2]Highveld Steel and Vanadium Corp. Ltd. (Witbank, Republic of South Africa). 1985 Annual Report. Pp. 6-23, 32-33.

[3]American Metal Market. V. 94, No. 213, Oct. 31, 1986.

[4]South African Mining & Engineering. Coal, Gold, and Base Minerals. Sept. 1986, p. 35.

[5]Aviation Week and Space Technology. Oct. 13, 1986, p. 74.

[6]American Metal Market. V. 94, No. 72, Apr. 14, 1986.

[7]Chemical and Engineering News. Nov. 1986, p. 7.

[8]Deborough, G. A. Preliminary Report on Certain Metals of Potential Vanadium-Rich Zones in the Meade Peak Member of the Phosphoria Economic Interest in Thin Formation in Western Wyoming and Eastern Idaho. U.S. Geol. Surv. OFR 77-341, 1977, p. 10.

[9]Judd, J. C., R. G. Sandberg, and J. L. Huiatt. Recovery of Vanadium, Uranium, and Phosphate From Idaho Phosphorite Ores. BuMines RI 9025, 1986, 15 pp.

[10]Yerramilli, A., C. S. Kavipurapu, R. R. Manda, and C. M. Pillutla. Extractive Spectrophotometric Method for the Determination of Vanadium (V) in Steels and Titanium Base Alloys. Anal. Chem., v. 58, No. 7, June 1986, pp. 1451-1453.

Vermiculite

By Arthur C. Meisinger[1]

U.S. production of vermiculite concentrate in 1986 increased about 3,000 short tons in quantity and $2 million in value to 317,000 tons and $34.4 million, respectively. Sales of exfoliated vermiculite from 41 plants in 28 States decreased slightly in quantity to 253,000 tons valued at $53.2 million. Apparent domestic consumption also declined slightly from 329,000 tons in 1985 to 327,000 tons.

The United States and the Republic of South Africa continued to be the leading vermiculite-producing countries with 93% of estimated world production of 570,000 tons.

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, 40 responded. The one nonrespondent's 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)

	1982	1983	1984	1985	1986
United States:					
Sold and used by producers:					
Concentrate	316	282	315	314	317
Value	$28,500	$27,200	$31,500	$32,400	$34,400
Average value[1] dollars per ton	$90.19	$96.45	$100.00	$103.18	$108.52
Exfoliated	235	224	264	258	253
Value	$55,500	$52,200	$56,500	$47,900	$53,200
Average value[1] dollars per ton	$236.17	$233.04	$214.02	$185.66	$210.28
Exports to Canada	22	19	22	e23	e25
Imports for consumption	e21	e24	32	e38	e35
World: Production[2]	560	490	545	p556	e570

eEstimated. pPreliminary.
[1]Based on rounded data.
[2]Excludes production by centrally planned economy countries.

DOMESTIC PRODUCTION

U.S. production of vermiculite concentrate increased slightly to 317,000 tons valued at $34.4 million compared with 314,000 tons valued at $32.4 million in 1985.

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. (Carolina Vermiculite) near Woodruff. Other companies producing vermiculite concentrate during the year were Virginia Vermiculite Ltd., Louisa County, VA, and Intermountain Products Inc., Salt Lake County, UT.

Domestic sales of exfoliated vermiculite by 12 producers declined slightly in quantity to 253,000 tons, but increased 11% in value to $53.2 million. 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 exfoliated vermiculite output sold and used, the principal producing States were California, Ohio, Texas, Florida, South Carolina, New Jersey, and Arkansas.

CONSUMPTION AND USES

Apparent domestic consumption of vermiculite concentrate was 327,000 tons, a slight decrease from 329,000 tons in 1985.

The quantity of exfoliated vermiculite sold and used for insulation increased slightly; however, the quantity used for construction aggregates and in agriculture decreased slightly from 1985 quantities. Other uses declined 37% to 2,900 tons.

Table 2.—Exfoliated vermiculite sold and used in the United States, by end use

(Short tons)

End use	1985	1986
Aggregates:		
Concrete	52,700	50,800
Plaster	2,500	2,200
Premixes[1]	80,200	80,000
Total[2]	135,300	133,000
Insulation:		
Loose-fill	20,500	21,000
Block	35,700	35,900
Other[3]	1,700	2,100
Total	57,900	59,000
Agricultural:		
Horticultural	22,400	19,700
Soil conditioning	8,400	5,300
Fertilizer carrier	29,000	33,500
Total	59,800	58,500
Other[4]	4,600	2,900
Grand total[2]	258,000	253,000

[1]Includes acoustic, fireproofing, and texturizing uses.
[2]Data may not add to totals shown because of independent rounding.
[3]Includes high-temperature and packing insulation and sealants.
[4]Includes various industrial uses not specified.

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.
Patterson Vermiculite Co	Laurens	South Carolina.
Robinson Insulation Co	Cascade	Montana.
The Schundler Co	Middlesex	New Jersey.
O. M. Scott & Sons	Union	Ohio.
Strong-Lite Products Corp	Jefferson	Arkansas.
Strong-Lite Products Corp. of Illinois	De Kalb	Illinois.
Verlite Co	Hillsborough	Florida.
Vermiculite Products Inc	Harris	Texas.

[1]2 plants in the county.

PRICES

The average value of vermiculite concentrate sold and used by U.S. producers increased nearly $6 per ton to $109, f.o.b. plant. The average value of exfoliated vermiculite, f.o.b. plant, increased 13% from $186 per ton to $210 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 compared with 38,000 tons in 1985. Exports to Canada were estimated to be 25,000 tons and represented 8% of total sales.

WORLD REVIEW

World production was estimated to be 570,000 tons, a slight increase over 1985 production of 556,000 tons. The United States and the Republic of South Africa, together, continued to account for 93% of the total output.

[1]Industry economist, Division of Industrial Minerals.

Table 4.—Vermiculite: World production, by country[1]

(Short tons)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Argentina	3,697	4,355	4,906	[e]4,400	4,400
Brazil	15,497	10,888	10,094	[e]11,000	11,000
Egypt	309	331	[e]360	538	[3]546
India	2,280	2,658	2,153	1,990	2,200
Japan[e]	19,000	19,000	19,000	19,000	19,000
Kenya	1,715	[e]1,300	961	1,670	1,700
Mexico	575	440	557	474	500
South Africa, Republic of	201,327	168,691	191,536	202,902	[3]213,470
United States (sold and used by producers)	316,000	282,000	315,000	314,000	[3]317,000
Total	560,400	489,663	544,567	555,974	569,816

[e]Estimated. [p]Preliminary.
[1]Excludes production by centrally planned economy countries. Table includes data available through July 14, 1987.
[2]In addition to the countries listed, Tanzania may produce vermiculite, but available information is inadequate for formulating reliable estimates of output levels, if any.
[3]Reported figure.

Zinc

By James H. Jolly[1]

Domestic mine output of zinc fell for the sixth straight year and was the lowest in 83 years. Production of slab zinc and zinc oxide also declined. Slab zinc output was affected mainly by an extended shutdown at a major secondary slab zinc producer in Michigan owing initially to equipment failure. The reduction in zinc oxide output was due largely to the permanent closure of an American-process zinc oxide plant in Ohio early in the year. The United States accounted for about 3.2% of the world zinc mine production and 4.7% of the world slab zinc output in 1986; in 1980, the comparable percentages were 5.8% and 6.1%, respectively.

U.S. slab zinc consumption was higher than that of 1985 mainly because of greater use in the galvanizing process. Record-high slab zinc imports, mainly from Canada, accounted for about two-thirds of apparent slab zinc consumption. Imports of zinc oxide were also at record-high levels and accounted for a record high 27% of apparent zinc oxide consumption.

World consumption of slab zinc was at a

Table 1.—Salient zinc statistics

(Metric tons unless otherwise specified)

	1982	1983	1984	1985	1986
United States:					
Production:					
Domestic ores, recoverable content	303,160	275,294	252,768	226,545	202,983
Value thousands	$257,116	$251,204	$270,833	$201,607	$170,050
Slab zinc:					
From domestic ores	193,284	210,315	197,912	r198,003	191,079
From foreign ores	34,892	25,379	55,220	63,204	62,288
From scrap	74,288	69,390	78,113	r72,567	62,914
Total	302,464	305,084	331,245	r333,774	316,281
Secondary zinc[1]	210,681	279,237	r317,968	r274,456	275,107
Exports:					
Ores and concentrates (zinc content)	77,289	60,168	30,579	23,264	3,269
Slab zinc	341	427	760	1,011	1,938
Imports for consumption:					
Ores and concentrates (zinc content)	66,809	63,156	86,172	90,186	75,786
Slab zinc	456,233	617,679	639,228	610,900	665,126
Stocks of slab zinc, Dec 31	159,174	148,139	137,626	r119,892	100,723
Government stockpile	340,578	340,577	340,577	340,577	340,577
Consumption:					
Slab zinc:					
Reported	709,491	805,891	848,903	r770,671	705,963
Apparent[2]	794,536	933,371	980,226	r961,396	998,638
All classes[3]	1,038,156	1,248,028	1,345,381	1,282,390	1,294,296
Price: High Grade, cents per pound (delivered)	38.47	41.39	48.60	40.37	38.00
World:					
Production:					
Mine thousand metric tons	r6,125	r6,368	6,602	p6,857	e6,853
Smelter do	r5,894	r6,249	6,526	p6,844	e6,784
Price: London, cents per pound	33.74	34.73	40.46	36.23	34.19

eEstimated. pPreliminary. rRevised.
[1]Excludes redistilled slab zinc.
[2]Domestic production plus net imports plus-minus stock changes.
[3]Data has been revised based on apparent consumption of slab zinc plus zinc content of ores and concentrates and secondary materials.

record-high level; however, both mine and smelter production fell slightly from those of 1985. U.S. and world zinc prices began the year at depressed levels but increased as the year progressed, aided in part by improved demand after the first few months of the year and by labor-management disputes in the Canadian and Australian zinc industries, which curtailed production.

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 surveys is the annual zinc survey, which, in part, covers the primary and secondary slab zinc producers. Of the 12 slab zinc producers to which the survey request was sent, 10 responded, representing 83% of the total slab zinc production shown for 1986 in tables 1, 7, and 8. Production for the two nonrespondents was estimated using prior year production levels.

Legislation and Government Programs.—The National Defense Stockpile goal for zinc was 1,292,739 metric tons, unchanged since May 1980. The total inventory held by the Government was 343,202 tons, including 2,625 tons of zinc in the form of brass.

On October 17, the President signed the Superfund Amendments and Reauthorization Act of 1986 (SARA). Under SARA, Public Law 99-499, the taxes on production of zinc chloride, $2.22 per ton, and zinc sulfate, $1.90 per ton, were unchanged from the initial Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund) and were to continue. No additional zinc materials were added to the taxable list. Overall responsibility and liability concerns were slightly modified under SARA; however, the main provisions addressing civil and criminal liability, with respect to cleanup costs involving identified hazardous waste sites, remain unchanged.

The Environmental Protection Agency (EPA) continued to exempt mining waste from the hazardous waste requirements of the Resource Conservation and Recovery Act at yearend.

In December, the EPA released a study on the Superfund cleanup site at the Bunker Hill lead-zinc mine and smelter complex. The study indicated that a cleanup effort involving a 21-square-mile area containing large tonnages of contaminated soil, slags, and other materials, and costing about $50 million, was required.

The Bureau of Mines, EPA, and various State agencies in Kansas studied public safety problems related to open, abandoned lead-zinc mine shafts in the Kansas portion of the Tri-State Mining District, formerly one of the world's most productive lead and zinc mining districts. About 377 mine shafts, often 2 or 3 per acre, with some up to 450 feet deep, were in and around Galena, KS. Because these open shafts posed hazards to area residences, efforts were made to reduce these dangers by using plugs and other means to block off the shafts at the surface.

In November, the U.S. Department of Labor approved Federal job aid for about 600 mine and mill workers at St. Joe Resources Co. zinc mines at Balmat and Pierrepont in New York. All workers who lost their jobs on or after April 2, 1985, became eligible for trade adjustment assistance.

DOMESTIC PRODUCTION

MINE PRODUCTION

U.S. zinc mine production continued its downtrend for the sixth straight year, resulting in the lowest production year since 1906. Mine closures owing to poor market conditions contributed most to the production decline. Mines in Idaho, Missouri, New Jersey, and Tennessee closed during 1986. Tennessee was the principal zinc-producing State, followed by New York and Missouri. The leading zinc mine producers were ASARCO Incorporated; St. Joe Resources, a division of St. Joe Minerals Corp., which is a wholly owned subsidiary of Fluor Corp.; and Jersey Minière Zinc Co., a subsidiary of the Belgian company Union Minière S.A. The 25 leading U.S. zinc-producing mines accounted for practically all of the zinc mine output, with the 10 leading mines accounting for 81%.

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 east Tennessee zinc mines (Coy, Immel, New Market, and Young), were the leading producers. Asarco's production was affected by temporary mine closures during the year mainly owing to depressed zinc prices and excessive inventories of zinc concentrate. The New Market Mine closed at the end of January and reopened in mid-September. The Coy, Immel, and Young Mines closed down April 1 and reopened in mid-June. According to Asarco's annual report, the company milled 1.77 million tons of ore producing 43,300 tons of zinc in concentrate in 1986 compared with 1.42 million tons milled yielding 34,000 tons of zinc in concentrates in strike-affected 1985. At yearend 1986, ore reserves at the four mines were estimated to be 6.1 million tons averaging 3.22% zinc.

The Tennessee Chemical Co., a producer of byproduct zinc in concentrate at Copperhill, TN, announced plans to shut down all mining operations in the summer of 1987, ending about 140 years of almost continuous mining in the district.

Zinc production in Missouri, a coproduct of lead at seven underground mines all along the Viburnum Trend in southeastern Missouri, fell substantially owing mainly to the closure of the Buick Mine in the latter half of the year. The lead-zinc-producing sector underwent a number of company ownership changes in 1986, resulting mainly in a significant restructuring of the U.S. lead industry. Five active and two inactive lead-zinc mines, five mills, and two lead smelter-refineries were involved in these changes. In mid-May, the Homestake Mining Co. acquired AMAX Lead Co.'s 50% interest in their jointly owned Buick Mine, mill, and smelting facilities at Boss, MO, for $13 million. The operation was placed on standby status at that time pending evaluation of various operating plans and business alternatives. On November 1, Homestake and St. Joe Minerals merged their Missouri lead-zinc operations forming a new jointly managed partnership called The Doe Run Co., owned 57.5% by St. Joe Resources and 42.5% by Homestake. St. Joe Resources contribution to Doe Run was four operating mines (Casteel, Fletcher, and Viburnum 28 and 29); the mothballed Brushy Creek Mine; and the Herculaneum lead smelter-refinery. Homestake contributed the Buick Mine and mill and its Boss, MO, lead smelter-refinery. In late December, Doe Run reopened the Buick Mine, placed the Fletcher Mine on care and maintenance, and resumed development work at the Brushy Creek Mine. As of November 1, the ore reserves at Doe Run mines were estimated to be 64 million tons averaging 5.5% lead and 0.5% zinc.

In late December, Asarco purchased the Milliken Mine and mill near Sweetwater, MO, from Ozark Lead Co., a Kennecott subsidiary, for $850,000 plus participation in future revenues. The Milliken Mine, renamed the Sweetwater Unit by Asarco, had been closed since 1983. Asarco announced no plans to reopen the mine, which had an annual production capacity of 80,000 tons of lead and 8,000 tons of zinc in concentrate when it closed. Ore reserves of the mine were estimated by Asarco to be about 23 million tons grading 4.8% lead and 0.6% zinc.

The Magmont Mine, a joint venture of Cominco American Incorporated, the U.S. subsidiary of Cominco Ltd., and Dresser Industries Inc., was the leading zinc producer in Missouri in 1986, despite lower-than-anticipated ore production because of a major ground fall in part of the mine. According to the Cominco annual report, the company milled 0.95 million tons of ore averaging 8.6% lead, 1.5% zinc, and 0.3% copper and produced 79,460 tons of lead, 11,450 tons of zinc, and 1,600 tons of copper in concentrate in 1986. In 1985, the company milled 1.04 million tons of ore averaging 1.9% zinc and produced 16,400 tons of zinc in concentrate. Ore reserves at yearend were estimated to be 4.8 million tons averaging 5.9% lead, 1.1% zinc, and 0.27 ounce of silver per ton.

For the fiscal year ending October 31, Fluor, in its annual 10-K report, reported that St. Joe's three Missouri mills processed 3.2 million tons of ore from four mining operations and produced 12,960 tons of zinc in concentrate; in 1985, slightly less ore tonnage was milled, and production was 11,700 tons of zinc in concentrate.

Output at Asarco's West Fork Mine, which opened in late 1985, was 30,500 tons of lead and 6,500 tons of zinc in concentrate on milling 276,000 tons of ore in 1986. Asarco planned to increase production to annual capacity levels, 75,000 tons of lead, 19,000 tons of zinc, and 225,000 ounces of silver, by the end of 1987. At yearend 1986, ore reserves at the West Fork Mine were estimated to be 10.2 million tons averaging 7.13% lead, 1.95% zinc, and 0.28 ounce of silver per ton.

In New York, St. Joe Resources operated the Balmat and Pierrepont Mines and a 3,900-ton-per-day mill at Balmat. Although the strike that began in July 1985 continued through 1986, zinc production was carried out by supervisory and nonunion personnel. For the fiscal year ending October 31, St. Joe Resources mined and milled 257,000 tons of ore averaging 15.64% zinc and produced 38,240 tons of zinc in concentrate. In fiscal year 1985, the company mined and milled 531,000 tons of ore averaging 10.65% zinc and produced 53,270 tons of zinc in concentrate. Estimated ore reserves for the Balmat and Pierrepont Mines at the end of fiscal year 1986 were 3.4 million tons averaging 12.65% zinc compared with 3.7 million tons averaging 13.6% zinc at the end of fiscal year 1985.

In Colorado, zinc production was largely a coproduct of gold-silver operations at the Leadville Mine, managed by Asarco but jointly owned by Resurrection Mining Co., a Newmont Mining Corp. subsidiary, and at the Sunnyside Mine, owned by Sunnyside Gold Corp., a subsidiary of Echo Bay Mines Ltd. According to the Asarco annual report, the 1986 production at the Leadville Mine was 13,150 tons of zinc, 6,800 tons of lead, 392,000 ounces of silver, and 17,700 ounces of gold in concentrate. Production was slightly higher than that of 1985 owing in part to improved ore grades. Ore reserves were increased by 140,000 tons despite production of 200,000 tons of ore in 1986. Yearend ore reserves were estimated to be 886,000 tons averaging 8.95% zinc, 4.54% lead, 0.13% copper, 2.2 ounces of silver per ton, and 0.07 ounce of gold per ton.

Echo Bay brought its Sunnyside gold-silver-zinc-lead-copper mine, which was acquired in November 1985 from Standard Metals Corp., back into initial production in late April after extensive rehabilitation. Commercial production began in August. In the last 5 months of 1986, the company averaged a milling rate of 620 tons per day; however, the average ore grade was lower than expected, and consequently, zinc and other metal production was less than planned. An aggressive exploration program was under way to establish further ore reserves. At the end of 1986, ore reserves totaled 425,000 tons containing an estimated 0.17 ounce of gold per ton, 2.5 ounces of silver per ton, and 6% combined zinc, lead, and copper.

Zinc mine production in Idaho fell sharply because of depressed silver prices which resulted in the April closure of the only significant producer, the Lucky Friday silver-lead-zinc mine, owned by the Hecla Mining Co. According to Hecla's annual report, the company produced only 1,140 tons of zinc in concentrates compared with a production of 3,550 tons in 1985. Ore reserves also declined 58,000 tons, ending the year at 548,000 tons averaging 15.1 ounces of silver per ton, 12.3% lead, and 1.9% zinc.

In New Jersey, the Sterling zinc mine, owned by The New Jersey Zinc Co. Inc. (NJZI), closed indefinitely at the end of March because of high operating costs and low zinc prices.

Pegasus Gold Inc. continued development of its $56 million Montana Tunnels gold-silver-zinc-lead project about 15 miles south of Helena, MT. Ore reserves were estimated to be 37.4 million tons averaging 0.025 ounce of gold per ton, 0.47 ounce of silver per ton, 0.72% zinc, and 0.27% lead. Production was scheduled to begin in the spring of 1987. Plans called for the open pit mining of about 4 million tons of ore per year, the milling of 11,300 tons per day, the production of bulk sulfide concentrate by flotation, the leaching of the bulk concentrate by cyanide to extract gold and silver, and the production of separate lead and zinc concentrates by a second flotation step. Average annual production over the 10-year expected life of the project was projected to be 106,000 ounces of gold, 1.7 million ounces of silver, 23,600 tons of zinc, and 5,200 tons of lead.

In Alaska, decisions were made to proceed with the development of both the Greens Creek silver-zinc-lead-gold deposit on Admiralty Island and the Red Dog zinc-lead-silver deposit in northwestern Alaska. In November, Cominco American and the NANA Regional Corp., owners of the Red Dog deposit, made the commitment to spend about $420 million to bring the Red Dog deposit into production by 1991. Arrangements for financing the road and port facilities and user fees were concluded with the State of Alaska. A $120 million letter of credit was delivered by Cominco American to the State guaranteeing the first 10 years of toll payments on the 52-mile road system to the mine. The $12 million annual toll fee, or about $18.00 per ton of concentrate at full capacity, was expected to provide the State with a 6.5% return on its investment. In the summer of 1986, a barge dock and staging area was built at the portsite on the Chukchi Sea south of Kivalina. Road construction was scheduled to start in 1987 with completion in 1988. Ore reserves at Red Dog were estimated to be 77 million tons averaging 17.1% zinc, 5% lead, and 2.6 ounces of silver per ton. At capacity, Cominco American planned to produce annually 314,000 tons of zinc and 64,000 tons of lead in concentrate.

In December, the Greens Creek Mining Co., a subsidiary of Amselco Minerals Inc., which in turn is a subsidiary of BP North America Inc., decided to proceed with a 2,000-foot development adit to be driven about 400 feet below the present 4,600-foot-long exploration drift. A 7-mile road from the portsite to the minesite was completed in 1986. Formal approval to develop the $80 million mine was not expected until March 1987; however, plans envisioned mine production to start in 1988. At capacity, an annual production of 20,000 tons of zinc, 6,000 tons of lead, and 4 to 5 million ounces of silver in concentrate was expected. Ore reserves were estimated to be 2.4 million tons averaging 9.05% zinc, 3.50% lead, 0.46% copper, 22.5 ounces of silver per ton, and 0.13 ounce of gold per ton.

Exxon Minerals Co. suspended its Crandon, WI, zinc-copper mine project indefinitely in December based mainly on unfavorable economic forecasts for zinc and copper. Exxon reportedly had invested $60 million in the project since 1976 when it announced discovery of the deposit.

SMELTER AND REFINERY PRODUCTION

Slab zinc was produced at four primary smelters and six secondary plants in 1986. The producers of primary slab zinc were St. Joe Resources, AMAX, and Jersey Minière, and the leading producers of metal from secondary materials were St. Joe Resources, Huron Valley Steel Corp., and Interamerican Zinc Co. Asarco's Corpus Christi, TX, zinc refinery remained on standby status in 1986. A 1-month strike settled in April at AMAX's Sauget, IL, zinc refinery did not significantly affect U.S. production.

St. Joe Resources, owners of primary zinc refineries at Bartlesville, OK, and Monaca, PA, was the largest domestic producer. The Bartlesville refinery utilized mainly purchased concentrates, whereas the Monaca refinery mainly utilized concentrate from the company's New York mines and purchased scrap. According to the Fluor annual 10-K report, for the fiscal year ending October 31, St. Joe Resources' zinc refineries produced 144,200 tons of zinc in the form of slab zinc, dust, and oxide compared with 147,200 tons in fiscal year 1985.

Huron Valley planned to resume production in January 1987 at its 30,000-ton-per-year secondary zinc refinery at Belleville, MI, following a 7-month program to rebuild and upgrade the operation. The refinery was crippled in June by a column collapse that damaged a furnace and related equipment.

Zinc Oxide.—The raw material sources of domestic zinc oxide production were 18% from ores and concentrates, 42% from slab zinc, and 40% from secondary materials. The percentage produced from ores and concentrates fell from about 35% in 1985 owing to the closure of the Sterling Mine, the ore from which NJZI produces American-process zinc oxide, and to the permanent closure of Asarco's zinc oxide plant at Columbus, OH. Of the total zinc oxide production, the French process accounted for an estimated 70%; the American process for 25%; and other processes,for 5%. Zinc oxide was produced at 12 plants. The largest producers were Asarco, NJZI, Pacific Smelting Co., and St. Joe Resources.

According to the Asarco annual report, zinc oxide production at its two plants, Columbus, OH, and Hillsboro, IL, was 7,125 tons and 8,125 tons, respectively. The Columbus plant, which produced American-process zinc oxide from Tennessee zinc concentrates, was closed permanently in April mainly because of continuing high costs.

NJZI processed direct shipping ore from its Sterling Mine, slab zinc, and waste and scrap materials, to produce both American- and French-process zinc oxide at its plant at Palmerton, PA. Horsehead Resource Development Co. used Waelz-kiln and sintering facilities at NJZI's Palmerton plant to produce crude zinc oxide from steelmaking electric arc furnace (EAF) dusts. The crude oxide products, typically containing about 75% zinc oxide, were shipped elsewhere for further processing. More than 100,000 tons of EAF dusts containing about 20% zinc were processed in 1986.

Zinc Salts.—Zinc sulfate was produced by 11 companies from secondary zinc materials and waste streams from electrolytic zinc plants. Most zinc sulfate was used for agricultural purposes. Zinc chloride was produced at five plants from secondary zinc materials and chemical waste streams.

Byproduct Sulfur.—Production of sulfur in byproduct sulfuric acid at four primary zinc refineries and one zinc oxide plant using zinc sulfide concentrate as raw material was 124,100 tons compared with 140,700 tons in 1985. The decrease in sulfur output was due largely to the nonoperation in 1986 of Asarco's Corpus Christi, TX, zinc refinery, which operated for 3 months in 1985.

CONSUMPTION AND USES

Domestic zinc consumption for most end-use categories increased slightly in 1986. The construction industry accounted for an estimated 45% of zinc consumption, followed by transportation, 20%; 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 alloys, 25%; brass and bronze alloys, 10%; rolled zinc, 4%; and other uses, 9%. Of the metal grades consumed, Special High Grade (SHG) accounted for about 50% and was mainly used for the production of zinc-base alloys. The Bureau of the Mint purchased only 13,150 tons of SHG zinc, compared with 28,550 tons in 1985, and produced about 8.9 billion pennies, 2.0 billion less than that of 1985. Prime Western (PW) was second in consumption and was mainly used for hot-dip galvanizing purposes.

According to the U.S. Department of Commerce, Bureau of the Census, domestic producers' shipments of zinc-base die and foundry castings were about 232,000 tons. The estimated distribution of zinc-base castings by weight was about one-third each for automotive, builders' hardware, and other uses.

The average weight of zinc diecastings in the typical 1986 U.S.-built automobile was an estimated 19.7 pounds, according to a Zinc Institute Inc. (ZI) study.[2] This represented a 0.7-pound decline from the 1985 model average weight of 20.4 pounds and an average decline of about 1 pound per year since 1980. The continuing decrease was attributable to continuing weight reduction programs, substitution, the trend away from the use of carburetors in favor of fuel injection systems, and improved zinc diecasting methods. Zinc die-cast usage in the automobile aftermarket or in trucks and vans, not included in the study, were estimated to be 3 to 5 pounds and 15 to 20 pounds, respectively.

In 1986, five new domestic electrogalvanizing facilities, having about 2.2 million tons of electrogalvanized steel sheet capacity, opened mainly to meet the material needs of automobile manufacturers for longerlasting corrosion-resistant steel, and indirectly, to meet the threat of steel substitution by plastics for automobile body parts. At capacity, the new plants were expected to consume about 50,000 tons of zinc in the form of metal granules, shot, and soluble anodes, and as zinc oxide. In 1986, domestic automobile manufacturers increased the amount of zinc used for corrosion-protection purposes. According to a ZI study, the typical U.S.-built, 1986-model automobile contained 8.34 pounds of zinc in the form of galvanized, electrogalvanized, galvannealed, and Zincrometal coated steel.[3] This represented a 1.57-pound gain over the 1985-model average. If zinc-rich paints and a 35% offal factor from coated steel stampings were included, the typical domestic-built 1986-model automobile required an average of 13.83 pounds of zinc for corrosion protection, or for 8 million domestic cars built in that model year, about 50,000 tons of zinc. The average amount of zinc used for automobile corrosion protection was not expected to continue its rapid growth after 1987, owing to substitution, the development of equally effective, lighter weight, or thinner coatings, and the increasing use of zinc alloy coatings, such as zinc-iron.

The trend toward the use of more galvanized and electrogalvanized steel in domestic automobile manufacture and less Zincrometal and zinc-rich paint continued. According to the same ZI report, the typical 1986 model included in its construction 74 pounds of one-sided zinc-coated steel, 205 pounds of two-sided zinc-coated steel, and 65 pounds of Zincrometal; comparative quantities for the 1985 model were 59 pounds, 161 pounds, and 83 pounds, respectively.

Zinc consumption in copper-base alloys by brass mills, ingot makers, and foundries increased about 4% from that of 1985. According to the Copper Development Association Inc., the brass and bronze industry consumed about 268,000 tons of zinc, the source of which was about equally divided between refined zinc metal and brass and bronze scrap metal.[4] Brass mills accounted for more than 87% of the total zinc consumed as metal and scrap.

The apparent consumption of zinc oxide was about 164,000 tons, down from 177,000 tons in 1985. Imports were at record-high levels, whereas domestic production and shipments declined. The rubber industry was the leading consumer of zinc oxide.

STOCKS

Slab zinc stocks held by domestic producers, consumers, and merchants fell as the year progressed, initially because of weak demand and low prices resulting in reduced levels in both producer and merchant stocks. In the latter half of the year, improved demand, higher prices, and tightness in world supply owing mainly to labor-management disputes in Australia and Canada, resulted in low domestic stock levels. However, in December, domestic stock levels rose substantially because of weakening demand coupled with improvement in world supply. Stock levels in the market economy countries, according to the International Lead and Zinc Study Group (ILZSG) followed the same basic pattern as in the United States. Stocks in 1986, as reported by ILZSG, were highest at the end of January, 645,000 tons, and lowest in October, 517,000 tons, and at yearend, stocks were 617,000 tons, about 11,000 tons higher than at the end of 1985.

The London Metal Exchange (LME) stocks of slab zinc in 1986 were substantially lower than typical historical levels mainly because of good demand and reduced availability of High Grade (HG) metal. In the latter half of the year, LME stocks fell substantially, in part because North American producers and merchants took advantage of wide price differentials between the two markets.

Inventories of zinc in ores and concentrates at domestic smelters at yearend totaled 43,800 tons, about the same as at the end of 1985, according to the American Bureau of Metal Statistics Inc. Stocks were highest, 54,000 tons, in August and lowest at yearend.

PRICES

In the first 2 months of 1986, domestic zinc prices continued the downward trend that began in May 1985, culminating in February at the lowest prices in constant dollar terms since the Great Depression of the 1930's. Prices rose slowly in March through May aided, in part, by the closure of a number of domestic zinc mines and declining world slab zinc stocks. Labor-management disputes at smelters in Australia and Canada with the subsequent loss in output fueled a substantial price increase beginning in June. In the summer months, prices continued upward spurred on by further decreases in world stocks, European producer price-support activities on the LME, and uncertainty of supply because of continuing foreign labor disputes. U.S. Mint tenders in July and October for SHG metal for penny production supported the trend toward higher zinc prices. In November, prices weakened mainly as a result of the strike settlement at the zinc refinery in Canada. Prices at the November and December Mint tenders fell, and consumers, anticipating lower prices, reduced their purchases despite substantial discounting from the North American producers quotes.

World zinc prices, which basically are the European producer price (EPP) and the LME price, paralleled U.S. price trends in 1986. The EPP, as quoted in Metal Bulletin, averaged $700 per ton of HG zinc in January, fell to a low of $650 in March, rose to $920 in October, but fell to $604 in December.

American- and French-process lead-free zinc oxide prices at the beginning of the year were quoted in Metals Week at 40 to 51 cents and 41.5 to 53 cents per pound, respectively. In July and October, prices for each were adjusted upward and ended the year at 55 to 57 cents per pound for American-process zinc oxide and 52 to 57 cents for French-process zinc oxide. Photoconductive grades of zinc oxide were generally priced 1 to 3 cents per pound higher than French-process zinc oxide in 1986.

The price quoted in Chemical Marketing Reporter (CMR) for zinc sulfate, granular monohydrate industrial grade, 36% zinc in bags in carload lots, ranged from $26.50 to $32 per 100 pounds. Agricultural zinc sulfate in bulk was quoted by CMR at $20 per 100 pounds until April and $22.50 thereafter. Standard pigment-grade zinc dust, types 1 and 2 in drums, was quoted by CMR at 59 and 67 cents per pound during the year. Technical-grade zinc chloride, 50% solution in tanks, was quoted at $20.20 per 100 pounds.

FOREIGN TRADE

Exports of waste and scrap reached record-high levels, exceeding those of 1985 by more than 50%. Taiwan was the principal importer, accounting for about 70% of the waste and scrap exported.

Slab zinc imports for consumption were at record-high levels, exceeding the record-high quantity imported in 1984 by almost

26,000 tons. Canada accounted for more than one-half of the total imports, followed by Mexico, Spain, Peru, and Australia, which together accounted for about one-quarter of the total. Zinc oxide imports exceeded last year's record high and captured about one-quarter of the domestic market, up slightly from 1985.

General imports of zinc concentrate rose sharply and greatly exceeded the quantities of zinc concentrate imported for consumption. The large increase was due to the reopening of the Faro lead-zinc mine in the Yukon Territory, by Curragh Resources Corp., who exported its production to world markets through Skagway, AK. Imports of zinc concentrate for consumption continued at relatively high levels, mainly because of decreased domestic production; conversely, exports of zinc concentrate fell substantially in 1986.

Table 2.—U.S. import duties for zinc materials, January 1, 1986

Item	TSUS No.	Most favored nation (MFN)		Non-MFN
		Jan. 1, 1986	Jan. 1, 1987	Jan. 1, 1986
Zinc oxide, dry	473.76	0.2% ad valorem	Free	5.5% ad valorem.
Ores and concentrates[1]	602.20	.35 cent per pound on zinc content.	0.3 cent per pound on zinc content.	1.67 cents per pound on zinc content.
Fume	603.50	do	do	Do.
Unwrought, other than alloys	626.02	1.6% ad valorem	1.5% ad valorem	1.75 cents per pound.
Alloys	626.04	19.0% ad valorem	19.0% ad valorem	45.0% ad valorem.
Waste and scrap[1]	626.10	2.5% ad valorem	2.1% ad valorem	11.0% ad valorem.

[1]Duty on zinc ores, concentrates, and zinc-bearing materials was suspended until Dec. 31, 1989, as provided by Public Law 98-573.

WORLD REVIEW

World consumption of zinc metal was an estimated record high 6.8 million tons in 1986, up slightly over the record-high consumption posted in 1985. The market economy countries, according to ILZSG, consumed about 4.9 million tons of zinc metal in 1986 compared with 4.7 million tons in 1985. Most countries recorded modest gains in consumption; the Federal Republic of Germany, the Republic of Korea, and the United States recorded significant increases, whereas in Japan, consumption declined. The Western European countries, the United States, and Japan accounted for about one-half of world consumption.

Despite the record-high consumption, world mine and smelter production declined slightly from the record-high levels of 1985 owing largely to industrial disputes. World mine output was about 6.8 million tons, slightly less than the 6.9 million tons produced in 1985. Canada, China, and Thailand mined significantly more zinc, whereas, the Federal Republic of Germany, Japan, Peru, and the United States mined significantly less zinc. Canada continued to be the principal world producer and, together with Australia, Peru, and the U.S.S.R., accounted for about one-half of world output. World smelter production was about 6.8 million tons in 1986, slightly less than that produced in 1985. Most countries produced at about the same levels as 1985; Brazil, Italy, and the Republic of Korea, each with additions to smelter capacity increased production, whereas Canada, because of strikes, and Japan recorded significant reductions in zinc smelter output. Canada, Japan, and the U.S.S.R. produced about one-third of the world smelter output of zinc in 1986.

World mine capacity (table 35) was about 8.2 million tons, up slightly from that of 1985. New mine openings mainly in Canada, Spain, and the Republic of South Africa accounted for the increase. In the market economy countries, five new zinc mines opened and seven zinc-producing mines closed permanently in 1986. World primary smelter capacity (table 35) was up about 0.1 million tons to 8.2 million tons owing mainly to the opening of a new smelter in the Republic of Korea.

The world zinc supply-demand position shifted toward the demand side as the year progressed, owing mainly to stronger demand from midyear and to a prolonged smelter strike in Canada. Metal stocks in the market economy countries fell steadily as the year progressed from about 644,000 in January to a low of 516,000 tons in October, ending the year at 616,000 tons or about 1 month's world consumption. The stock levels declined even though market economy countries net exports of zinc metal to centrally planned economy countries were only 75,000 tons in 1986 compared with 249,000 tons in 1985. Zinc prices rose as stocks declined, but weakened near yearend when the Canadian strike was settled, demand slackened, and stocks rose.

A number of foreign mining and smelting operations were involved in ownership changes during the year. Major changes occurred in the Canadian zinc industry. Falconbridge Ltd., early in the year, acquired Kidd Creek Mines Ltd. from the Canadian Development Corp. A consortium consisting of Teck Corp., MIM (Canada) Inc., and Metallgesellschaft Canada Ltd. gained control of Cominco Ltd. by buying 31% of the company from Canadian Pacific Enterprises Ltd. Brunswick Mining and Smelting Corp. Ltd. (BMS), 63% owned by Noranda Ltd., acquired Asarco's 25% interest in the Little River joint venture, owner of the Heath Steele lead-zinc mine, which ceased operation in 1983 and was written off by Asarco in 1984. Brunswick was evaluating the property in 1986.

Outokumpu Oy, the Finnish company, acquired Tara Exploration and Development Co. Ltd., owner of 75% of Tara Mines Ltd., which operates the Tara Mine in Ireland, the largest zinc-lead mine in Europe. The Swedish company, Boliden AB, acquired the major interest in the Black Angel zinc-lead mine in Greenland from the Cominco Ltd. subsidiary, Vestgron Mines Ltd. Vestgron had announced its intention to close the mine unless a buyer was found. Other changes included the sale by St. Joe International Corp., a subsidiary of St. Joe Minerals, of its two Peruvian operating mining companies, Compañía Minerales Santander Inc. and Compañía Minera del Madrigal S.A. to Peruvian Enterprises Inc.

Australia.—Australia was the world's third largest mine producer of zinc in 1986; however, production was down about 80,000 tons from 1985 owing largely to strikes and reductions in employment at the Broken Hill zinc-lead mines in New South Wales. Australia Mining & Smelting Ltd. (AM&S) produced 43% less ore at its Broken Hill mines, and the North Broken Hill Group (NBH) milled 13% less ore and treated 57% less dump material at its North Mine at Broken Hill. MIM Holdings Ltd. continued trial stoping at its Hilton Mine in Queensland and planned to gradually increase ore production at the mine to about 2.5 million tons per year over the next 9 years as a second source of millfeed for the company's nearby Mount Isa Mine operations. Ore production at the Mount Isa Mine was expected to gradually decline over the same period despite substantial lead-zinc ore reserves, 49 million tons grading 6.79% zinc, 5.85% lead, and 3.9 ounces of silver per ton. At yearend, the higher grade Hilton ore reserves were estimated to be 72 million tons averaging 10.16% zinc, 6.41% lead, and 7.7 ounces of silver per ton. In the fiscal year ending June 30, 1986, MIM milled about 5 million tons of zinc-lead-silver ore produced at the Mount Isa Mine, yielding a record-high 205,000 tons of zinc in concentrate.

AM&S completed expansion programs at its Cobar copper-zinc-lead-silver mine increasing its annual zinc production capacity to about 23,000 tons, up 8,000 tons. AM&S virtually ceased open pit mining at the Woodland Mine in New South Wales by yearend and commenced underground mining though at a rate lower than the previous pit-mining rate. Underground ore reserves, about 1.9 million tons averaging 12% zinc, 5% lead, 1.3% copper, and 3.2 ounces of silver per ton, were sufficient for about 4 year's operation.

Aberfoyle Ltd., 47% owned by Cominco Ltd., planned to bring its Hellyer zinc-lead-silver deposit in Tasmania into production in February 1987. Plans called for the milling of 250,000 tons of ore per year producing 80,000 tons of bulk concentrate at the company's nearby converted and upgraded Cleveland tin mill. The estimated in situ ore reserves at Hellyer totaled about 15 million tons averaging 22.8% zinc, 6.4% lead, and 3.9 ounces of silver per ton.

For the fiscal year ending June 30, 1986, NBH milled a record high 1.2 million tons of ore from its Elura Mine, producing 84,900 tons of zinc in 179,400 tons of zinc concentrate. At the end of the fiscal year, ore reserves at the Elura Mine were about 25.7 million tons averaging 8.6% zinc, 6.1% lead, and 3.4 ounces of silver per ton. NBH also produced 90,600 tons of zinc in 176,000 tons of concentrate at its West Coast operations in Tasmania. About one-third of the feed for this production was purchased from Aberfoyle's Que River Mine, which has no mill. Ore reserves at the West Coast mines were increased substantially and, at the end of fiscal year 1986, totaled about 7.7 million tons averaging about 16.0% zinc, 5.0% lead, 0.65% copper, 3.7 ounces of silver per ton, and some gold.

Canada.—Canada was the world's leading producer of mined zinc, accounting for about 19% of total world output. Four mines—BMS's No. 12 Mine in New Brunswick; Falconbridge's Kidd Creek Mine at Timmins, Ontario; and Cominco Ltd.'s Polaris Mine on Little Cornwallis and the Pine Point Mine, both in the Northwest Territories, accounted for over 60% of Canadian zinc production. The two largest producing mines were Cominco Ltd.'s Pine Point and BMS's No. 12. Pine Point Mines, 50% owned by Cominco Ltd., accelerated production at the Pine Point Mine, producing record quantities of lead and zinc in concentrate. The company milled about 3.0 million tons of ore averaging 8.7% zinc and 4.1% lead yielding 238,800 tons of zinc in concentrate compared with 2.1 million tons milled yielding 161,400 tons of zinc in concentrate in 1985. Plans called for mining operations at the Pine Point Mine to cease by July 1987 and milling to end by yearend 1987. As a result, ore reserves likely to be mined and milled in 1987 were 3.4 million tons averaging 9.6% zinc and 3.5% lead. Excess concentrate output was expected to be stockpiled for consumption at Cominco Ltd.'s Trail, British Columbia, smelter in future years. In 1986, BMS milled 3.4 million tons of ore at its No. 12 Mine producing 238,100 tons of zinc in concentrate, up slightly from that of 1985. At yearend, proven ore reserves totaled 78.6 million tons grading 8.95% zinc, 3.64% lead, 0.31% copper, and 2.5 ounces of silver per ton. An additional 23 million tons of similar grade probable ore was also identified.

Kidd Creek mined about 4.1 million tons of copper-zinc-lead-silver ores at Timmins, about the same as in 1985, producing an estimated 210,000 tons of zinc. Zinc concentrate produced for sale totaled 76,500 compared with 165,200 tons in 1985. Zinc smelter output at the company's Timmins smelter was 133,500 tons, up from 127,700 in 1985. Cominco Ltd.'s ore production at the Polaris Mine fell slightly to 0.9 million tons because of a 6-week shutdown to control concentrate inventory levels. In 1986, Cominco Ltd. produced 114,400 tons of zinc in concentrate at the Polaris operations compared with 117,000 tons in 1985. At yearend, ore reserves were 18.1 million tons averaging 14.5% zinc and 3.9% lead.

In June, Curragh reopened the Faro Mine, which had been closed since 1982, and in July began shipments of zinc concentrate to Skagway, AK. In 1986, 122,000 tons of zinc contained in about 230,000 tons of concentrate were shipped through Skagway to world markets. In 1987, zinc output in concentrate was expected to increase to about 170,000 tons, and lead in concentrate, to about 120,000 tons.

Sherritt Gordon Mines Ltd. wrote down the value of its Ruttan copper-zinc mine in Manitoba and planned to either close down the mine or sell it in 1987. Sherritt Gordon produced about 11,000 tons of zinc in concentrate in 1986. Corporation Falconbridge Copper announced it was proceeding with the development of its Winston Lake zinc-copper deposit in northwest Ontario. The project was suspended in 1985 because of poor economic conditions. Plans called for production to start in early 1988 with an annual capacity of 57,500 tons of zinc in concentrate. Ore reserves were estimated to be 2.2 million tons averaging 18% zinc, 1.1% copper, and significant precious metal values. Another high-grade zinc deposit, 2.1 million tons of ore reserves grading 22.4% zinc, 1.23% copper, and 2.7 ounces of silver per ton, was under development at Isle Dieu, Quebec. Noranda planned to bring the deposit into production in 1988 mainly to replace declining production at its nearby Mattagami Mine. An annual production of 50,000 tons of zinc in concentrate was envisioned.

Canadian zinc smelter production fell about 120,000 tons in 1986, owing largely to a 5-month strike at Noranda's 230,000-ton-per-year smelter at Valleyfield, Quebec. Production at Cominco Ltd.'s Trail, British Columbia, 272,000-ton-per-year zinc smelter was also off about 20,700 tons in 1986, owing to a 1-month shutdown in August because of an oversupply in the zinc market.

Japan.—The Japanese zinc industry, affected mainly by high costs associated with the marked strengthening of the yen against the U.S. dollar, reduced output and closed down operations at both mines and smelters in 1986. Three zinc-producing mines and three smelters, including the 116,000-ton-per-year Miike smelter owned by Mitsui Mining & Smelting Co. Ltd., were closed indefinitely. Japanese smelter output compared with that of 1985, however, was not severely affected by the smelter closures because Mitsui contracted to have Miike concentrates toll-smelted at other domestic smelters with excess production capacity.

Spain.—Exploracíon Minera Internacional España S.A. (EXMINESA), operators of the Rubiales zinc-lead mine in Lugo Province, milled 0.8 million tons of ore, about 18% less than in 1985, yielding about 51,000 tons of zinc and about 8,900 tons of lead in concentrates in 1986. Mining and labor difficulties contributed to the production decline. At yearend, EXMINESA estimated the ore reserves at the Rubiales Mine to be 6.4 million tons averaging 6.8% zinc, 1.1% lead, and 0.36 ounce of silver per ton.

EXMINESA began the production startup phase at its Troya zinc-lead mine in November, and in the last 2 months of 1986, milled 22,000 tons of ore grading 12.4% zinc and 0.8% lead. The company planned to be at full production by July 1987, producing at an annual rate of 31,000 tons of zinc and 2,000 tons of lead in concentrate. Ore reserves were estimated to total 2.2 million tons averaging 12.0% zinc and 1.0% lead.

U.S.S.R.—Snamprogetti S.p.A., the engineering subsidiary of Italian state-owned company Ente Nazionale Idrocarburi, was awarded a $60 million contract to supply engineering, equipment, and construction supervision for the construction of a 200,000-ton-per-year electrolytic zinc refinery at Celiabinsk in western Siberia. The new plant, expected to be completed in 1989, was believed to be a replacement for an old but operating 150,000-ton-per-year zinc plant built on the site in 1935.

TECHNOLOGY

The Bureau of Mines investigated the use of waste products containing zinc as a source of zinc for electrogalvanizing.[5] Lead smelter flue dust, wastewater treatment sludge, copper smelter flue dust, and brass smelter flue dust were used in the investigation. After zinc extraction with sulfuric acid, zinc solutions were used to electrogalvanize 1070 steel alloy wire. Corrosion tests conducted on waste-derived electrogalvanized coatings on wire compared favorably with coatings on commercially produced wire.

The Bureau also developed a cyclic voltammetry technique to monitor the active concentration of liquorice and other polarizing additives in zinc electrolytes.[6] Because these additives influence the quality of electrogalvanizing coatings, better monitoring could result in superior coatings and improved corrosion resistance.

A hydrometallurgical procedure was developed by the Bureau to recover gold, silver, and byproduct zinc and lead from complex lead-zinc sulfide ore that typically cannot be handled by existing smelters or is too costly to process economically.[7] The procedure involved a ferric chloride preleach to extract 50% of the zinc, followed by acid thiourea leaching to extract gold and silver and a NaCl brine leach to recover the lead electrolytically.

A Bureau of Mines handbook providing a methodology for developing capital and operating costs for electrolytic zinc refining facilities was prepared.[8] The costs developed were for a mid-U.S. location with the methodology prepared to allow translation of costs worldwide. Costs for environmental and alternative unit processes were also identified.

Tests conducted on unpainted, zinc-alloy electroplated steel sheets indicated that the corrosion resistance of zinc-manganese alloys containing 30% to 50% manganese was superior to those of conventional zinc, zinc-nickel, and zinc-iron alloys.[9] The high level of resistance to corrosion was attributed to the formation of a fine, dense, and adherent film of manganese oxide. The zinc-manganese alloy electroplated sheet was expected to find use mainly in automobile manufacture.

The world's first water-atomized zinc dust production unit was installed at Canadian Electrolytic Zinc Ltd.'s Valleyfield, Quebec, zinc refinery and was expected to result in a 30% reduction in zinc dust consumption for electrolyte purification at the refinery.[10] Reduced consumption was attributed to the fact that water-atomized zinc dust particles were jagged with no oxide coatings owing to rapid quenching and as a result have greater surface area for cementation reactions than the typical air-atomized zinc dust particles, which are smooth, spherical, and somewhat oxidized on their surfaces.

A comprehensive coverage of zinc-related investigations and an extensive review of current world literature on zinc extraction, alloys, uses, products, and research was published in quarterly issues of Zinc Abstracts, renamed Zincscan at the end of 1986, issued by the Zinc Development Association, London, the United Kingdom.[11]

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[1]Physical scientist, Division of Nonferrous Metals.
[2]Zinc Institute. U.S. Automotive Market for Zinc Die Castings 1984-1986. 1986, 2 pp.

[3]Zinc Institute. U.S. Automotive Market for Zinc Coatings 1984-1986. 1986, 3 pp.

[4]Copper Development Association Inc. Annual Data 1987, Copper Supply & Consumption 1966-1986. 1986, 20 pp.

[5]Dattilo, M., E. R. Cole, Jr., and T. J. O'Keefe. Electrogalvanizing Using Zinc Recovered From Nonferrous Smelter Dusts. Conserv. & Recycl., v. 9, No. 1, 1986, pp. 55-66.

[6]O'Keefe, T. J., S. F. Chen, E. R. Cole, Jr., and M. Dattilo. Electrochemical Monitoring of Electrogalvanizing Solutions. J. Appl. Electrochem., v. 16, No. 6, Nov. 1986, pp. 913-919.

[7]Sandberg, R. G., and J. L. Huiatt. Recovery of Silver, Gold, and Lead From a Complex Sulfide Ore Using Ferric Chloride, Thiourea, and Brine Leach Solutions. BuMines RI 9022, 1986, 14 pp.

[8]Neider, R. F. Capital and Operating Cost Estimating System Handbook for Electrolytic Zinc Refining Facilities. BuMines OFR 82-86, 199 pp.; NTIS PB 86-246584.

[9]Sagiyama, M., T. Urakawa, T. Adaniya, and T. Hara. Zinc-Manganese Alloy Electroplated Steel for Automotive Body. Pres. at SAE Intl. Congr. and Exposition, Detroit, MI, Feb. 24-28, 1986; available as SAE Tech. Paper 860268 from Soc. Automotive Eng., 400 Commonwealth Drive, Warrendale, PA 15096.

[10]Leroux, G., and J. P. St-Onge. Wet Zinc Dust Atomization. J. Met., v. 8, Aug. 1986, pp. 46-48.

[11]Zinc Development Association. Zinc Abstracts. V. 44, Nos. 1-3, 1986, 209 pp.

Table 3.—Mine production of recoverable zinc in the United States, by month

(Metric tons)

Month	1985	1986
January	20,500	20,606
February	22,722	18,617
March	24,527	19,790
April	18,552	15,472
May	19,694	12,358
June	19,366	14,382
July	14,459	16,724
August	14,781	15,510
September	15,458	16,726
October	19,926	19,576
November	16,958	15,355
December	19,602	17,867
Total	226,545	202,983

Table 4.—Mine production of recoverable zinc in the United States, by State

(Metric tons)

State	1982	1983	1984	1985	1986
Colorado	W	W	W	W	W
Idaho	W	W	W	W	351
Illinois	W	W	W	W	W
Kentucky	W	W	W	W	--
Missouri	63,680	57,044	45,458	49,340	37,919
Montana	W	--	--	--	--
New Jersey	16,800	16,475	W	W	W
New York	52,237	56,748	W	W	W
Pennsylvania	24,762	16,792	--	--	--
Tennessee	121,306	109,958	116,526	104,471	102,118
Utah	--	--	W	--	--
Total	303,160	275,294	252,768	226,545	202,983

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

Table 5.—Production of zinc and lead in the United States in 1986, by State and class of ore, from old tailings, etc., in terms of recoverable metals

(Metric tons)

State	Zinc ore			Lead ore			Zinc-lead ore		
	Gross weight (dry basis)	Zinc	Lead	Gross weight (dry basis)	Zinc	Lead	Gross weight (dry basis)	Zinc	Lead
Arizona	--	--	--	--	--	--	--	--	--
Colorado	W	W	W	--	--	--	--	--	--
Idaho	--	--	--	--	--	--	--	--	--
Illinois	--	--	--	--	--	--	--	--	--
Missouri	--	--	--	3,335,823	26,086	229,432	705,431	10,147	50,718
Montana	--	--	--	--	--	--	--	--	--
New Jersey	W	W	--	--	--	--	--	--	--
New Mexico	--	--	--	--	--	--	--	--	--
New York	W	W	W	--	--	--	--	--	--
Tennessee	W	W	--	--	--	--	--	--	--
Total	4,152,848	156,400	([1])	3,335,823	26,086	229,432	705,431	10,147	50,718
Percent of total zinc or lead	XX	77	([1])	XX	13	67	XX	5	15

State	Copper-zinc, copper-lead, copper-zinc-lead ores			All other sources[2] [3]			Total		
	Gross weight (dry basis)	Zinc	Lead	Gross weight (dry basis)	Zinc	Lead	Gross weight (dry basis)	Zinc	Lead
Arizona	--	--	--	W	--	W	W	--	W
Colorado	--	--	--	139,953	W	2,368	W	W	W
Idaho	--	--	--	487,077	351	9,951	487,077	351	9,951
Illinois	--	--	--	--	W	W	--	W	W
Missouri	1,054,193	1,686	39,750	--	--	--	5,095,447	37,919	319,900
Montana	--	--	--	W	--	W	W	--	W
New Jersey	--	--	--	--	--	--	W	W	--
New Mexico	--	--	--	17,387	--	10	17,387	--	10
New York	--	--	--	--	--	--	W	W	W
Tennessee	W	W	--	--	--	--	5,180,028	102,118	--
Total	([1])	([1])	39,750	13,911,456	10,350	19,893	22,105,558	202,983	339,793
Percent of total zinc or lead	XX	([1])	12	XX	5	6	XX	100	100

W Withheld to avoid disclosing company proprietary data; included in "Total." XX Not applicable.
[1]Included with "All other sources" to avoid disclosing company proprietary data.
[2]Includes zinc and lead recovered from copper, gold, and silver ores, from fluorspar, and from mill tailings.
[3]Excludes tonnages of fluorspar in Illinois from which zinc and lead were recovered as byproducts.

Table 6.—Twenty-five leading zinc-producing mines in the United States in 1986, 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	St. Joe Resources Co	Do.
3	Zinc Mine Works	Jefferson, TN	USX Corp	Do.
4	Young	do	ASARCO Incorporated	Do.
5	Immel	Knox, TN	do	Do.
6	Leadville Unit	Lake, CO	do	Lead-zinc ore.
7	Balmat	St. Lawrence, NY	St. Joe Resources Co	Zinc ore.
8	Magmont	Iron, MO	Cominco American Incorporated.	Lead ore.
9	Buick	do	The Doe Run Co	Lead-zinc ore.
10	West Fork	Reynolds, MO	ASARCO Incorporated	Lead ore.
11	Coy	Jefferson, TN	do	Zinc ore.
12	Fletcher	Reynolds, MO	The Doe Run Co	Lead ore.
13	New Market	Jefferson, TN	ASARCO Incorporated	Zinc ore.
14	Viburnum No. 29	Washington, MO	The Doe Run Co	Lead ore.
15	Sterling	Sussex, NJ	The New Jersey Zinc Co. Inc	Zinc ore.
16	Rosiclare	Hardin and Pope, IL.	Ozark-Mahoning Co	Fluorspar.
17	Sunnyside	San Juan, CO	Sunnyside Gold Corp	Gold ore.
18	Casteel	Iron, MO	The Doe Run Co	Copper-lead ore.
19	Copperhill	Polk, TN	Tennessee Chemicals Co	Copper-zinc ore.
20	Viburnum No. 28	Iron, MO	The Doe Run Co	Lead ore.
21	Lucky Friday	Shoshone, ID	Hecla Mining Co	Silver ore.
22	Black Pine	Granite, MT	Black Pine Mining Co	Do.
23	Center	Grant, NM	Mount Royal Mining & Exploration.	Gold ore.
24	Clayton	Custer, ID	Clayton Silver Mines Inc	Silver ore.
25	Yankee Fork	Duray, CO	U.S. Antimony Corp	Gold ore.

Table 7.—Primary and redistilled secondary slab zinc produced in the United States

(Metric tons)

	1982	1983	1984	1985	1986
Primary:					
From domestic ores	193,284	210,315	197,912	r198,003	191,079
From foreign ores	34,892	25,379	55,220	63,204	62,288
Total	228,176	235,694	253,132	r261,207	253,367
Secondary:					
At primary smelters	42,418	40,545	44,930	r39,723	49,852
At secondary smelters	31,870	28,845	33,183	32,844	13,062
Total	74,288	69,390	78,113	r72,567	62,914
Grand total (excludes zinc recovered by remelting)	302,464	305,084	331,245	r333,774	316,281

rRevised.

Table 8.—Distilled and electrolytic zinc, primary and secondary, produced in the United States, by grade

(Metric tons)

Grade	1982	1983	1984	1985	1986
Special High	112,648	95,395	123,325	98,282	78,978
High	31,076	78,511	71,892	r98,979	84,738
Continuous Galvanizing	57,739	50,661	48,200	26,139	20,589
Controlled Lead	7,612	10,231	9,384	20,952	18,883
Prime Western	93,389	70,286	78,444	r89,422	113,093
Total	302,464	305,084	331,245	r333,774	316,281

rRevised.

Table 9.—Annual slab zinc capacity of primary zinc plants in the United States, by type of plant and company

Type of plant and company	Plant location	Slab zinc capacity (metric tons) 1985	1986
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
St. Joe Resources Co	Bartlesville, OK	51,000	51,000
Electrothermic:			
St. Joe Resources Co	Monaca, PA	91,000	91,000

[1]Zinc plant reopened in May 1984 closed indefinitely in Apr. 1985.

Table 10.—Secondary slab zinc plant capacity in the United States, by company

Company	Plant location	Capacity (metric tons) 1985	1986
W. J. Bullock Inc	Fairfield, AL	r65,000	65,000
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		
The New Jersey Zinc Co. Inc	Palmerton, PA		
Pacific Smelting Co	Torrance, CA		
Do	Memphis, TN		

rRevised.

Table 11.—Stocks and consumption of new and old zinc scrap in the United States in 1986, by type of scrap

(Metric tons, zinc content)

Type of scrap	Stocks, Jan. 1	Receipts	Consumption: New scrap	Consumption: Old scrap	Consumption: Total	Stocks, Dec. 31
Diecastings	1,103	5,518	--	5,839	5,839	782
Flue dust	3,748	26,487	21,403	5,351	26,754	3,481
Fragmentized diecastings	2,966	29,011	--	28,285	28,285	3,692
Galvanizer's dross	9,807	32,066	32,642	--	32,642	9,231
Old zinc[1]	1,125	3,967	--	4,867	4,867	225
Remelt die-cast slab	504	11,408	--	11,203	11,203	709
Remelt zinc[2]	161	3,044	3,157	--	3,157	48
Skimmings and ashes[3]	29,807	79,145	87,918	--	87,918	21,034
Other[4]	W	5,388	5,388	--	5,388	W
Total	49,221	196,034	150,508	55,545	206,053	39,202

W Withheld to avoid disclosing company proprietary data.
[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 12.—Production of zinc products from zinc-base scrap in the United States

(Metric tons)

Product	1982	1983	1984	1985	1986
Redistilled slab zinc	74,288	69,390	78,113	[r]72,567	62,914
Zinc dust	25,296	34,773	[r]35,254	[r]27,115	24,295
Remelt zinc	69	66	71	--	--
Remelt die-cast slab	3,905	3,109	3,380	3,059	1,814
Zinc die and diecasting alloys	5,366	6,535	6,112	5,667	4,184
Galvanizing stocks	2,507	2,801	2,368	W	W
Secondary zinc in chemical products	61,827	59,085	66,221	[r]56,109	64,378

[r]Revised. W Withheld to avoid disclosing company proprietary data.

Table 13.—Zinc recovered from scrap processed in the United States, by kind of scrap and form of recovery

(Metric tons)

	1985	1986
KIND OF SCRAP		
New scrap:		
Zinc-base	[r]161,268	155,859
Copper-base	[r]116,439	111,193
Magnesium-base	68	41
Total	[r]277,775	267,093
Old scrap:		
Zinc-base	[r]50,615	50,193
Copper-base	[r]18,125	20,236
Aluminum-base	294	336
Magnesium-base	214	163
Total	[r]69,248	70,928
Grand total	[r]347,023	338,021
FORM OF RECOVERY		
As metal:		
By distillation:		
Slab zinc[1]	[r]72,567	62,914
Zinc dust	[r]27,115	24,295
By remelting	1,112	1,300
Total	[r]100,794	88,509

See footnotes at end of table.

Table 13.—Zinc recovered from scrap processed in the United States, by kind of scrap and form of recovery —Continued

(Metric tons)

	1985	1986
FORM OF RECOVERY —Continued		
In zinc-base alloys	8,726	5,998
In brass and bronze	r180,780	178,582
In aluminum-base alloys	332	350
In magnesium-base alloys	282	204
In chemical products:		
Zinc oxide (lead free)	r32,337	38,422
Zinc sulfate	15,506	20,524
Zinc chloride	7,841	4,797
Miscellaneous	425	635
Total	r246,229	249,512
Grand total	r347,023	338,021

rRevised.
[1]Includes zinc content of redistilled slab made from remelt die-cast slab.

Table 14.—U.S. production of zinc dust[1]

Year	Quantity (metric tons)	Value	
		Total (thousands)	Average per pound
1982	37,516	$49,327	$0.596
1983	40,508	45,849	.513
1984	r41,044	r59,902	.662
1985	r30,813	r38,721	.570
1986	27,247	33,039	.550

rRevised.
[1]Does not include zinc dust produced for internal plant use.

Table 15.—U.S. consumption of zinc

(Metric tons)

	1982	1983	1984	1985	1986
Slab zinc, apparent	r794,536	r933,371	r980,226	r961,396	998,638
Ores and concentrates (zinc content)[1]	35,515	38,287	47,637	42,284	21,851
Secondary (zinc content)[2]	208,105	276,370	318,018	r278,710	273,807
Total[3]	1,038,156	1,248,028	1,345,881	1,282,390	1,294,296

rRevised.
[1]Includes ore used directly in galvanizing.
[2]Excludes redistilled slab and remelt zinc.
[3]Data have been revised based on apparent consumption; previously based on reported consumption.

Table 16.—U.S. reported consumption of slab zinc in 1986, by industry and grade

(Metric tons)

Industry	Special High Grade	High Grade	Continuous Galvanizing Grade	Controlled Lead Grade	Prime Western	Remelt	Total
Galvanizing	80,930	65,632	35,004	24,784	158,482	1,119	365,951
Zinc-base alloys	39,282	19,186	22	11	9,573	5,607	73,681
Brass and bronze	159,100	2,413	--	--	13,495	102	175,110
Rolled zinc	16,052	--	--	12,545	--	--	28,597
Zinc oxide	40,061	--	--	--	--	--	40,061
Other	18,013	1,906	--	--	424	2,220	22,563
Total	353,438	89,137	35,026	37,340	181,974	9,048	705,963

Table 17.—U.S. reported consumption of slab zinc, by industry and product

(Metric tons)

Industry and product	1982	1983	1984	1985	1986
Galvanizing:					
Sheet and strip	204,519	230,541	222,872	226,489	241,872
Wire and wire rope	17,180	18,328	18,430	14,437	13,090
Tubes and pipe	34,322	34,907	39,463	27,580	20,745
Fittings (for tubes and pipe)	5,707	5,990	4,446	3,830	3,025
Tanks and containers	6,507	4,195	4,044	5,442	3,537
Structural shapes	28,816	29,822	35,494	r32,350	32,484
Fasteners	2,898	2,614	2,518	6,411	4,208
Pole-line hardware	2,955	3,013	3,326	3,755	1,904
Fencing, wire cloth, netting	17,330	15,916	12,644	13,319	10,953
Other and unspecified uses	21,810	27,853	32,386	r28,814	34,133
Total	342,044	373,179	375,623	r362,427	365,951
Brass and bronze products:					
Sheet, strip, plate	31,718	43,083	55,583	30,487	25,906
Rod and wire	26,551	32,387	34,231	17,814	15,065
Tubes	3,465	4,058	4,750	2,705	2,093
Castings and billets	2,211	7,499	9,726	12,183	15,979
Copper-base ingots	13,278	16,405	19,446	13,986	13,635
Other copper-base products	3,915	4,503	1,858	745	1,003
Total	81,138	107,935	125,594	77,920	73,681
Zinc-base alloys:					
Diecasting alloys	191,607	204,820	216,306	r205,457	163,957
Dies and rod alloys	--	--	1,666	2,552	3,068
Slush and sand-casting alloys	6,147	8,071	14,660	10,373	8,085
Total	197,754	212,891	232,632	r218,382	175,110
Rolled zinc[1]	37,168	56,291	56,886	48,020	28,597
Zinc oxide	32,374	36,201	37,038	r44,438	40,061
Other:					
Light-metal alloys	8,326	12,538	14,922	15,204	13,007
Miscellaneous[2]	10,687	6,856	6,208	4,280	9,556
Total	19,013	19,394	21,130	19,484	22,563
Grand total	709,491	805,891	848,903	r770,671	705,963

rRevised.
[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 mentioned.

Table 18.—U.S. reported consumption of slab zinc in 1986, by State

(Metric tons)

State	Galvanizers	Brass mills[1]	Diecasters[2]	Other[3]	Total
Alabama	W	W	--	--	9,724
Arkansas	W	--	--	W	W
California	6,954	W	--	W	11,057
Colorado	W	--	W	--	W
Connecticut	2,194	2,587	W	W	9,930
Delaware	W	--	--	--	W
Florida	W	--	--	--	W
Georgia	W	--	W	--	6,562
Hawaii	W	--	--	--	W
Illinois	63,195	16,244	21,650	7,128	108,217
Indiana	41,580	W	W	W	49,583
Iowa	W	--	W	W	W
Kansas	--	--	W	--	W
Kentucky	15,428	--	--	--	15,428
Louisiana	W	--	W	--	2,346
Maryland	10,667	--	--	--	10,667
Massachusetts	2,853	W	--	W	3,510
Michigan	W	10,175	41,730	W	56,685
Minnesota	343	--	--	--	343
Mississippi	W	--	--	--	W
Missouri	W	--	--	W	3,507
Nebraska	W	--	--	W	4,739
New Jersey	1,083	W	--	W	2,511
New York	3,348	W	62,149	W	85,961
North Carolina	W	--	W	W	W

See footnotes at end of table.

Table 18.—U.S. reported consumption of slab zinc in 1986, by State —Continued

(Metric tons)

State	Galva-nizers	Brass mills[1]	Die-casters[2]	Other[3]	Total
Ohio	38,644	W	32,970	W	79,863
Oklahoma	W	--	--	W	2,777
Oregon	W	--	W	W	859
Pennsylvania	101,274	W	W	31,738	138,784
South Carolina	W	--	W	--	W
Tennessee	1,924	--	W	W	28,065
Texas	9,431	--	W	W	9,520
Utah	W	--	--	--	W
Virginia	W	W	W	--	4,676
Washington	W	--	--	W	968
West Virginia	W	--	--	W	23,533
Wisconsin	744	W	W	W	8,984
Undistributed	65,170	39,068	16,509	50,135	18,116
Total[4]	364,832	68,074	175,008	89,001	696,915

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 19.—Rolled zinc produced and quantity available for consumption in the United States

(Metric tons)

	1985[r]	1986
Production[1]	46,641	34,316
Exports	776	721
Imports for consumption	3,559	3,811
Available for consumption	50,735	42,737

[r]Revised.
[1]Includes other plate over 0.375 inch thick, and rod and wire.

Table 20.—Production and shipments of zinc pigments and compounds[1] in the United States

(Metric tons)

	1985[r]		1986	
	Production	Shipments	Production	Shipments
Zinc oxide	137,418	136,166	120,448	121,480
Zinc sulfate	42,316	42,509	55,221	53,796
Zinc chloride[2]	14,668	14,322	16,214	13,216

[r]Revised.
[1]Excludes leaded zinc oxide and lithopone.
[2]Includes zinc content of zinc ammonium chloride.

Table 21.—Zinc content of zinc pigments[1] and compounds produced by domestic manufacturers, by source

(Metric tons)

	1985				1986			
	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	38,168	39,662	32,036	109,866	17,311	40,585	38,422	96,318
Zinc sulfate	W	--	17,138	17,138	W	--	22,363	22,363
Zinc chloride[2]	--	--	[r]6,961	[r]6,961	--	--	7,690	7,690

[r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Secondary material."
[1]Excludes leaded zinc oxide, zinc sulfate, and lithopone.
[2]Includes zinc content of zinc ammonium chloride.

Table 22.—Distribution of zinc oxide shipments, by industry

(Metric tons)

Industry	1982	1983	1984	1985[r]	1986
Agriculture	3,929	2,569	2,380	2,575	3,910
Ceramics	5,215	5,987	7,472	7,286	5,012
Chemicals	19,432	19,217	23,611	22,477	22,704
Paints	9,283	9,716	8,117	8,215	10,797
Photocopying	9,516	10,239	9,246	8,324	W
Rubber	62,923	67,971	79,390	71,574	70,307
Other	17,136	19,355	16,702	15,715	8,750
Total	127,434	135,054	146,918	136,166	121,480

[r]Revised. W Withheld to avoid disclosing company proprietary data; included in "Other."

Table 23.—Distribution of zinc sulfate shipments

(Metric tons)

Year	Agriculture	Other	Total
1983	29,373	5,613	34,986
1984	28,162	8,950	37,112
1985	33,786	8,723	42,509
1986	45,965	7,831	53,796

Table 24.—Stocks of slab zinc in the United States, December 31

(Metric tons)

	1982	1983	1984	1985	1986
Primary producers	30,381	20,750	42,025	29,030	16,722
Secondary producers	3,831	3,149	4,303	3,389	3,203
Consumers	77,565	89,041	72,506	[r]60,310	54,239
Merchants	47,397	35,199	18,792	27,163	26,559
Total	159,174	148,139	137,626	[r]119,892	100,723

[r]Revised.

Table 25.—Average monthly U.S., LME,[1] and European producer prices for equivalent zinc

(Metallic zinc, cents per pound)

Month	1985			1986		
	United States[2]	LME cash	European producer	United States[2]	LME cash	European producer
January	42.94	39.20	40.82	32.87	29.18	31.75
February	42.65	40.14	40.82	30.88	27.58	30.08
March	43.20	41.70	41.90	31.22	28.35	29.48
April	44.88	42.14	43.54	32.13	29.91	31.34
May	45.12	39.87	42.99	32.97	32.06	33.24
June	43.73	36.56	40.48	36.54	36.45	37.24
July	41.44	34.70	38.06	39.55	36.58	38.10
August	39.84	33.29	37.14	40.83	37.01	38.53
September	37.86	31.24	35.38	43.70	39.48	40.95
October	35.76	[3]28.62	33.53	45.98	40.17	41.73
November	33.36	27.06	30.10	45.78	37.17	40.59
December	33.61	31.05	30.56	43.51	36.18	39.46
Average	40.37	36.23	37.94	38.00	34.19	38.04

[1]London Metal Exchange.
[2]Based on High Grade zinc delivered.
[3]Contract changed to High Grade from Good Ordinary Brand basis.

Source: Metals Week.

Table 26.—U.S. exports of zinc and zinc alloys, by country

Country	1984		1985		1986	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Unwrought zinc and zinc alloys:						
Belgium-Luxembourg	([1])	$1	20	$22	5	$18
Canada	88	222	432	925	1,081	2,550
Chile	398	419	501	451	([1])	3
Egypt	1	4	255	250	--	--
Finland	--	--	--	--	33	31
Germany, Federal Republic of	16	35	21	18	9	33
Ghana	--	--	26	26	--	--
India	--	--	48	62	34	32
Israel	1	3	25	56	--	--
Jamaica	--	--	--	--	59	50
Japan	166	220	37	73	27	72
Korea, Republic of	108	96	87	98	431	774
Malaysia	--	--	--	--	11	8
Mexico	73	137	79	207	93	133
Netherlands	([1])	1	27	67	11	19
Panama	40	63	5	9	32	52
Salvador	--	--	3	4	21	22
Spain	22	24			6	14
Switzerland	2	6	1	1	21	63
Taiwan	361	332	618	463	1,610	1,074
Trinidad	--	--	--	--	17	19
United Kingdom	8	34	12	40	1	11
Venezuela	2	4	20	63	--	--
Other[2]	[r]62	[r]197	[r]37	[r]95	46	205
Total	1,348	1,798	[r]2,254	[r]2,930	3,548	5,183
Wrought zinc and zinc alloys:						
Argentina	19	53	17	47	8	21
Australia	6	13	1	2	10	16
Bahamas	46	53	41	52	10	21
Brazil	37	71	--	--	1	5
Canada	769	1,571	1,379	2,085	1,300	1,599
Chile	--	--	11	80	3	7
Colombia	24	56	13	56	10	26
Costa Rica	2	4	1	2	200	90
Dominican Republic	8	29	11	45	1	10
Ecuador	12	35	20	41	13	23
Egypt	1	4	6	17	--	--
El Salvador	3	14	6	18	10	41
France	4	6	23	69	--	--
Guyana	5	9	4	11	1	2
India	19	21	--	--	18	11
Germany, Federal Republic of	1	1	2	3	49	84
Japan	15	25	9	24	47	108
Korea, Republic of	([1])	2	14	34	2	3
Leeward and Windward Islands	43	33	1	1	34	48
Mexico	387	932	397	821	288	613
Netherlands Antilles	19	23	6	4	6	12
Pakistan	1	4	--	--	6	11
Panama	4	10	20	41	2	12
Philippines	12	33	3	9	24	54
Saudi Arabia	9	16	2	24	--	--
Singapore	3	15	1	1	--	--
South Africa, Republic of	95	203	11	26	8	24
Spain	--	--	--	--	20	11
Switzerland	46	130	17	63	--	--
Taiwan	92	177	34	83	20	42
Trinidad and Tobago	15	42	27	35	1	5
United Kingdom	33	142	48	41	75	158
Venezuela	4	21	33	182	40	56
Zimbabwe	36	79	--	--	--	--
Other[3]	[r]45	[r]120	[r]52	[r]154	45	106
Total	1,815	3,947	2,210	4,071	2,252	3,219

[r]Revised.
[1]Less than 1/2 unit.
[2]Includes Argentina, Australia, Barbados, Costa Rica, Dominican Republic, Ecuador, El Salvador, France, Guatemala, Honduras, Hong Kong, Italy, Leeward and Windward Islands, Libya, Netherlands Antilles, New Zealand, Peru, Philippines, Saudia Arabia, Singapore, the Republic of South Africa, and the United Arab Emirates.
[3]Includes Austria, Belgium-Luxembourg, Belize, Bermuda, China, Denmark, Finland, French Guiana, Ghana, Guatemala, Hong Kong, Iran, Israel, Italy, Jamaica, Kuwait, Libya, Morocco, 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 27.—U.S. exports of zinc

Year	Ores and concentrates: Quantity (metric tons)	Ores and concentrates: Value (thousands)	Blocks, pigs, anodes, etc.: Unwrought: Quantity (metric tons)	Blocks, pigs, anodes, etc.: Unwrought: Value (thousands)	Blocks, pigs, anodes, etc.: Unwrought alloys: Quantity (metric tons)	Blocks, pigs, anodes, etc.: Unwrought alloys: Value (thousands)
1984	30,579	$13,353	760	$975	588	$823
1985	23,264	8,216	1,011	1,525	r1,243	r1,405
1986	3,269	1,590	1,938	3,533	1,610	1,650

Year	Wrought zinc and zinc alloys: Sheets, plates, strips: Quantity (metric tons)	Wrought zinc and zinc alloys: Sheets, plates, strips: Value (thousands)	Wrought zinc and zinc alloys: Angles, bars, pipes, rods, etc.: Quantity (metric tons)	Wrought zinc and zinc alloys: Angles, bars, pipes, rods, etc.: Value (thousands)	Waste and scrap (zinc content): Quantity (metric tons)	Waste and scrap (zinc content): Value (thousands)	Dust and flake: Quantity (metric tons)	Dust and flake: Value (thousands)
1984	975	$2,421	840	$1,526	39,146	$20,360	2,933	$3,511
1985	776	1,973	1,434	2,098	43,947	19,600	2,037	2,480
1986	721	1,513	1,050	1,706	68,660	32,803	1,551	2,104

rRevised.

Source: Bureau of the Census.

Table 28.—U.S. exports of zinc ores and concentrates, by country

(Zinc content)

Country	1985: Quantity (metric tons)	1985: Value (thousands)	1986: Quantity (metric tons)	1986: Value (thousands)
Canada	6,141	$3,226	3,265	$1,582
France	3,793	426	--	--
Germany, Federal Republic of	1,948	683	--	--
Israel	2	4	--	--
Italy	5,275	2,338	--	--
Japan	6,043	1,519	--	--
Mexico	--	--	3	7
Panama	--	--	(1)	1
Taiwan	62	20	--	--
Total	23,264	8,216	[2]3,269	1,590

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

Source: Bureau of the Census.

Table 29.—U.S. general imports of zinc, by country

Country	1984: Quantity (metric tons)	1984: Value (thousands)	1985: Quantity (metric tons)	1985: Value (thousands)	1986: Quantity (metric tons)	1986: Value (thousands)
ORES AND CONCENTRATES (zinc content)						
Australia	2,577	$1,264	2,934	$819	1,981	$262
Canada	34,717	14,631	47,200	18,351	150,100	23,512
Chile	--	--	--	--	68	57
Honduras	10,352	4,365	14,302	4,175	14,218	1,756
Mexico	20,125	6,650	12,988	4,232	6,251	1,693
Peru	17,610	7,100	13,402	4,970	25,118	5,057
South Africa, Republic of	10,186	2,633	473	1,963	--	--
United Kingdom	--	--	92	64	--	--
Total	95,567	36,643	91,391	34,574	197,736	32,337

Table 29.—U.S. general imports of zinc, by country —Continued

Country	1984 Quantity (metric tons)	1984 Value (thousands)	1985 Quantity (metric tons)	1985 Value (thousands)	1986 Quantity (metric tons)	1986 Value (thousands)
BLOCKS, PIGS, OR SLABS[1]						
Algeria	403	$374	--	--	--	--
Argentina	--	--	2,500	$1,741	--	--
Australia	23,188	23,292	29,610	26,482	40,686	$28,421
Belgium-Luxembourg	3,366	2,750	1,000	802	--	--
Brazil	3,280	4,260	--	--	--	--
Canada	340,380	351,715	383,618	326,388	349,335	253,110
China	--	--	--	--	1,342	1,185
Colombia	--	--	--	--	200	162
Congo	1,311	1,032	--	--	--	--
Costa Rica	--	--	--	--	147	92
Finland	15,953	16,197	19,601	16,832	23,134	18,896
France	12,923	12,807	5,410	4,027	5,756	4,933
French Polynesia	--	--	--	--	2,938	1,962
Germany, Federal Republic of	27,930	27,543	11,991	11,937	9,712	7,236
Greece	--	--	--	--	1,011	884
Hong Kong	--	--	--	--	40	48
India	99	84	--	--	--	--
Italy	13,719	12,270	--	--	12,743	9,668
Japan	3,000	3,050	2,700	2,386	1,951	1,283
Mauritius	--	--	--	--	430	292
Mexico	56,221	55,352	53,846	38,355	49,619	36,372
Netherlands	17,296	16,284	13,053	10,293	20,767	15,538
New Zealand	--	--	--	--	300	257
Norway	13,348	12,790	10,822	8,975	12,809	10,133
Panama	--	--	13	13	--	--
Peru	34,025	32,117	36,326	29,104	43,590	30,720
Poland	600	607	652	491	1,183	973
Saudi Arabia	--	--	39	25	--	--
South Africa, Republic of	993	1,054	3,696	2,753	11,730	7,106
Spain	16,907	16,476	17,058	13,370	48,948	40,515
Sweden	4,000	3,937	--	--	--	--
Switzerland	100	78	--	--	--	--
Taiwan	--	--	6	7	22	27
Tanzania	173	173	--	--	--	--
United Kingdom	5,685	5,251	6,779	5,320	5,968	3,929
U.S.S.R	--	--	--	--	812	544
Yugoslavia	2,467	2,251	--	--	3,979	3,398
Zaire	32,329	25,769	12,042	8,597	15,974	9,346
Zambia	2,476	2,291	--	--	--	--
Total	632,172	629,804	610,762	507,898	665,126	487,030

[1]In addition, in 1986, 802 tons of zinc anodes was imported from Canada, France, the Federal Republic of Germany, Hong Kong, Italy, 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, by country

Country	1984 Quantity (metric tons)	1984 Value (thousands)	1985 Quantity (metric tons)	1985 Value (thousands)	1986 Quantity (metric tons)	1986 Value (thousands)
ORES AND CONCENTRATES (zinc content)						
Australia	1,683	$307	1,936	$256	1,226	$477
Canada	27,467	9,533	50,031	20,017	28,645	10,069
Honduras	10,118	4,102	14,302	4,175	14,218	1,756
Mexico	20,113	6,639	12,900	4,149	6,251	1,693
Peru	16,605	5,972	10,452	3,002	25,446	5,101
South Africa, Republic of	10,186	2,633	473	1,963	--	--
United Kingdom	--	--	92	64	--	--
Total	86,172	29,186	90,186	33,626	75,786	19,096
BLOCKS, PIGS, OR SLABS[1]						
Algeria	403	374	--	--	--	--
Argentina	--	--	2,500	1,741	--	--
Australia	23,188	23,292	29,610	26,483	40,686	28,421
Belgium-Luxembourg	3,366	2,750	1,000	802	--	--
Brazil	3,280	4,260	--	--	--	--

See footnotes at end of table.

Table 30.—U.S. imports for consumption of zinc, by country —Continued

Country	1984 Quantity (metric tons)	1984 Value (thousands)	1985 Quantity (metric tons)	1985 Value (thousands)	1986 Quantity (metric tons)	1986 Value (thousands)
BLOCKS, PIGS, OR SLABS[1] —Continued						
Canada	340,490	$351,836	383,618	$326,388	349,335	$253,110
China	--	--	--	--	1,342	1,185
Colombia	--	--	--	--	200	162
Congo	1,311	1,032	--	--	--	--
Costa Rica	--	--	--	--	147	92
Finland	20,704	20,506	19,601	16,832	23,134	18,896
France	12,923	12,807	5,410	4,027	5,756	4,935
French Polynesia	--	--	--	--	2,938	1,962
Germany, Federal Republic of	27,930	27,543	11,991	11,937	9,712	7,236
Greece	--	--	--	--	1,011	884
Hong Kong	--	--	--	--	40	48
India	99	84	--	--	--	--
Italy	13,719	12,270	--	--	12,743	9,668
Japan	3,000	3,050	2,700	2,386	1,951	1,283
Mauritius	--	--	--	--	430	292
Mexico	58,416	57,058	53,984	38,460	49,619	36,372
Netherlands	17,296	16,284	13,053	10,293	20,767	15,537
New Zealand	--	--	--	--	300	257
Norway	13,348	12,790	10,822	8,975	12,809	10,133
Panama	--	--	13	12	--	--
Peru	34,025	32,117	36,326	29,104	43,590	30,720
Poland	600	607	652	491	1,183	973
Saudi Arabia	--	--	39	25	--	--
South Africa, Republic of	993	1,054	3,696	2,753	11,730	7,106
Spain	16,907	16,476	17,058	13,370	48,948	40,515
Sweden	4,000	3,937	--	--	--	--
Switzerland	100	78	--	--	--	--
Taiwan	--	--	6	7	22	27
Tanzania	173	173	--	--	--	--
U.S.S.R.	--	--	--	--	812	544
United Kingdom	5,685	5,251	6,779	5,320	5,968	3,928
Yugoslavia	2,467	2,251	--	--	3,979	3,398
Zaire	32,329	25,769	12,042	8,597	15,974	9,346
Zambia	2,476	2,291	--	--	--	--
Total	639,228	635,940	610,900	508,003	665,126	487,030

[1]In addition, in 1986, 802 tons of zinc anodes was imported from Canada, France, the Federal Republic of Germany, Hong Kong, Italy, Japan, Mexico, Netherlands, Norway, Sweden, Taiwan, and the United Kingdom.

Source: Bureau of the Census.

Table 31.—U.S. imports for consumption of zinc

Year	Ores and concentrates (zinc content) Quantity (metric tons)	Ores and concentrates Value (thousands)	Blocks, pigs, slabs[1] Quantity (metric tons)	Blocks, pigs, slabs Value (thousands)	Sheets, plates, strips, other forms Quantity (metric tons)	Sheets, plates, strips, other forms Value (thousands)	Waste and scrap Quantity (metric tons)	Waste and scrap Value (thousands)
1984	86,172	$29,186	639,228	$635,940	850	$1,308	6,259	$3,940
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

Year	Dross and skimmings (zinc content) Quantity (metric tons)	Dross and skimmings Value (thousands)	Zinc fume (zinc content) Quantity (metric tons)	Zinc fume Value (thousands)	Dust, powder, flakes Quantity (metric tons)	Dust, powder, flakes Value (thousands)	Total value[2] (thousands)
1984	5,027	$3,161	314	$171	7,572	$9,505	$683,211
1985	4,942	2,419	--	--	8,681	10,781	559,434
1986	6,087	3,098	11	2	7,446	8,260	522,473

[1]Unwrought alloys of zinc were imported as follows, in metric tons: 1984—118 ($100,047); 1985—1,096 ($841,413); and 1986—113 ($107,389).
[2]In addition, the value of manufactures of zinc imported was as follows: 1984—$926,981; 1985—$713,112; and 1986—$1,206,175.

Source: Bureau of the Census.

Table 32.—U.S. imports for consumption of zinc pigments and compounds

	1985		1986	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Zinc oxide	39,375	$35,122	43,924	$32,769
Zinc sulfide	672	1,037	766	1,197
Lithopone	1,108	620	1,204	729
Zinc chloride	2,385	1,668	1,572	1,278
Zinc sulfate	3,615	2,049	3,311	1,971
Zinc cyanide	160	254	122	199
Zinc hydrosulfite	142	227	256	462
Zinc compounds, n.s.p.f	4,853	7,267	6,162	8,401

Source: Bureau of the Census.

Table 33.—Zinc: World mine production (content of concentrate and direct shipping ore unless noted), by country[1]

(Thousand metric tons)

Country	1982	1983	1984	1985[p]	1986[e]
Algeria	11.1	12.1	14.6	13.5	12.0
Argentina	[r]36.6	36.6	34.9	36.4	38.9
Australia	664.8	699.0	676.5	759.1	[2]662.3
Austria	19.1	19.4	20.9	24.3	22.0
Bolivia	45.7	47.1	37.8	37.1	32.4
Brazil	110.6	118.6	103.2	120.0	120.0
Bulgaria[e]	66.0	68.0	68.0	68.0	70.0
Burma	5.4	4.5	5.3	4.4	[2]4.6
Canada	1,036.1	1,069.7	1,207.1	1,172.2	1,294.0
Chile	5.7	6.0	19.2	22.3	10.5
China[e]	160.0	160.0	160.0	[r]300.0	[2]396.0
Colombia	--	--	--	2.0	11.0
Congo (Brazzaville)	[e]3.0	[e]3.0	2.8	2.3	2.3
Czechoslovakia	9.3	9.8	7.2	[e]7.3	6.0
Ecuador	([3])	([3])	[r e]([3])	[r e]([3])	([3])
Finland	54.6	55.9	60.2	[e]61.0	60.0
France	37.0	34.3	36.2	40.6	[2]39.5
Germany, Federal Republic of	105.8	113.5	113.1	117.6	102.0
Greece	20.4	21.3	22.5	21.5	[2]22.5
Greenland	80.0	[r]79.2	71.3	70.3	[2]62.1
Guatemala	([3])	--	--	--	--
Honduras	24.6	38.0	41.5	44.0	40.0
Hungary[e]	1.5	2.4	2.3	2.2	--
India	29.1	40.4	44.3	45.3	[2]49.2
Iran	[e]40.0	39.5	47.1	50.0	[2]36.0
Ireland	167.2	186.0	206.1	191.6	[2]181.7
Italy	39.6	42.9	42.3	45.4	[2]26.3
Japan	251.4	255.7	252.7	253.0	[2]222.2
Korea, North[e]	140.0	140.0	140.0	[r]180.0	180.0
Korea, Republic of	58.2	56.0	49.2	45.7	50.0
Mexico	242.3	266.3	303.6	291.9	285.0
Morocco[e]	11.2	7.5	[r]10.7	[r]14.7	13.1
Namibia	[e]32.2	33.5	32.2	30.3	[2]35.4
Nigeria[e]	[r]([3])	[r]([3])	[r]([3])	[r]([3])	--
Norway	[r]31.9	[r]32.4	28.5	27.8	27.5
Peru	507.1	576.4	558.5	588.6	[2]597.6
Philippines	3.0	2.3	2.2	1.9	[2]1.6
Poland	183.5	189.0	190.7	190.8	190.8
Romania[e]	45.0	45.0	44.0	43.0	43.0
South Africa, Republic of	91.5	110.0	106.1	96.9	[2]101.9
Spain	167.0	167.7	230.4	234.7	[2]223.1
Sweden	185.0	[r]204.2	210.0	216.4	[2]213.9
Thailand	--	--	41.4	77.5	[2]97.2
Tunisia	8.4	7.5	6.7	5.6	6.0
Turkey	33.5	31.1	50.4	37.4	33.8
U.S.S.R.[e]	800.0	805.0	810.0	810.0	810.0
United Kingdom	10.2	8.9	7.5	5.4	[2]5.6
United States	326.5	296.7	277.5	251.9	[2]216.0
Vietnam[e]	6.0	7.0	7.0	5.0	5.0
Yugoslavia[4]	83.8	86.8	82.0	[e]84.0	86.0
Zaire	82.1	76.2	74.8	[e]74.0	74.0
Zambia	52.0	55.2	41.1	32.0	[2]33.0
Total	[r]6,125.0	[r]6,367.6	6,601.6	6,856.9	6,853.0

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through July 14, 1987.
[2]Reported figure.
[3]Revised to less than 1/2 unit.
[4]Content in ore hoisted.

Table 34.—Zinc: World smelter production, by country[1]

(Thousand metric tons)

Country	1982	1983	1984	1985[p]	1986[e]
Algeria, primary	28.5	31.2	35.0	35.7	34.5
Argentina:					
Primary	28.9	[r]30.0	27.7	30.4	29.1
Secondary	2.5	2.0	2.2	2.5	3.0
Total	31.4	32.0	29.9	32.9	32.1
Australia:					
Primary[2]	291.4	298.5	301.9	288.7	[3]305.7
Secondary[e]	4.5	4.5	4.5	4.5	4.5
Total[e]	295.9	303.0	306.4	[r]293.2	310.2
Austria, primary and secondary	23.0	23.0	24.0	25.0	22.0
Belgium, primary and secondary	[r]240.9	[r]275.8	285.3	289.6	290.0
Brazil:					
Primary	95.5	99.9	106.9	114.4	[3]130.6
Secondary	14.4	11.0	7.5	4.7	[3]4.7
Total	109.9	110.9	114.4	119.1	[3]135.3
Bulgaria, primary and secondary[e]	90.0	90.0	90.0	90.0	90.0
Canada, primary	511.9	617.0	683.2	692.4	572.0
China, primary and secondary[e]	160.0	175.0	185.0	[r]275.0	[3]336.0
Czechoslovakia, undifferentiated	[3]9.2	9.1	9.1	9.2	9.0
Finland, primary	155.0	155.3	158.8	160.4	155.4
France:					
Primary[e]	223.8	231.5	[r]238.5	[r]268.6	269.5
Secondary[e]	20.0	18.0	20.0	17.0	20.0
Total	243.8	249.5	258.5	285.6	[3]289.5
German Democratic Republic, primary and secondary[e]	17.0	16.5	17.0	16.0	16.0
Germany, Federal Republic of:					
Primary	303.4	328.7	325.6	339.9	344.7
Secondary	31.6	27.8	30.8	27.9	26.6
Total	335.0	356.5	356.4	367.8	371.3
Hungary, secondary[e]	.6	.6	.6	.6	.6
India:					
Primary	52.6	53.3	55.8	70.9	[3]72.0
Secondary[e]	.2	.2	.2	.2	.2
Total	52.8	53.5	56.0	[e]71.1	72.2
Italy, primary and secondary	158.6	155.9	169.7	215.6	[3]229.4
Japan:					
Primary	549.0	579.0	644.4	629.5	[3]626.5
Secondary	113.4	122.3	110.1	110.1	[3]81.5
Total	662.4	701.3	754.5	739.6	[3]708.0
Korea, North, primary[e]	120.0	120.0	120.0	[r]180.0	180.0
Korea, Republic of, primary	99.2	108.0	108.5	111.7	[3]127.4
Mexico, primary	127.0	175.7	167.0	175.4	[3]173.7
Netherlands, primary and secondary	186.0	187.5	209.7	201.7	195.0
Norway, primary	[r]72.0	90.7	94.2	92.7	[3]90.4
Peru, primary	[r]160.2	154.0	148.4	169.7	[3]155.4
Poland, primary and secondary	165.4	170.3	176.0	180.0	[3]179.0
Portugal, primary	[r]4.5	3.8	6.4	5.9	6.5
Romania, primary and secondary[e]	39.8	42.0	41.0	40.0	39.0
South Africa, Republic of, primary	79.7	84.4	88.4	93.7	81.0
Spain, primary	181.8	189.9	207.4	213.3	213.6
Thailand, primary	--	--	--	62.1	[3]58.6
Turkey, primary	14.9	14.3	19.9	22.2	20.0
U.S.S.R.:[e]					
Primary	[r]850.0	[r]870.0	[r]900.0	[r]900.0	900.0
Secondary	90.0	95.0	95.0	100.0	105.0
Total	[r]940.0	[r]965.0	[r]995.0	[r]1,000.0	1,005.0
United Kingdom, primary and secondary	79.3	87.7	85.6	74.3	[3]85.9

See footnotes at end of table.

Table 34.—Zinc: World smelter production, by country[1] —Continued

(Thousand metric tons)

Country	1982	1983	1984	1985[p]	1986[e]
United States:					
Primary	228.2	235.7	253.1	261.2	[3]253.4
Secondary	74.3	69.4	78.1	72.6	[3]62.9
Total	302.5	305.1	331.2	333.8	[3]316.3
Vietnam, primary[e]	5.0	6.0	6.0	4.2	4.2
Yugoslavia:					
Primary[e]	76.8	77.0	81.6	71.4	77.0
Secondary[e]	10.0	11.0	11.0	12.0	12.3
Total	86.8	88.0	92.6	83.4	[3]89.3
Zaire, primary	64.4	62.5	66.1	67.9	68.0
Zambia, primary	39.2	37.9	29.2	22.8	[3]22.5
Grand total	[r]5,893.6	[r]6,248.9	6,526.4	6,843.6	6,784.3
Of which:					
Primary	[r]4,362.9	[r]4,654.3	4,874.0	5,135.1	5,092.7
Secondary	[r]361.5	[r]361.8	360.0	352.1	321.3
Undifferentiated	[r]1,169.2	[r]1,232.8	1,292.4	1,356.4	1,370.3

[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 14, 1987.
[2]Excludes zinc dust.
[3]Reported figure.

Table 35.—Zinc: World mine and primary smelter capacity, by country

(Thousand metric tons)

Country	Mine	Smelter
Algeria	15	40
Argentina	40	41
Australia	775	339
Austria	23	25
Belgium-Luxembourg	--	325
Bolivia	50	--
Brazil	130	140
Bulgaria[e]	70	90
Burma	5	--
Canada	1,510	705
Chile	35	--
China[e]	400	350
Colombia	12	--
Congo	3	--
Czechoslovakia	8	--
Ecuador	1	--
Finland	65	160
France	40	335
Germany, Federal Republic of	125	415
Greece	30	--
Greenland	140	--
Honduras	50	--
Hungary	2	--
India	60	93
Iran	60	--
Ireland	210	--
Italy	60	253
Japan	280	1,019
Korea, North	220	200
Korea, Republic of	110	204
Mexico	340	307
Morocco[e]	25	--
Namibia	40	--
Netherlands	--	185
Norway	35	110
Peru	630	185
Philippines	5	--
Poland	220	240

See footnotes at end of table.

Table 35.—Zinc: World mine and primary smelter capacity, by country —Continued

(Thousand metric tons)

Country	Mine	Smelter
Portugal	--	11
Romania	45	60
South Africa, Republic of	130	105
Spain	290	268
Sweden	220	--
Thailand	80	60
Tunisia	10	--
Turkey	50	60
U.S.S.R.[e]	900	1,080
United Kingdom	12	100
United States	375	404
Vietnam	6	10
Yugoslavia	120	160
Zaire	75	72
Zambia	60	55
Total	8,197	8,206

[e]Estimated.

Table 36.—Zinc: World reserves and reserve base 1986, by continent and country

(Million metric tons)

Continent and country	Reserves	Reserve base
North America:		
Canada	25	56
Mexico	6	8
United States	21	50
Other	([1])	([1])
Total	52	114
South America:		
Brazil	2	3
Peru	7	12
Other	1	1
Total	10	16
Europe:		
Finland	1	2
France	1	1
Germany, Federal Republic of	1	2
Greece	1	1
Ireland	5	7
Italy	2	3
Poland	3	4
Portugal	2	3
Spain	5	6
Sweden	1	3
U.S.S.R	10	15
Yugoslavia	2	3
Other	2	4
Total	36	54
Africa:		
South Africa, Republic of	3	14
Zaire	5	7
Other	1	2
Total	9	23
Asia:		
China	5	9
India	5	7
Iran	2	6
Japan	4	6
Korea, North	4	6
Thailand	1	1
Turkey	1	2
Other	1	2
Total	23	39
Oceanic: Australia	18	49
Grand total	148	295

[1]Less than 1 million metric tons.

Zirconium and Hafnium[1]

By W. Timothy Adams[2]

Zircon, the principal ore mineral of zirconium, was mined as a coproduct of ilmenite and rutile from sand deposits in Florida. Most zircon was used in the Eastern United States, with 35% being used in foundry sands and the remainder in refractories, ceramics, abrasives, and in miscellaneous uses including the manufacture of chemicals and the production of zirconium metal and alloys. The value of zircon consumed was about $27 million. Hafnium was used in nuclear reactors, refractory alloys, and cutting-tool alloys.

Zirconium and hafnium were increasingly being used in advanced technological applications such as in partially stabilized (transformation-toughened) zirconia, which is used in extrusion dies in the nonferrous metals industry and in parts for high-temperature and experimental adiabatic automotive engines. Also, zirconium fluoride and hafnium fluoride glasses were being developed as replacements for silicon dioxide glasses in fiber optics. Signal attenuation in the fluoride glasses was significantly less than in the silica glasses, and fluoride glass fibers were the only glass fibers capable of transmitting near-infrared radiation.

Domestic Data Coverage.—Domestic mine production data for zircon are developed by the Bureau of Mines from one voluntary survey of U.S. operations entitled "Production of Zircon." Of the two operations to which a survey request was sent, both responded, representing 100% of production. Data are withheld to avoid disclosing company proprietary data.

Table 1.—Salient U.S. zirconium statistics

(Short tons)

	1982	1983	1984	1985	1986
Zircon:					
Production	W	W	W	W	W
Exports	11,011	13,222	9,528	16,855	17,474
Imports for consumption	68,465	44,487	66,436	43,787	75,799
Consumption[e 1]	93,000	100,000	130,000	130,000	158,000
Stocks, yearend: Dealers and consumers[e 2]	48,595	36,498	32,861	29,288	30,916
Zirconium oxide:					
Production[3]	5,059	[e]4,118	[e]7,373	[e]9,173	[e]7,879
Exports	1,017	698	422	1,048	1,817
Imports for consumption	332	451	793	1,468	511
Consumption[e]	5,600	3,400	5,800	7,500	6,700
Stocks, yearend: Producers[e 3]	1,357	895	1,183	1,524	2,207

[e]Estimated. W Withheld to avoid disclosing company proprietary data.
[1]Includes insignificant amounts of baddeleyite.
[2]Excludes foundries.
[3]Excludes oxide produced by zirconium metal producers.

Legislation and Government Programs.—As part of a longstanding program to supply contractors with nuclear reactor construction materials manufactured to U.S. Navy specifications, the U.S. Department of Energy had an inventory, as of December 31, 1985, of about 38 short tons of zirconium sponge, 999 tons of zirconium ingots and shapes, 1,045 tons of zirconium scrap, 30 tons of hafnium ingots and shapes, 3 tons of hafnium crystal bar, 5 tons of hafnium oxide, and 39 tons of hafnium scrap.

DOMESTIC PRODUCTION

Zircon was recovered, 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 zircon capacity of these plants was estimated to be 125,000 tons per year. Production data are withheld from publication to avoid disclosing company proprietary data.

Five firms produced 51,776 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 7,879 tons of zirconium dioxide. Two companies produced zirconium sponge, ingot, and alloys, as well as hafnium sponge and crystal bar. Two companies produced cubic zirconia for use in jewelry.

It was reported that ICI Australia Operations Pty. Ltd. (ICIA) purchased Ferro Corp.'s zirconia operation at Bow, NH. The plant produces a range of zirconia powder grades suitable for applications in electronics, ceramic colors, welding fluxes, and grinding media. The plant was to operate as a wholly owned subsidiary of ICIA under the name of Z-Tech Corp.[3]

Table 2.—Producers of zirconium and hafnium materials in 1986

Company	Location	Materials
ZIRCONIUM MATERIALS		
American Minerals Inc	Camden, NJ	Milled zircon.
Associated Minerals (USA) Ltd. Inc	Green Cove Springs, FL	Zircon.
Ceres Corp	North Billerica, MA	Cubic zirconia.
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	Zircon and foundry mixes.
Do	Trail Ridge, FL	Do.
Elkem Metals Co	Alloy, WV	Alloys.
Foote Mineral Co	Cambridge, OH	Do.
Harshaw Chemical Co	Elyria, OH	Oxide and other compounds.
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.
Reading Alloys Inc	Robesonia, PA	Alloys.
Shieldalloy Corp	Newfield, NJ	Welding rods and alloys.
Singh Industries	Cedar Knolls, NJ	Cubic zirconia.
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	Bow, NH	Do.
Western Zirconium Inc	Ogden, UT	Oxide, sponge, ingot, mill products.
Z-Tech Corp	Bow, NH	Oxide.
Zedmark Inc	Butler, PA	Refractories.
Zircar 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.

CONSUMPTION AND USES

Of the domestic zircon produced in 1986, 35% 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 weighting agents; in glazes and enamels; in refractories; in ceramics; in zircon-titanium dioxide blends for welding-rod coatings; for sandblasting applications; and for the production of zirconium and hafnium metals. Baddeleyite, another zirconium mineral, was used mainly in the manufacture of alumina-zirconia abrasives, and also for ceramic colors, refractories, and other uses.

Table 3.—Estimated[1] consumption of zircon[2] in the United States, by end use

(Short tons)

End use	1985	1986
Zircon refractories[3]	[r]21,300	24,000
AZS refractories[4]	[r]11,200	14,600
Zirconia[5] and AZ abrasives[6]	20,600	16,400
Alloys[7]	4,700	6,000
Foundry applications	45,500	56,000
Other[8]	26,700	41,000
Total	130,000	158,000

[r]Revised.
[1]Based on incomplete reported data.
[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[1] consumption of zirconium oxide[2] in the United States, by end use

(Short tons)

End use	1985	1986
AZ abrasives	W	W
AZS refractories[3]	300	700
Other refractories	4,300	3,100
Chemicals	1,300	1,600
Glazes, opacifiers, colors	1,600	1,300
Total	7,500	6,700

W Withheld to avoid disclosing company proprietary data.
[1]Based on incomplete data.
[2]Excludes oxide produced by zirconium metal producers. Includes baddeleyite.
[3]Fused cast and bonded.

Research on calcia, magnesia, and yttria transformation-toughened zirconias continued. These materials were considered to have considerable potential for use in ceramic coatings in jet aircraft engines and in other applications where strength and high-temperature oxidation resistance is important. Zirconia ceramics were also used in the automobile industry in sensors for the microprocessor controls of engines.

All of the hafnium metal and most of the zirconium metal consumed were used by the nuclear power industry. For the eighth consecutive year, there were no new orders for commercial nuclear powerplants. Most of the remainder of the zirconium metal was used in superalloys and in the chemical and electronics industries.

Table 5.—Estimated[1] yearend stocks of zirconium and hafnium materials in the United States

(Short tons)

Item	1985	1986
Zircon concentrate held by dealers and consumers excluding foundries	20,240	25,120
Milled zircon held by dealers and consumers excluding foundries	9,048	5,796
Zirconium:[2]		
Oxide	1,524	2,207
Sponge, ingot, scrap, alloys	924	491
Refractories	6,673	8,579
Hafnium: Sponge and crystal bar	30	30

[1]Based on incomplete data.
[2]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 1985	77- 83	99-108	102-108
December 1986	114-120	126-138	138-144

Source: Industrial Minerals (London). No. 219, Dec. 1985, p. 101; and No. 231, Dec. 1986, p. 87.

Table 7.—Published yearend prices of zirconium and hafnium materials

Specification of material	1985	1986
Zircon:		
Domestic, standard-grade, f.o.b. Starke, FL, bulk, per short ton[1]	$175.00	$190.00
Domestic, 75% minimum quantity zircon and aluminum silicates, Starke, FL, bulk, per short ton[1]	99.00	99.00
Imported sand, containing 65% ZrO_2, f.o.b., bulk, per metric ton[2]	$86.00- 92.00	$126.00- 133.00
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	.97
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]	31.75	31.75
Zirconium:[5]		
Powder, per pound	75.00- 150.00	75.00- 150.00
Sponge, per pound	12.00- 17.00	12.00- 17.00
Sheets, strip, bars, per pound	20.00- 40.00	20.00- 40.00
Hafnium: Sponge, per pound[5]	80.00- 130.00	80.00- 130.00

[1]E. I. du Pont de Nemours & Co. Inc. price lists. Dec. 1985 (effective Jan. 1, 1986); and Dec. 1986 (effective Jan. 1, 1987).
[2]Industrial Minerals (London). No. 219, Dec. 1985, p. 101; and No. 231, Dec. 1986, p. 87.
[3]Chemical Marketing Reporter. V. 228, No. 27, Dec. 30, 1985 (effective Dec. 27, 1985), p. 32; and v. 230, No. 26, Dec. 31, 1986 (effective Dec. 26, 1986), p. 32.
[4]Ronson Metals Corp. Baddeleyite price lists. Jan. 1, 1986, and Jan. 1, 1987.
[5]American Metal Market. V. 93, No. 249, Dec. 27, 1985, p. 5; and v. 94, No. 252, Dec. 31, 1986, p. 15.

Table 8.—U.S. exports of zirconium ore and concentrate, by country

Country	1985		1986	
	Short tons	Value	Short tons	Value
Algeria	56	$28,050	10	$5,157
Argentina	370	102,218	847	272,789
Australia	--	--	129	106,567
Belgium-Luxembourg	80	51,736	140	93,896
Brazil	3,601	557,658	179	68,000
Canada	249	72,678	249	66,964
Colombia	291	115,725	800	358,600
Ecuador	104	65,006	212	91,911
Germany, Federal Republic of	2,194	752,900	8,495	1,439,411
India	10	5,850	--	--
Ireland	--	--	49	23,550
Japan	3,578	493,252	3	3,660
Mexico	5,391	1,242,628	5,008	1,372,807
United Kingdom	38	9,752	209	43,563
Venezuela	662	344,829	952	513,590
Other	231	123,179	192	106,579
Total	16,855	3,965,461	17,474	4,567,044

Source: Bureau of the Census.

Table 9.—U.S. exports of zirconium, by class and country

Class and country	1985		1986	
	Short tons	Value	Short tons	Value
Zirconium and zirconium alloys, wrought:				
Belgium-Luxembourg	12	$918,662	12	$1,272,400
Canada	184	9,658,049	163	8,016,468
Finland	--	--	19	722,611
France	1	45,012	28	1,007,609
Germany, Federal Republic of	107	5,782,189	211	11,851,377
Italy	31	2,644,304	24	3,002,167
Japan	473	20,938,200	364	20,016,720
Korea, Republic of	1	55,851	--	--
Spain	7	52,948	27	6,798,024
Sweden	37	1,434,725	69	2,357,298
Switzerland	4	385,578	(1)	5,552
Taiwan	17	1,405,102	(1)	5,665
United Kingdom	53	2,232,026	76	3,320,340
Other	3	120,091	3	86,757
Total	930	45,672,737	996	58,462,988
Zirconium and zirconium alloys, unwrought and waste and scrap:				
Chile	12	380,000	--	--
France	48	491,293	36	359,080
Germany, Federal Republic of	18	375,887	8	87,676
Japan	122	4,086,304	90	3,324,723
Netherlands	1	9,110	8	43,315
Peru	16	328,000	--	--
Sweden	--	--	12	267,784
United Kingdom	1	80,776	31	376,689
Other	5	133,751	9	211,340
Total	223	5,885,121	194	4,670,607

[1]Less than 1/2 unit.

Source: Bureau of the Census.

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

Country	1985		1986	
	Short tons	Value	Short tons	Value
Argentina	--	--	18	$83,153
Belgium-Luxembourg	18	$25,106	90	94,920
Brazil	20	777,387	7	37,070
Canada	157	516,629	470	556,051
Ecuador	--	--	79	36,580
France	31	109,597	3	29,330
Germany, Federal Republic of	9	58,966	13	105,103
Greece	5	6,400	--	--
Hong Kong	5	10,886	5	29,473
Italy	38	114,279	(1)	29,123
Japan	45	162,614	70	224,848
Korea, Republic of	315	125,819	5	17,536
Mexico	93	287,644	51	158,715
Netherlands	2	10,506	15	44,675
Singapore	--	--	10	15,960
Sweden	2	38,276	18	64,642
Taiwan	19	66,965	59	152,645
United Kingdom	281	942,148	884	2,247,335
Other	8	78,693	20	82,784
Total	1,048	3,331,915	1,817	4,009,943

[1]Less than 1/2 unit.

Source: Bureau of the Census.

Table 11.—U.S. imports for consumption of zirconium ores, by country

Country	1984 Quantity (short tons)	1984 Value (thousands)	1985 Quantity (short tons)	1985 Value (thousands)	1986 Quantity (short tons)	1986 Value (thousands)
Argentina	--	--	5,799	$520	8,933	$847
Australia	44,214	$5,289	24,348	2,272	41,067	4,233
Belgium-Luxembourg	461	87	--	--	--	--
Canada[1]	1,451	151	2,307	225	737	81
Hong Kong	--	--	333	28	--	--
Italy	--	--	64	25	132	46
Netherlands	--	--	--	--	31	4
Philippines	--	--	87	407	--	--
South Africa, Republic of[2]	20,309	2,016	10,849	1,120	24,899	2,625
Other	1	5	([3])	2	--	--
Total	66,436	7,548	43,787	4,599	75,799	7,836

[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 1986, by class and country

Class and country	Short tons	Value
Zirconium, wrought:		
Canada	14	$1,310,876
France	231	10,935,620
Japan	2	29,248
Other	2	294,321
Total	249	12,570,065
Zirconium, unwrought and waste and scrap:		
Canada	16	81,047
France	39	180,520
Germany, Federal Republic of	21	118,038
Japan	5	29,046
Sweden	([1])	5,648
United Kingdom	12	64,544
Total	93	478,843
Zirconium alloys, unwrought:		
Canada	2	246,258
Germany, Federal Republic of	([1])	27,529
United Kingdom	5	26,209
Total	7	299,996
Zirconium oxide:		
Canada	([1])	1,808
France	27	56,184
Germany, Federal Republic of	2	45,997
Italy	6	9,850
Japan	52	482,290
South Africa, Republic of	12	13,750
United Kingdom	412	1,828,036
Total	511	2,437,915
Zirconium compounds:		
Belgium-Luxembourg	([1])	1,003
France	2	7,880
Germany, Federal Republic of	5	236,486
Japan	21	92,391
South Africa, Republic of	2,113	1,868,730
United Kingdom	615	974,131
Other	([1])	6,783
Total	2,756	3,187,404
Hafnium, unwrought and waste and scrap: France	([1])	76,213

[1]Less than 1/2 unit.

Source: Bureau of the Census.

WORLD REVIEW

Australia led the world in the production of zircon in 1986. Zircon was also produced in the Republic of South Africa, the U.S.S.R., and the United States, and in lesser amounts in six other countries. Baddeleyite was produced in Brazil and in the Republic of South Africa. A review of the worldwide zircon industry was published giving a brief summation of the sources of mineral sands that contain zircon and the methods in the concentration and separation of the minerals. The industry structure and the changes occurring in it were given in detail, and the markets for zircon in various countries were also outlined.[4]

Australia.—A two-stage plant reportedly was under construction at Kwinana, Western Australia, by ICIA. The $7.5 million plant was expected to produce 2,200 tons of zirconia annually by 1987. The company's product range of zirconia ceramic powders and zirconium chemicals will provide a new domestic market for Australian zircon.[5]

France.—At the beginning of 1987, Pechiney will start up a new production unit for ultrafine zirconia powders at the Jarrie plant of its fine ceramic powders subsidiary, Criceram. The annual output of 88 tons reportedly will be used to develop new high-strength cutting tools and plasma coatings.[6]

Korea, Republic of.—Three U.S. companies were selected to supply nuclear powerplants to the Republic of Korea's state-operated electric utility. Combustion Engineering Inc. was selected to supply the two reactors, Sargent and Lundy (Engineering) to design the twin reactor plant, and General Electric Co. to supply the turbines.[7]

Mozambique.—Edlow Resources Inc. of Bermuda acquired mineral rights to a 125-mile by 3-mile strip along the coastlines of Zambezia and the Nampula Provinces. U.S. Geological Survey personnel investigated the area in November 1985 and reported mineral sand deposits beyond expectations. Preussag AG, of the Federal Republic of Germany, reported 3.3 million tons of zircon reserves in 1970.[8]

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

(Short tons)

Country	1982	1983	1984	1985[p]	1986[e]
Australia	509,792	421,419	501,037	485,016	443,000
Brazil	5,507	[r]8,191	7,737	14,052	13,200
China[e]	16,500	16,500	16,500	16,500	16,500
India[2]	11,556	12,561	[e]13,000	16,314	17,600
Malaysia (exports)	2,367	2,809	8,393	12,844	7,700
South Africa, Republic of	[e]140,000	178,884	168,789	176,957	176,400
Sri Lanka	6,381	6,306	4,087	4,476	4,400
Thailand	216	219	320	968	880
U.S.S.R.[e]	90,000	90,000	90,000	95,000	95,000
United States	W	W	W	W	W
Total	782,319	[r]736,889	809,863	822,127	774,680

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

[1]Includes data available through May 19, 1987.

[2]Data are for fiscal year beginning Apr. 1 of that stated.

TECHNOLOGY

Battelle Laboratories, Columbus Div., reportedly developed a low-cost method for producing high-quality doped zirconia powders that could be used in manufacturing toughened zirconia components for advanced automotive engines and other applications. It is claimed that by using a hydrothermal process, doped zirconia powders can be prepared having physical and chemical characteristics superior to those produced by other means.[9]

Teledyne Wah Chang Albany reportedly was successful in producing high-quality extrusions of zirconium and other specialty metals with a 3,500-ton extrusion press, using temperature-resistant resin as a lubricant. The products did not require machining or other finishing.[10]

A new ceramic material was reportedly produced by the addition of 10 weight percent of yttria-stabilized zirconia to silicon nitride. The new ceramic material offered significantly improved high-temperature properties as well as improved room-temperature properties.[11]

A tubular solid oxide fuel cell based on zirconia ceramics produced electricity and heat from the chemical reaction between hydrogen or carbon monoxide and air. Westinghouse Electric Corp. linked 24 of the cells to form a module that generated 400 watts of electricity. Under a 3-year, $15 million contract from the U.S. Department of Energy, Westinghouse began the development of a 50-kilowatt module. The fuel cell operates at a temperature of 1,800° F.[12]

The ferroelectric form of the transparent ceramic lead lanthanum zirconate titanate (PLZT) was made more photosensitive by ion implantation. The photosensitivity of PLZT in the near-ultraviolet range was increased by a factor of 104 with no reduction in image quality. PLZT was reported as the most photosensitive, nonvolatile image-storing material that is also erasable and reusable.[13]

Low-temperature methods of synthesizing ceramic materials were reviewed. It was stated that the ceramic raw materials must be extremely pure, equiaxed, and limited to submicrometer particle sizes within a narrow and specific size distribution. Methods were described for the preparation of ceramic powders from solution, gels, and emulsions.[14]

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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, Division of Nonferrous Metals.

[3]Industrial Minerals (London). ICIA To Expand Zirconia Base. No. 225, June 1986, pp. 18-19.

[4]Clark, G. Zircon in Demand as Availability Squeezed. Ind. Miner. (London). No. 232, Jan. 1987, pp. 49-53.

[5]American Metal Market. Aussies Building Zircon Sand Facility. V. 94, No. 5, Jan. 8, 1986, p. 6.

[6]———. Pechiney Will Start Up Zirconium Powders Unit. V. 94, No. 112, June 10, 1986, p. 12.

[7]Business Week. A Rare Order for a Reactor. No. 2968, Oct. 13, 1986, p. 54.

[8]Metal Bulletin (London). Edlow Seeks Mozambique Titanium. No. 7126, Oct. 10, 1986. p. 7.

[9]Industrial Minerals (London). Doped Zirconia Powders. No. 221, Feb. 1986, p. 68.

[10]American Metal Market. Alloying and Precious Metals. Teledyne Wah Chang Making Extrusions From Zirconium, Other Specialty Metals. V. 94, No. 65, Apr. 3, 1986, p. 5.

[11]NASA Tech Briefs. Si_3N_4 Based Ceramic With Greater Hot Strength. V. 10, No. 2, Mar.-Apr. 1986, p. 80.

[12]Chemical & Engineering News. Scaleup Slated for Ceramic Fuel Cell. V. 64, No. 17, Apr. 28, 1986, p. 21.

[13]Advanced Materials and Processes. Photosensitive Image-Storing Ceramics. V. 130, No. 4, Oct. 1986, p. 47.

[14]Sheppard, L. M. Low Temperature Synthesis of Ceramics. Adv. Mater. and Processes, v. 130, No. 5, Oct. 1986, pp. 47-51.

Other Industrial Minerals

By Staff, Division of Industrial Minerals

CONTENTS

ASPHALT (NATIVE)[1]

Native asphalt was produced by three companies in two States, Texas and Utah. Bituminous limestone, used primarily as a paving material for street and road repair, was produced by one firm, R. L. White Co., Uvalde County, TX.

Gilsonite, a solidified hydrocarbon found only in Colorado and Utah, was mined by two firms, American Gilsonite Co., a division of Chevron Resources Co. (a subsidiary of Standard Oil Co. of California), and Ziegler Chemical and Mineral Corp. Hydrocarbon Mining Co. (a subsidiary of Oberon Oil Inc., a Utah corporation) closed its mining operation during the year.

Gilsonite is used for a variety of purposes including automobile bodysealer, lightweight aggregate for cement used in oil well drilling, asphaltic building board, protective coverings, anticorrosive paints, and roofing compounds. The gilsonite industry continued to be depressed because of reductions in oil well drilling activity.

Specific information on bituminous limestone and gilsonite production and value is withheld to avoid disclosing company proprietary data.

GREENSAND[2]

Greensand, also known as glauconite, a natural silicate of potassium, aluminum, iron, and magnesium, was produced by Iversand 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 from publication to avoid disclosing company proprietary data. Total production has risen erratically over the past 15 years, and classified raw greensand production has provided most of the variability. Processed greensand continued to be sold as filter media for the removal of hydrogen sulfide, iron, and manganese from drinking water supply systems in 1986. Classified raw greensand was resold by Zook and Ranck Inc. as a soil conditioner and as a source of slowly released potash to organic farmers in North America.

MEERSCHAUM[3]

Imports of crude or block meerschaum during the year, all from Canada, totaled 99 pounds with a customs declared value of $2,429. The low unit value of this imported material, $24.54 per pound, indicates that the shipment probably consisted of crude meerschaum blocks instead of the shaped or formed meerschaum usually imported. The major suppliers in the past were the Federal Republic of Germany, Somalia, and the United Kingdom.

Crude or block meerschaum continues to be mined in Turkey and recovered by craftsmen in Somalia and Tanzania. The block material is used by companies in New York and Ohio for manufacturing smokers' pipes and cigarette holders. Smokers' specialty houses continued to complement their finished meerschaum items with mail-order kits with detailed carving instructions for fashioning meerschaum smoking implements. Turkish meerschaum production in 1986 was estimated to be about 320 unit boxes, 50 kilograms or 110 pounds each, of block meerschaum. Turkey, the largest producer of quality crude or block meerschaum, has prohibited export of uncarved material since 1975.

QUARTZ CRYSTAL[4]

U.S. mine production of lascas increased in 1986. Lascas consumed as feedstock for producing cultured quartz crystal also increased. A significant decrease in imports of lascas from Brazil was due in part to a large increase in price caused by growth in demand for specimen-quality quartz. Domestic production of cultured quartz crystal continued at less than 50% of capacity, although consumption increased significantly. Producers withdrew material from stocks for captive use or sale, and increased sales of as-grown rather than lumbered material.

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 operations 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 30 operations that were canvassed concerning consumption of quartz crystal, all responded, and the 25 active operations represented 100% of total consumption also shown in table 1.

Table 1.—Salient U.S. electronic- and optical-grade quartz crystal statistics

(Thousand pounds and thousand dollars)

	1982	1983	1984	1985	1986
Production:					
Mine[e] [1]	200	600	2,500	1,000	1,200
Cultured	478	426	1,027	568	524
Exports:					
Natural:[2]					
Quantity	69	28	42	60	74
Value	$380	$156	$234	$290	$411
Cultured:[2]					
Quantity	115	80	277	185	324
Value	$3,500	$3,258	$11,021	$3,723	$5,686
Lascas:					
Quantity	NA	[3]339	[e]1,600	[e]800	--
Imports of Brazilian lascas:[4]					
Quantity	417	153	569	173	52
Value	$245	$121	$373	$99	$51
Consumption:					
Natural (electronic- and optical-grade)	16	13	7	7	2
Cultured (lumbered)	99	112	77	44	43
Cultured (as-grown)	383	312	391	224	428
Total	498	437	475	275	473

[e]Estimated. NA Not available.
[1]Excludes lascas produced for specimen and jewelry material uses.
[2]Bureau of the Census.
[3]The Journal of Commerce Port Import/Export Reporting Service.
[4]Bureau of the Census as adjusted by the Bureau of Mines.

Legislation and Government Programs.—The National Defense Stockpile contained 1.8 million pounds of natural quartz crystal throughout the year.

DOMESTIC PRODUCTION

Coleman Crystal Inc. was the only producer of lascas in 1986. The company mined lascas in Arkansas for use as feed material for the cultured quartz crystal industry. The feedstock lascas was used exclusively for U.S. cultured quartz crystal operations.

Domestic producers of cultured quartz crystal continued to operate at reduced capacity, and sales from stocks increased. Production from six companies decreased 8%. The two largest producers, Sawyer Research Products Inc., Eastlake, OH, and Thermo Dynamics Corp., Shawnee-Mission, KS, were independent growers that produced crystal bars for domestic and foreign consumers in the crystal device fabrication industry. Motorola Inc., Chicago, IL, and Electro Dynamics Corp., Overland Park, KS, provided quartz crystals for both internal consumption and the domestic crystal device fabrication industry. P. R. Hoffman Material Processing Co., Carlisle, PA, also reported outside sales. Bliley Electric Co., Erie, PA, produced only for internal consumption.

CONSUMPTION AND USES

U.S. consumption of lascas by the six quartz crystal growers increased to 610,000 pounds in 1986 from 522,000 pounds in 1985. Quartz crystal consumption by 25 companies in 9 States increased to about 473,000 pounds from 275,000 pounds despite the closure of 2 operations. Of these companies, 21 consumed only cultured quartz crystal, 3 consumed both natural and cultured material, and 1 consumed only 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. Such applications included timing signals for watches and clocks; microprocessors in industrial, automotive, and consumer products; and military-aerospace and commercial band-pass filters and oscillators that require very high selectivity and stability.

STOCKS

Crystal growers' stocks of as-grown cultured quartz crystals were 204,000 pounds at the beginning of 1986. By yearend, these stocks had been reduced to 146,000 pounds.

PRICES

The average price for domestic lascas reported by consumers was about $0.50 per pound. The customs value of Brazilian lascas increased 72% to $0.98 per pound. The average value of as-grown cultured quartz, based on reported sales of about 413,000 pounds, was $13.58 per pound, a 15% decrease. Sales volume increased 95%. The average value of lumbered quartz, as-grown quartz that has been processed by sawing and grinding, increased slightly to $63.53 per pound, based on reported sales of 74,000 pounds. Sales volume decreased 16%.

FOREIGN TRADE

Cultured quartz crystal exports, as reported by the Bureau of the Census, increased 75% in 1986, to 323,802 pounds. The average f.a.s. value was $17.56 per pound, a 13% decrease. Most of these exports, 206,000 pounds, went to Japan. The Republic of Korea received 91,000 pounds of cultured quartz crystal from U.S. producers.

Imports of Brazilian lascas, designated as "Crude Brazilian Pebble," declined 70% to 52,000 pounds with a customs value of $51,318.

STAUROLITE[5]

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 in the United States was produced commercially in 1986 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 fraction 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% titanium dioxide (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 a 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 not released for publication, but the 1986 production of staurolite increased 26% from that of 1985; shipments decreased 9% in tonnage and 25% in price per ton. Domestic productive capacity has declined to slightly under 100,000 short tons per year, because of the absence of a small producer and because of a shift to a more purified product, entailing a greater processing loss. The purified product was created in response to the need to lower the free silica content of staurolite used for sandblasting in order to reduce the risk of silicosis caused by free silica dust.

Staurolite has continued to be produced in India in small quantities and sometimes by other nations as well.

STRONTIUM[6]

Total imports of strontium compounds increased, whereas imports of celestite, a strontium sulfate mineral, decreased. Demand for strontium chemicals increased in several end-use applications, as indicated by increased imports of strontium carbonate and strontium metal. Demand for strontium chromate decreased. 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 celestite because the ore was not mined in the United States.

Domestic Data Coverage.—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 a 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 major strontium compounds by end use. Of the 12 operations to which a survey request was sent, all responded, representing 100% of the end-use data shown in table 3.

Table 2.—Major producers of strontium compounds in 1986

Company	Location	Compounds
Chemical Products Corp	Cartersville, GA	Carbonate and nitrate.
Mallinckrodt Inc	St. Louis, MO	Chloride.
Mineral Pigments Corp	Beltsville, MD	Chromate.

DOMESTIC PRODUCTION

CPC was the only domestic producer of strontium carbonate from imported celestite. Several other firms manufactured various strontium compounds from strontium carbonate.

CONSUMPTION AND USES

The largest end use for strontium was in the manufacture of faceplate glass for color television picture tubes, the production of which accounted for over one-half of the annual consumption of strontium chemicals. The presence of strontium carbonate in the glass blocks X-ray emissions from the picture tube.

Use of strontium nitrate in pyrotechnics and signal flares was the second largest end use for strontium compounds. The strontium nitrate creates a brilliant red flame when burned.

Other applications of strontium chemicals included conversion of strontium carbonate to strontium ferrite. Ferrites find application in the manufacture of ceramic ferrite magnets, which are used in fractional horsepower motors for automobile accessories, loudspeakers, and computers. The carbonate was also used in the electrolytic production of zinc. Strontium chromate was used as a corrosion inhibitor in pigments and paints, strontium phosphate was used in fluorescent lights, and strontium chloride was used in the manufacture of toothpaste for sensitive teeth.

Table 3.—U.S. estimated distribution of primary strontium compounds, by end use

(Percent)

End use	1984	1985	1986
Electrolytic production of zinc	6	6	6
Ferrite ceramic magnets	11	12	7
Pigments and fillers	8	8	7
Pyrotechnics and signals	14	15	15
Television picture tubes	53	52	58
Other	1	1	1
Unidentified	7	6	6
Total	100	100	100

PRICES

The average customs value of imported celestite from Mexico was $96.78 per short ton. The average value per ton was $172.37 for material from Spain and $183.06 for material from China. The weighted average value for all imported celestite was $102.18 per ton, an increase of about 16% from the average value in 1985. Values for imported strontium compounds varied according to the type of compound.

FOREIGN TRADE

Celestite was imported from China, Mexico, and Spain in 1986. Strontium compounds were imported from Canada, China, Japan, Mexico, and several Western European countries. Imports of unwrought strontium metal were more than five times greater than those of 1985. Canada was the source of all strontium metal imported into the United States. The Federal Republic of Germany was the primary supplier of imported strontium carbonate, and Mexico was becoming more important as a source. Imports for consumption of strontium carbonate, the most common strontium compound, increased almost 19%, and imports for consumption of strontium nitrate remained about the same.

According to the Port Import/Export Reporting Service of the Journal of Commerce, exports of various strontium compounds were about 1,500 tons. This figure represents a significant increase in exports above the 38 tons that were reported in 1985 from the same source. Of these exports, 94% was strontium carbonate exported to Japan. Other strontium compounds exported were the chloride, chromate, nitrate, and peroxide.

Table 4.—U.S. imports for consumption of strontium minerals,[1] by country

Country	1985 Quantity (short tons)	1985 Value[2] (thousands)	1986 Quantity (short tons)	1986 Value[2] (thousands)
China	--	--	348	$64
Mexico	37,552	$3,321	30,904	2,991
Spain	--	--	1,983	342
Total[3]	37,552	3,321	33,236	3,396

[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 5.—U.S. imports for consumption of strontium compounds and metal, by country

Country	1985 Pounds	1985 Value[1]	1986 Pounds	1986 Value[1]
Strontium carbonate, not precipitated:				
Germany, Federal Republic of	--	--	39,682	$11,663
Mexico	186,384	$51,256	--	--
Total	186,384	51,256	39,682	11,663
Strontium carbonate, precipitated:				
Canada	119,049	35,169	--	--
China	37,478	11,003	--	--
Germany, Federal Republic of	9,676,889	2,955,649	8,208,672	2,247,425
Mexico	244,100	64,800	3,739,467	931,557
United Kingdom	--	--	27	2,536
Total	10,077,516	3,066,621	11,948,166	3,181,518

See footnotes at end of table.

Table 5.—U.S. imports for consumption of strontium compounds and metal, by country —Continued

Country	1985		1986	
	Pounds	Value[1]	Pounds	Value[1]
Strontium chromate:[2]				
Belgium	154,102	$149,580	101,853	$266,510
France	207,154	231,333	41,005	49,275
Germany, Federal Republic of	260,541	244,541	59,524	53,017
Italy	17,637	19,456	--	--
Spain	187,714	212,206	46,297	53,592
United Kingdom	--	--	453	2,432
Total	827,148	857,116	249,132	424,826
Strontium nitrate:				
Germany, Federal Republic of	882	3,014	1,320	6,389
Italy	935,633	371,571	975,865	398,385
Spain	2,427,631	966,496	2,103,227	816,793
Switzerland	--	--	88,184	41,762
United Kingdom	--	--	79,971	35,841
Total	3,364,146	1,341,081	3,248,567	1,299,170
Strontium compounds, other:				
Belgium	7,716	9,450	--	--
Germany, Federal Republic of	58,863	55,379	46,295	32,433
Japan	261,795	175,069	247,486	180,311
Netherlands	--	--	66	1,237
United Kingdom	22,157	29,695	6,324	14,857
Total	350,531	269,593	300,171	228,838
Strontium salts, potassium oxalate and other:				
Canada	65,150	5,693	--	--
Germany, Federal Republic of	--	--	115,985	21,986
Total	65,150	5,693	115,985	21,986
Strontium sulfate, other than celestite:				
Belgium	37,038	35,576	407,407	43,698
France	--	--	110	1,439
Germany, Federal Republic of	--	--	630,302	189,948
Total	37,038	35,576	1,037,819	235,085
Strontium metal, unwrought: Canada	9,052	86,160	50,928	467,759

[1]Customs value.
[2]Imported as strontium chromate pigment (TSUS 473.19).

Source: Bureau of the Census.

WORLD REVIEW

Canada.—The Chromasco Div. of Timminco Ltd. in Toronto, Ontario, was the largest producer of strontium metal in the world and the only producer in North America.[7] The company began construction of a new production facility in Westmeath, Ontario, for magnesium, strontium, and calcium metals. The first phase of the expansion, a new facility for producing high-purity strontium metal, was expected to be completed in the spring of 1987. The facility was to be equipped with new energy-efficient gas-fired vacuum furnaces specifically designed to maximize yield. Strontium production was expected to increase over 40% upon operation of the new facility. Strontium metal produced by Chromasco was used by the aluminum industry to enhance castings used principally for automotive parts. Timminco owned, but did not operate, a celestite mine in Nova Scotia.[8]

Cyprus.—The Hellenic Mining Co. Ltd. started mining the Maroni celestite deposit in the beginning of the year.[9] The ore was treated at the Vasilico dressing plant to produce commercial concentrates that contain 94% strontium sulfate.

Iran.—Iran Strontium Co., a wholly owned subsidiary of the Simiran group of companies, worked one of the largest celestite deposits in the world.[10] The mine is located at Nakhjir, in the Dasht-e-Kavir salt desert, southeast of Tehran. Because the Iranian celestite has been exported to the U.S.S.R., production figures traditionally have been estimated. In 1986 estimates for past years were revised to indicate significantly greater production than that previously reported.

Qatar.—Celestite deposits estimated to contain about 70,000 tons of celestite ore averaging 75% to 85% strontium sulfate were discovered on the southwestern coast.[11] The celestite was discovered during a study to assess total limestone reserves in the country. About 32,000 tons of celestite occurs as surface outcrops, with the rest occurring in underground deposits.

Table 6.—Strontium minerals: World production, by country[1]

(Short tons)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Algeria[e]	6,000	6,000	6,000	6,000	6,000
Argentina	855	742	440	[e]550	550
Cyprus	--	--	--	1,500	6,000
Iran[3]	[4]33,070	[4]23,150	25,350	22,050	[4]24,250
Italy	3,607	[4]456	([5])	5,083	[4]5,144
Mexico (celestite)	34,917	41,343	35,264	35,627	35,300
Pakistan	513	149	622	791	1,200
Spain	38,470	38,000	29,760	46,850	44,000
Turkey[e]	16,500	[4]42,808	38,600	38,600	38,600
United Kingdom	19,800	13,340	17,750	25,350	22,000
Total	[r]153,732	[r]165,988	153,786	182,401	183,044

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through June 9, 1987.
[2]In addition to the countries listed, China, the Federal Republic of Germany, Poland, and the U.S.S.R. produce strontium minerals, but output is not reported quantitatively, and available information is inadequate for formulation of reliable estimates of output levels.
[3]Year beginning Mar. 21 of that stated.
[4]Reported figure.
[5]Revised to zero.

WOLLASTONITE[12]

Wollastonite is a natural calcium silicate and has a theoretical composition of $CaO \cdot SiO_2$.

The tonnage of wollastonite sold or used by U.S. producers in 1986 was approximately the same as that of 1985. Specific data are 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. In early 1986, Vanderbilt opened a new processing operation in the Netherlands in cooperation with Ankersmit Maalbedrijven BV. The new plant was to produce ground wollastonite using a specially designed process that preserves the integrity of the mineral's acicular crystalline structure. Wollastonite ore was to be shipped from Vanderbilt's U.S. operation to its grinding plant in the Netherlands for supplying European customers.[13]

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.

A comprehensive article on wollastonite discussed production and active companies in Finland, India, Mexico, and the United States and also applications for both powder and long-grained material. Also covered were synthetic wollastonite and markets for wollastonite in Europe.[14]

The Chinese wollastonite industry was described, including deposits, mining methods, processing, and marketing aspects. Exports from Jilin Province in 1985, including both wollastonite ore and ground product, were an estimated 34,000 short tons. Ore was exported in small lots to Japan and several European nations.[15]

Yugoslavia was seeking interested parties to revitalize a development program for a high-grade wollastonite deposit, for which initial exploration and research work was shelved in the late 1960's. The deposit, located approximately 120 miles south of Belgrade, in Serbia, was reported to contain 60% to 70% wollastonite with associated minerals such as quartz and calcite. Using flotation and electromagnetic separation, under laboratory conditions, concentrates assayed as high as 90% wollastonite with a maximum of 0.5% ferric oxide. The initial exploration work indicated that the deposit had reserves sufficient for 15 years at a production rate of 27,000 tons per year.[16]

Chemical Marketing Reporter, December 29, 1986, 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.

ZEOLITES[17]

Five companies mined or sold chabazite, clinoptilolite, and phillipsite from deposits in five States. Natural zeolites were used for removing ammonium ions from aquacultural systems, as deodorizers and absorbents for household and farm applications, for removing radioactive ions from nuclear plant effluent, and for removing heavy metals from industrial wastewaters.

East West Minerals NL purchased five zeolite properties from Anaconda Minerals Co. These properties were the Ash Meadows deposit in California, the Ash Meadows Ranch in Nevada, the Rome and Harney Lake deposits in Oregon, and the Bowie deposit in Arizona. East West Minerals will continue production at the Ash Meadows deposit.[18] The company installed a new screening plant at the site and began processing stockpile materials.[19]

Following a joint meeting of the American Society for Testing and Materials (ASTM) committees on soil, rock, and catalysts, ASTM initiated plans to develop standards for characterizing and describing zeolites. Tests for characterizing the chemical, physical, and catalytic properties of zeolites, their biological reactivities, and standard methods of synthesizing zeolite A and zeolite B will be considered.[20]

Zeolites are tectosilicates whose frameworks are formed by interconnected SiO_4^{-4} and AlO_4^{-5} tetrahedra. Thirty-nine structures representing slight variations in the angular relationships between adjoining framework tetrahedra were recognized. All zeolites contain channels and open areas or cages within the crystalline structure. The sizes of the channel openings and cages are different for each zeolite type and were major factors in determining the industrial applications of zeolites.[21]

Zeolites are useful catalysts because of the channels and cages. The channels are important because their size determines which molecules can enter the cages to undergo catalysis and which molecules can leave the cage as a product of the catalytic reaction. Molecules with physical dimensions larger than the channel opening will be excluded from the cage and will not be involved in the catalytic reactions. Catalysis products that are larger than the channel opening will be trapped in the cage and undergo further catalysis. The cages within the zeolite structures also affect the catalytic reaction because their size determines which transition state compounds are formed. By choosing zeolites with the appropriate channel opening and cage sizes, chemists controlled the reactions that occur.

Several catalysts for fluidized-bed catalytic cracking were developed over the past few years because of decreased oil prices, requirements for emission controls, and increased gasoline demand. New catalysts for increasing octane ratings of gasoline were based on the ultrastable zeolite Y. In general, they possessed high silicon to aluminum ratios, had small crystalline cell sizes, and contained either no rare-earth oxides or rare-earth oxides in low concentrations.

One problem encountered with the octane-boosting catalysts as a result of the low rare-earth oxide content was decreased gasoline yield. In response, catalysts that increased both the octane rating and the yield were developed. Using new technology, zeolites possessing silicon to aluminum ratios as large as 20 to 1 with fewer, more reactive sites were synthesized. Katalistics International BV's Beta catalyst, which is based on this new technology, improved conversion activity by 1.9% without compromising gasoline yield, increased the octane rating, resisted vanadium poisoning, and had a higher output of isomers for alkylation process feed.

Refiners also increased both octane rating and gasoline yield by including size selective catalysts, such as ZSM-5, with fluidized-bed catalytic cracking catalysts. The ZSM-5 catalyst preferentially cracked straight-chain hydrocarbons to higher octane branched-chain hydrocarbons.

Homogeneous catalysts, which are catalysts in solution with the reactant, offered advantages over conventional catalysts. These included lower reaction temperatures and more control over the number of competing reactions that occur during catalysis. Homogeneous catalysts, however, can be expensive, must be separated from the final products, and may be lost during the processing stage. Researchers studied ways of immobilizing homogeneous catalysts in solid substrates. By trapping the homogeneous catalyst within a zeolite structure, the catalyst participated in the reactions, yet remained separate from the products.

Zeolites also were used to take advantage of the catalytic properties of metal atoms. Clusters of some metal atoms were more efficient catalysts than individual metal atoms but were usually unstable at room temperatures. Researchers found that metal clusters could be stabilized if formed within a zeolite structure. The zeolite containing the metal clusters could then be used as a catalyst, capitalizing on the catalytic capabilities of the metal clusters and the size and shape selectivity of zeolite catalysts.[22]

One reason for the recent advances in zeolite technology was the increased knowledge of the crystal structure. Information about the relationships between atoms in the crystal lattice was obtained using infrared spectroscopy, Mossbauer spectroscopy, electron spin resonance spectroscopy, and nuclear magnetic resonance spectroscopy. Sample purity and homogeneity were determined using electron microscopy. Analytical electron microscopes provided images of the zeolite crystal lattice, and X-ray diffraction techniques were used for crystal structure analysis.[23]

A process was developed to synthesize zeolites using chrysotile as a starting material. The magnesium was stripped from the chrysotile structure. The remaining siliceous material was mixed with alumina and heated under pressure to synthesize zeolite crystals. Production of 1 ton of zeolite consumed 2 tons of chrysotile.[24]

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[2]Prepared by James P. Searls, physical scientist.
[3]Prepared by Sarkis G. Ampian, physical scientist.
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Other Metals

By Staff, Divisions of Nonferrous and Ferrous Metals

CONTENTS

ARSENIC[1]

Although ASARCO Incorporated, the only domestic producer, had terminated copper smelting operations and associated recovery of byproduct arsenic trioxide at Tacoma, WA, in 1985, it shipped small quantities of both trioxide and metal from its remaining stocks in 1986. Imports for consumption of arsenic trioxide increased significantly, owing to increased demand for arsenical wood preservatives and the decrease in domestic shipments of trioxide. Prices remained unchanged throughout the year. Development of gallium arsenide integrated circuits, important in advanced military and commercial electronics circuitry, continued to gain momentum during 1986.

Domestic Data Coverage.—Shipments of small amounts of arsenic trioxide and metal from remaining stocks by Asarco were reported voluntarily to the Bureau of Mines.

Legislation and Government Programs.—In September, an agreement was reached between the Environmental Protection Agency (EPA) and Asarco concerning the demolition of arsenic production facilities at Asarco's closed copper smelter in Tacoma, WA, in such a manner as to prevent releases of arsenic to the environment.

In January, following challenges filed by the wood preservative industry, the EPA issued an amendment to its July 1984 regulations governing the use and handling of arsenical, creosote, and pentachlorophenol wood preservatives. The changes were minor in scope and provided clarification of certain provisions, a somewhat different mechanism for achieving the same degree of risk protection, and changes in timing for certain label requirements.

In August 1986, the EPA issued its final rules on arsenic emissions from copper smelters and glass manufacturing plants. The final rules in effect require installation of additional air pollution control equipment at one copper smelter and two glass manufacturing plants, at a total estimated cost of $4.5 million. The regulations as first proposed in July 1983 would have required additional controls at 7 copper smelters and 14 glass manufacturing plants.

On October 17, 1986, Public Law 99-499, an Act to Extend and Amend the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund) was enacted. The new law provides that effective January 1, 1987, arsenic and arsenic trioxide will be taxed at the same rates, $4.45 per short ton and $3.41 per short ton, respectively, as imposed by Superfund, which had expired more than a year earlier on September 30, 1985.

DOMESTIC PRODUCTION

Asarco shipped small quantities of arsenic trioxide and metal to customers from the remaining stocks at its closed copper smelter at Tacoma, WA. The company also refined high-purity arsenic metal, for use in electronic devices, from commercial-grade metal at Globe, CO.

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 (CCA) wood preservatives. Mineral Research Development Corp. in Charlotte, NC, also produced arsenic acid for use in wood preservatives. 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 1986. Demand for arsenic increased above the 1985 level and equaled the peak demand of 1981. Increased consumption of arsenic trioxide by the wood preservative industry in formulating CCA wood preservatives accounted for most of the increase in demand. Three major producers of arsenical wood preservatives and four producers of agricultural chemicals accounted for most of the domestic consumption of arsenic trioxide. Arsenic acid, produced from arsenic trioxide, was used directly, or as an intermediate product. The estimated end-use distribution of arsenic was 67% in wood preservatives, 25% 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.).

CCA, by far the most important of the arsenical wood preservatives, is a waterborne, leach-resistant wood preservative prepared by mixing arsenic acid with copper oxide or sulfate and chromic acid. It is used to pressure treat a variety of wood products that are subject to outdoor or inground exposure, and may serve to extend the service life of wood by a factor of at least 15.[2]

The principal agricultural market for arsenicals was in cotton growing, where arsenic acid was used as a desiccant to aid in mechanical stripper harvesting of cotton, and other arsenical chemicals, such as monosodium methanearsonate and disodium methanearsonate, were used as herbicides for control of grassy and broadleaf weeds. To a lesser extent, arsenical herbicides were used in noncrop areas such as railroad rights-of-way.

Arsenic trioxide and arsenic acid were used in the glass industry primarily as fining agents to remove tiny, dispersed air bubbles, and also as decolorizing agents. Use in recent years has been limited to the pressed and blown glass sector for products such as tableware, lead glass, optical glass, and glass ceramics.

The bulk of metallic arsenic was used in lead- and copper-based 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, on the order of 15 metric tons, of high-purity arsenic metal was used in the electronics industry. Gallium arsenide and its alloys have been used in such products as light-emitting diodes and displays, room-temperature lasers, microwave devices, solar cells, and photoemissive surfaces. Gallium arsenide integrated circuits, currently undergoing commercial development, have, compared with silicon circuits, 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

The price of domestically produced crude arsenic trioxide, guaranteed minimum 95% purity, remained constant thoughout the year at $0.33 per pound. Prices for imported refined trioxide also remained virtually constant throughout the year; Mexican trioxide had a published price of $0.44 per pound.

The price of domestically produced arsenic metal, 99% pure, remained constant at $1.85 per pound. High-purity arsenic metal for electronics usage was sold in evacuated or argon-filled ampules. Domestic high-purity metal, guaranteed to be 99.999% pure, sold for $100 per kilogram, while imported material of higher guaranteed purity cost as much as $100 per gram in small quantities.

Table 1.—Arsenic price quotations

(Cents per pound, yearend)

	1984	1985	1986
Trioxide, domestic, 95% As_2O_3, f.o.b. Tacoma, WA[1]	33	33	33
Trioxide, Mexican, 99.13% As_2O_3, f.o.b. Laredo, TX[2]	42	42	44
Metal, domestic, 99% As[1]	210	210	185

[1]Producers' quote.
[2]Metals Week.

FOREIGN TRADE

As demand increased and domestic shipments fell sharply, imports for consumption of arsenic trioxide increased to a record-high level of 25,728 metric tons.

Table 2.—U.S. imports for consumption of arsenicals, by class and country

Class and country	1984		1985		1986	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Arsenic trioxide:						
Australia	--	--	30	$3	--	--
Belgium-Luxembourg	843	$654	1,498	1,074	1,255	$967
Bolivia	16	4	98	67	--	--
Canada	4,767	1,468	3,669	4,059	1,924	310
Chile	--	--	191	101	1,659	727
China	--	--	105	46	39	25
France	1,261	849	3,608	2,264	6,274	4,072
Germany, Federal Republic of	(1)	1	--	--	200	169
Japan	--	--	371	184	141	74
Korea, Republic of	68	51	--	--	--	--
Mexico	3,115	2,820	3,399	2,946	4,408	3,471
Namibia	--	--	--	--	354	224
Netherlands	--	--	236	149	--	--
Philippines	--	--	23	10	936	335
Portugal	--	--	18	12	36	24
Saudi Arabia	--	--	--	--	96	53
South Africa, Republic of	--	--	113	72	1,210	475
Sweden	3,914	3,608	2,996	3,014	7,069	5,341
United Kingdom	--	--	116	58	128	80
Total[2]	13,985	9,454	16,472	14,059	25,728	16,347
Arsenic acid:						
Australia	21	15	--	--	--	--
Canada	(1)	1	--	--	--	--
Germany, Federal Republic of	(1)	(1)	--	--	(1)	1
Japan	(1)	1	--	--	--	--
Mexico	65	57	--	--	--	--
United Kingdom	2,420	1,973	1,993	1,360	1,381	999
Total	2,506	2,047	1,993	1,360	1,381	1,000
Arsenic sulfide:						
Canada	20	3	--	--	--	--
Japan	(1)	1	--	--	--	--
Philippines	--	--	2	2	--	--
Sweden	--	--	--	--	16	2
United Kingdom	--	--	--	--	(1)	12
Total	20	4	2	2	16	14
Arsenic metal:						
Canada	21	712	23	644	8	731
China	102	350	136	311	295	951
France	(1)	4	--	--	--	--
Germany, Federal Republic of	2	215	2	195	7	272
Hong Kong	--	--	47	158	34	115
Japan	1	127	22	171	2	382
Netherlands	5	19	--	--	(1)	4
Sweden	158	614	171	642	34	124
Switzerland	--	--	--	--	10	53
Taiwan	--	--	5	17	--	--

See footnotes at end of table.

Table 2.—U.S. imports for consumption of arsenicals, by class and country —Continued

Class and country	1984		1985		1986	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Arsenic metal —Continued						
United Kingdom	15	$87	(1)	$12	5	$17
Total[2]	304	2,127	407	2,150	395	2,649
Lead arsenate:						
Canada	3	3	29	13	--	--
Germany, Federal Republic of	3	9	--	--	6	56
Japan	--	--	(1)	1	--	--
Netherlands	12	26	66	128	--	--
Peru	54	105	68	144	--	--
United Kingdom	1	2	--	--	60	114
Total[2]	73	145	162	287	66	170
Sodium arsenate:						
France	--	--	20	7	--	--
Other	1	3	(1)	3	--	--
Total	1	3	20	10	--	--
Arsenic compounds, n.e.c.:						
Brazil	--	--	--	--	9	482
Canada	17	588	--	--	(1)	1
Mexico	--	--	23	52	--	--
Sweden	17	20	--	--	--	--
United Kingdom	1	165	(1)	66	(1)	175
Other	(1)	29	(1)	13	(1)	13
Total[2]	35	801	23	131	10	671

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

Source: Bureau of the Census.

Table 3.—U.S. import duties for arsenicals

Item	TSUS No.	Most favored nation (MFN)		Non-MFN
		Jan. 1, 1986	Jan. 1, 1987	Jan. 1, 1986
Arsenic metal	632.04	0.3 cent per pound	Free	6.0 cents per pound.
Trioxide and sulfide	417.62, 417.60	Free	do	Free.
Other compounds	417.64	3.9% ad valorem	3.7% ad valorem	25% ad valorem.

WORLD REVIEW

Arsenic trioxide was produced in at least 15 countries as a byproduct of processing nonferrous ores. The six principal producing countries accounted for about 81% of world production.

In addition to the United States, which accounted for more than 60% of the world demand, the United Kingdom was a major consumer of arsenic trioxide and metal.

Table 4.—Arsenic trioxide:[1] World production, by country[2]

(Metric tons)

Country[3]	1982	1983	1984	1985[p]	1986[e]
Belgium[e]	3,000	3,000	3,000	3,000	3,000
Bolivia	261	107	144	361	200
Canada[e 4]	2,000	2,000	3,000	3,000	3,000
Chile[5]	--	--	[e]3,500	[e]4,000	6,000
France	[e]6,000	4,727	3,828	[r e]8,000	10,000
Germany, Federal Republic of[e]	360	360	360	360	360
Japan[e]	100	300	500	500	500
Korea, Republic of	306	560	NA	NA	NA
Mexico	4,740	4,557	5,496	6,312	6,000
Namibia[6]	1,895	1,126	2,504	2,471	[7]1,936
Peru[8]	[r]1,910	[r]1,009	1,090	1,257	1,210
Philippines[9]	--	--	--	[e]5,000	5,000
Portugal[e]	200	180	180	170	150
Sweden[e 10]	[r]9,000	[r]9,000	[r]10,000	[r]10,000	10,000
U.S.S.R.[e]	7,800	7,900	8,000	8,100	8,100
United States	8,000	7,300	6,800	2,200	--
Total	[r]45,572	[r]42,126	48,402	54,731	55,456

[e]Estimated. [p]Preliminary. [r]Revised. 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 9, 1987.
[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]Reported figure.
[8]Output of Empresa Minera del Centro del Perú (Centromín Perú) as reported by the Ministerio de Energia y Mines.
[9]The Philippines may have had some arsenic output in 1984 from the Philippine Smelting and Refining Corp. (PASAR) copper smelter, but available data are not adequate to make reliable estimates of output levels, if any.
[10]Based on arsenic trioxide exported plus the arsenic trioxide equivalent of the output of metallic arsenic exported.

TECHNOLOGY

Advances continued in the commercial development of gallium arsenide integrated circuit technology. Because of the potential advantages of gallium arsenide for military applications, the defense budget for fiscal year 1987 included an authorization of $41 million for gallium arsenide production technology.

For a more extensive discussion of gallium arsenide, its uses, and potential uses, see the chapter on gallium in the 1986 Minerals Yearbook.

CESIUM AND RUBIDIUM[3]

Cesium, usually in the form of chemical compounds, was used mainly in research and development, including the development of magnetohydrodynamic (MHD) electric power generators, thermionic energy converters, and biological research. Commercially, cesium was used in electronic, photoelectric, and medical applications. Rubidium, usually in the form of chemical compounds, also was used mainly in research and development. It was also used commercially in electronic and medical applications.

Domestic Data Coverage.—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, all responded, but only one company reported production of cesium and rubidium products. Production data are withheld to avoid disclosing company proprietary data.

DOMESTIC PRODUCTION

Small quantities of cesium metal and compounds were produced from pollucite ore imported from Canada and Zimbabwe. Rubidium metal and compounds were produced from lepidolite ores imported from Canada.

The only producer of cesium and rubidium metals was the KBI Div. of Cabot Corp., at Revere, PA. The KBI Div. also produced cesium and rubidium compounds. The Special Products Div. of Carus Chemical Co. completed expansion of its production of cesium chemicals and became a principal supplier of these materials.[4] The Callery Chemical Co., Callery, PA, a producer in past years, retained its production capacity and was considered a potential supplier.

CONSUMPTION AND USES

Data concerning specific end uses and consumption patterns for cesium and rubidium and their compounds were not available. Cesium and rubidium and their respective compounds were interchangeable in most applications, although cesium compounds were the most widely accepted because of their availability and price advantages.

More than 75% of the cesium and rubidium consumed in the United States was used in research. The principal use in this application was developmental research on direct energy-conversion devices, such as MHD generators, solar photovoltaic cells, and thermionic and high-temperature Rankine-cycle turboelectric power generators. Commercial consumption included uses for high-voltage rectifying tubes and for infrared lighting. Cesium chloride was used in photoelectric cells because its color sensitivity is higher than that of other alkali salts.

PRICES

Prices of technical-grade cesium and rubidium compounds increased slightly in 1986. The price of high-purity cesium compounds decreased an average of 4% while that of high-purity rubidium compounds increased an average of 7%. Cesium metal prices remained unchanged from the prices established in 1982. At yearend, cesium metal was $275 per pound for technical-grade metal and $375 per pound for high-purity metal. Rubidium metal remained unchanged from the levels established in 1980 at $300 per pound for technical-grade metal and $375 for high-purity metal. All price data were obtained from the KBI Div. of Cabot.

Table 5.—Prices of selected cesium and rubidium compounds

(Base price per pound[1])

Compound	1984		1985		1986[2]	
	Technical grade	High-purity grade	Technical grade	High-purity grade	Technical grade	High-purity grade
Cesium bromide	$36.80	$74.70	$36.80	$74.70	$37.00	$73.00
Cesium carbonate	36.80	74.70	36.80	74.70	39.00	74.00
Cesium chloride	39.20	78.00	39.20	78.00	41.50	76.00
Cesium fluoride	46.80	86.00	46.80	86.00	44.50	79.00
Cesium hydroxide	44.40	83.90	44.40	83.90	44.50	79.00
Rubidium carbonate	89.80	134.40	98.80	147.80	103.50	155.00
Rubidium chloride	90.90	135.50	100.00	149.10	103.50	155.00
Rubidium fluoride	97.80	141.90	107.60	156.10	112.00	170.00
Rubidium hydroxide	97.80	141.90	107.60	156.10	112.00	170.00

[1]For quantities of less than 100 pounds, f.o.b. Revere, PA, excluding packaging costs.
[2]Effective Mar. 15, 1986.

Source: Cabot Corp. (KBI Div.).

Table 6.—U.S. imports for consumption of cesium compounds, by class and country

Class and country	1984		1985		1986	
	Quantity (pounds)	Value	Quantity (pounds)	Value	Quantity (pounds)	Value
Cesium chloride:						
Germany, Federal Republic of	25,050	$741,468	20,452	$630,635	27,924	$952,998
Netherlands	110	6,465	33	1,887	44	2,639
Norway	--	--	362	11,335	210	12,187
Sweden	18	884	115	7,367	124	9,096
United Kingdom	--	--	192	5,464	--	--
Total	25,178	748,817	21,154	656,688	28,302	976,920
Cesium compounds, n.s.p.f.:						
Canada	520	4,100	--	--	--	--
German Democratic Republic	--	--	119	2,625	--	--
Germany, Federal Republic of	18,206	626,885	28,358	735,785	7,140	165,717
Greece	--	--	110	2,726	--	--
Israel	100	30,000	--	--	--	--
Japan	210	60,087	170	32,250	1,984	5,821
Netherlands	231	11,980	--	--	58	11,390
United Kingdom	9,207	69,925	626	164,468	3	1,076
Total	28,474	802,977	29,383	937,854	9,185	184,004

Source: Bureau of the Census.

Table 7.—U.S. import duties for cesium and rubidium

Item	TSUS No.	Most favored nation (MFN) Jan. 1, 1986	Most favored nation (MFN) Jan. 1, 1987	Non-MFN Jan. 1, 1986
Ore and concentrate	601.66	Free	Free	Free.
Cesium	415.10	5.7% ad valorem	5.3% ad valorem	25% ad valorem.
Cesium chloride	418.50	4.3% ad valorem	4.0% ad valorem	Do.
Other cesium compounds	418.52	4.1% ad valorem	do	Do.
Rubidium	415.40	3.9% ad valorem	3.7% ad valorem	Do.
Rubidium compounds	423.00	do	do	Do.

WORLD REVIEW

The Tantalum Mining Corp. of Canada Ltd.'s mine at Bernic Lake, Canada, the major world source of the cesium ore pollucite and the rubidium ore lepidolite, remained on standby throughout 1986. The mine suspended operations at yearend 1982 owing to weak markets and large inventories.

GERMANIUM[5]

Domestic production and consumption of refined germanium were estimated at the same levels as those of 1985. Infrared systems and fiber optics continued to be the major markets for germanium; however, germanium consumption in fiber optics decreased slightly compared with that of 1985. Underutilization of existing telecommunications systems reportedly led to cancellations or delays in the construction of additional fiber-optic systems. The General Services Administration (GSA) announced that it planned to acquire germanium metal for the National Defense Stockpile (NDS) in fiscal year 1987.

Research in advanced technology applications for germanium continued in 1986. Germanium films for electronic components were reportedly formed using a newly developed laser-induced chemical vapor deposition method. Systems utilizing the infrared properties of germanium were designed to aid in the geological interpretation of the surfaces of the Earth and Mars. Research continued on the use of germanium-tellurium alloys for erasable and rerecordable optical disks.

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.—On December 23, the GSA announced plans to begin purchasing germanium metal for the NDS in fiscal year 1987. GSA issued Basic Ordering Agreements (BOA) to potential suppliers of germanium. Upon examination of these agreements, the GSA will decide which companies will be eligible to bid for contracts. Under executed BOA's, all terms and conditions for delivery of germanium would be agreed to except unit price, specified quantities, and exact delivery period. Revised NDS Purchase Specifications for germanium metal (P-114-R) were published by the U.S. Department of Commerce with the approval of the Federal Emergency Management Agency on December 16, 1986.

As of December 31, the NDS goal for germanium metal was 30,000 kilograms, and no germanium metal had been acquired.

DOMESTIC PRODUCTION

Domestic refinery production from both primary and secondary materials was estimated to be 22,000 kilograms. Based on the published U.S. producer price for refined germanium metal, the approximate value of production was $23 million.

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.

Technical problems in the extraction process delayed full production of germanium and gallium at Musto Explorations Ltd.'s plant near St. George, UT. The plant was designed to process 100 metric tons of ore per day. Actual plant throughput in 1986 totaled 9,300 tons. Construction of the germanium refinery was completed on July 1. Full-scale production reportedly began on August 4, and the first shipment of germanium dioxide was made on August 12. According to the company's annual report, total production of germanium dioxide in 1986 amounted to 2,555 kilograms of contained germanium. In July, the purification section of the gallium refinery was modified, and the purity of the gallium product was improved from 99.9% to 99.99%. Recovery rates for both gallium and germanium were well below the projected annual recovery rates of 9,000 kilograms and 19,000 kilograms, respectively, and sales of the products reportedly were not generating enough working capital for the plant. A pressure-leaching system was proposed to improve recovery rates. Musto was the only operation in the world to recover germanium and gallium as principal products.

CONSUMPTION AND USES

The consumption of germanium was estimated at 38,000 kilograms, the same level as that of 1985. The estimated consumption pattern by end use of germanium in 1986 was as follows: infrared systems, 65%; fiber optics, 12%; gamma-ray, X-ray, and infrared detectors, 5%; semiconductors, 5%; and other, 13%.

The largest end use for germanium continued to be in infrared optics, especially military use in guidance and weapon-sighting systems. Germanium-containing lenses and windows transmit thermal radiation in a manner similar to visible light transmission by optical glass. Several military programs using germanium windows, including the M-1 tank and the B-52 bomber, reportedly were given multiyear funding during the year. Other important uses for germanium glass included nonmilitary surveillance and monitoring systems in fields such as satellite systems and fire alarms.

Another important market for germanium was in fiber-optic cables used in telecommunications systems. Fiber-optic systems provided a compact, short-circuit-free transmission medium that was not susceptible to distortion by an electromagnetic field and could not be tapped by currently available technology. These attributes and the relatively light weight of the fibers reportedly made fiber-optic systems ideal for some military applications. Descriptions of some of these potential military uses were presented in papers published during the year.[6] Although not used in all fiber-optic systems, germanium was an important constituent in many fiber-optic cables.

The initial dramatic growth in fiber-optic telecommunications systems reportedly slowed in 1986. Many of the previously announced long-distance systems were virtually completed, and growth in the installation of additional systems slowed. The efficiency of optical fibers and improvements in technology reportedly resulted in fewer transmission lines being required than originally predicted. This leveling out in fiber-optic demand for long-distance applications was expected to be offset by an increase in demand from local telephone companies. However, the demand from local telephone companies to link their central switching offices to residential customers using fiber-optic systems did not materialize in 1986.

Despite this overall slowdown in the fiber-optics market, the planned installation of a few new long-distance fiber-optic telecommunications systems was announced in 1986. A consortium of five companies from Canada, France, Spain, the United Kingdom, and the United States announced their intention to construct a new transatlantic fiber-optic cable system to be known as TAT-9. This new system, which reportedly would carry up to 80,000 voice transmissions, was scheduled to be operational by late 1990 or early 1991.[7] In 1986, MCI Communications Corp. announced that the company had obtained the rights-of-way for expansion of its fiber-optic route from Chicago to Los Angeles. The company stated that this expansion would provide a coast-to-coast fiber network by linking the company's eastern network to its recently completed San Francisco to San Diego network. Construction reportedly was expected to begin in early 1987 and was scheduled for completion by yearend.[8]

Germanium was used as a substrate upon which gallium arsenide phosphide was deposited to form an essential part of light-emitting diodes. Germanium was also used in the manufacture of other semiconductor electronic equipment; to improve the hardness of aluminum, copper, and magnesium alloys; and in some foreign countries, as a catalyst in the production of polyester fibers and plastic bottles.

PRICES

The domestic producer prices, published in Metals Week, for germanium metal and germanium dioxide were unchanged throughout 1986 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 $942 and $571 per kilogram, respectively.[9] On April 21, the prices decreased to $933 per kilogram for germanium metal and $565 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, less estimated processing charges, was used to estimate the germanium content of imported scrap. In 1986, the estimated germanium content of total imports was calculated to be approximately 8,000 kilograms.

Table 8.—U.S. imports for consumption of germanium, by class and country

Class and country	1985		1986	
	Gross weight (kilograms)	Value	Gross weight (kilograms)	Value
Unwrought and waste and scrap:				
Belgium-Luxembourg	3,772	$1,980,066	833	$850,804
Canada	23	7,206	21	17,058
China	4,044	1,952,255	6,296	2,746,121
Costa Rica	1,000	597,643	--	--
France	1,227	722,304	19	16,590
German Democratic Republic	8	2,220	--	--
Germany, Federal Republic of	102	165,612	137	197,860
Hong Kong	--	--	489	209,186
India	--	--	85	13,337
Israel	--	--	195	38,948
Italy	--	--	542	30,063
Netherlands	141	7,191	889	85,757
Nigeria	3	3,205	--	--
Sweden	--	--	179	127,806
Switzerland	111	41,037	45	10,490
Taiwan	--	--	213	89,329
U.S.S.R	5	1,865	--	--
United Kingdom	611	242,226	--	--
Total	11,047	5,722,830	9,943	4,433,349
Wrought:				
Belgium-Luxembourg	2,540	2,385,340	2,347	2,726,407
Brazil	249	307,609	--	--
Canada	9	5,625	--	--
China	--	--	198	73,856
France	--	--	8	1,315
Germany, Federal Republic of	5	4,624	415	290,640
Norway	130	72,661	--	--
Singapore	679	203,378	--	--
Sweden	182	126,492	--	--
Total	3,794	3,105,729	2,968	3,092,218

Source: Bureau of the Census.

Table 9.—U.S. import duties for germanium metal and germanium dioxide

Item	TSUS No.	Most favored nation (MFN)		Non-MFN
		Jan. 1, 1986	Jan. 1, 1987	Jan. 1, 1986
Germanium dioxide	423.00	3.9% ad valorem	3.7% ad valorem	25.0% ad valorem.
Metal, unwrought and waste and scrap	628.25	do	do	Do.
Metal, wrought	628.30	5.9% ad valorem	5.5% ad valorem	45.0% ad valorem.

WORLD REVIEW

World refinery production was estimated at 80,000 kilograms. Germanium was produced by MHO, Belgium; Société Minière et Métallurgique de Penarroya S.A., France; Società Mineraria e Metallurgica di Pertusola S.A., Italy; Bleiberger Bergwerks-Union AG, Austria; and Preussag Metall AG and Otavi Minen AG, Federal Republic of Germany. Germanium refineries also were in China, Japan, and the U.S.S.R.

Australia.—The Overseas Telecommunications Commission (OTC) announced plans to build a submarine fiber-optic telecommunications network linking Australia to New Zealand and later to North America and Asia. Phase 1 of the project, Tasman II, was a joint venture with the New Zealand Post Office to connect Tasmania, Australia, with New Zealand by 1991. According to OTC, the phase 2 extension to North America was scheduled for completion by 1993, and phase 3 to Asia by 1995.[10]

Canada.—Cominco Ltd. announced plans to construct a germanium refinery at its complex in Trail, British Columbia. The plant reportedly would have an initial capacity of 5,000 kilograms of metal per year. The company stated that it planned to produce germanium preconcentrates during the first quarter of 1987, germanium concentrates in the second quarter, and zone-refined metal bars in the third quarter of 1987.

A paper was published describing the geology, reserve estimation, mine planning, ore dressing, refining, and economic evaluation of Fargo Oil Corp.'s Lang Bay property in British Columbia. This sedimentary deposit reportedly contained lignite seams enriched in germanium. American Cyanamid Co. engineers reported the development of a proprietary flotation reagent effective for concentrating the germanium-rich vitrain portion of the Lang Bay lignite.[11]

Denmark.—American Telephone & Telegraph Co. (AT&T) of Morristown, NJ, and Nordiske Kabel & Traadfabriken A/S (NKT) of Denmark announced the formation of a joint venture to manufacture optical fiber at NKT's facility in Broendby, outside of Copenhagen. AT&T, which reportedly owned 51% of the joint venture, predicted a tripling of the fiber production capacity at the Broendby plant in the near future.

Japan.—Germanium metal production was 8,810 kilograms, a decrease of 14% compared with 1985 metal production levels. Germanium dioxide production decreased from 14,083 kilograms in 1985 to 13,619 kilograms in 1986.[12]

Dowa Mining Co. Ltd. announced that the company would begin employing a new extraction method in August for the recovery of germanium, gallium, and indium from zinc smelting residues produced at its Kosaka complex. The new method reportedly would enable the company to lower extraction costs by 30% compared with the existing solvent extraction method. The annual production capacities of germanium, gallium, and indium employing the new method were expected to be 15,000 kilograms, 7,000 kilograms, and 4,000 kilograms, respectively.[13]

Spain.—Corning Glass Works and the Compañia Telefónica Nacional de España S.A. announced the formation of a new company, Compañia de Fibra Optica Telcor S.A., to manufacture and sell optical fiber within Spain and for export. The manufacturing facility reportedly was scheduled to begin operations in mid-1988 with a planned annual optical fiber capacity of 85,000 kilometers.

U.S.S.R.—A paper was published analyzing the progress of the fiber-optic telecommunications industry from 1981 to 1986. The author drew his information from public journals on physics and engineering. The author contends that while the installed fiber-optic telecommunications capacity at present seemed to be limited, the U.S.S.R. appeared to have made significant advances in some specialty areas, such as frost-resistant fiber cables, radiation-hard fibers, and laser sources for fiber-optic transmission.[14]

TECHNOLOGY

To develop alternative methods for synthesizing electronic products for defense applications, germanium and doped-germanium films reportedly were formed using a photolytic carbon dioxide laser-induced chemical vapor deposition method. The purest germanium is presently obtained by the thermal decomposition of highly pure germanium hydride; however, conversions of from 70% to 80% are rarely exceeded. In the experiments performed in this study, conversions of 86% reportedly were obtained without difficulty. Doping of germanium with cadmium and aluminum also was accomplished with this laser-induced deposition methodology.[15]

Martin Marietta Corp., Denver, CO, announced that it was awarded a contract to design and build a gamma-ray spectrometer to be carried aboard the *Mars Observer* mission, scheduled by the National Aeronautics and Space Administration for launch in 1990. A germanium crystal is the heart of the spectrometer, which will analyze the composition of the surface of Mars from orbit by measuring the spectral content of gamma rays emitted from the surface.

An airborne remote sensing instrument, a thermal infrared multispectral scanner (TIMS), reportedly proved to be an efficient detector of mineral deposits. The TIMS system collected multispectral data from an area below the flight path of a high-altitude aircraft, receiving the radiation from the ground on a line-by-line basis and recording this data onto magnetic tape for later analysis. Recently published results of work performed by investigators at the Jet Propulsion Laboratory and the U.S. Geological Survey reportedly showed considerable promise in the use of multispectral thermal infrared scanner data for discrimination between and, perhaps, identification of, certain rock types. The TIMS scanner included two optical assemblies of major importance to the system; the collecting telescope and the spectrometer. A three-element antireflection coated germanium lens was selected as the focusing optic for the spectrometer.[16]

Research continued on the development of erasable and rerecordable optical disks as a means of storing information for computers as well as for audio and video systems. One of the most promising materials reportedly developed for these devices was a germanium-tellurium alloy. The basic principles of these phase-change optical storage devices were as follows: The disk was coated with a layer of polycrystalline germanium alloy; the data was encoded by hitting the disk with very brief laser pulses and converting tiny spots of the crystalline alloy to a metallic glass; because the metallic glass had different optical properties than the crystalline alloy, the data could be read by a low-intensity laser; and the data could be erased and the disk made ready to accept new data by using longer laser pulses to anneal the metallic glass back to a crystalline alloy.[17]

The rapid increase in resistance of high-purity semiconducting germanium with decreasing temperature in the superfluid helium range of temperature reportedly made this material highly adaptable as a very sensitive thermometer. The germanium thermometer exhibited a highly reproducible resistance versus temperature characteristic curve upon cycling between liquid helium temperatures and room temperature. These two factors combined to make germanium thermometers ideally suited for measuring temperatures in many cryogenic studies at superfluid helium temperatures, as is frequently the case in space science applications. The loss of sensitivity of ordinary metallic resistance thermometers and thermocouples at extremely low temperatures makes these devices unsuited for thermometers below a temperature of about 15 kelvin. The major drawback to purchasing a calibrated germanium thermometer was its fairly high cost. However, with in-house calibration capabilities, it reportedly was possible to realize a substantial savings on thermometer purchases. The objective of the project discussed in this report was the construction of a cryostat and probe for in-house calibration of germanium thermometers.[18]

INDIUM[19]

Indium was produced by the Arconium Corp., Providence, RI, and Indium Corp. of America, Utica, NY. Domestic production in 1986 remained about the same as that of 1985, 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 coatings, solar cells, and semiconductors.

CONSUMPTION AND USES

Indium usage increased in 1986. 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 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 electrical and electronic components, 40%; solders, alloys, and coatings, 40%; and research and other uses, 20%.

PRICES

The producer price of indium, published in Metals Week, was $2.50 per troy ounce at the beginning of the year, increased to $2.65 in April, and to $2.87 in October, at which level it remained for the duration of the year.

FOREIGN TRADE

Imports for consumption of indium rose substantially, compared with those of 1985, and continued at the relatively high levels of other recent years. Italy was the leading supplier in 1986, followed by Belgium-Luxembourg, the United Kingdom, and China.

Table 10.—U.S. imports for consumption of indium, by class and country

(Thousand troy ounces and thousand dollars)

Class and country	1984		1985		1986	
	Quantity	Value	Quantity	Value	Quantity	Value
Unwrought and waste and scrap:						
Belgium-Luxembourg	263	837	99	257	313	751
Canada	26	98	16	100	41	107
China	7	19	128	423	218	520
France	231	844	140	308	113	411
Germany, Federal Republic of	13	43	2	30	2	50
Hong Kong	--	--	19	50	26	72
Italy	101	207	259	596	331	759
Jamaica	--	--	(1)	17	--	--
Japan	9	40	2	43	6	104
Netherlands	78	242	16	67	23	50
Peru	84	273	111	260	60	139
Switzerland	58	125	16	36	8	17
Taiwan	8	42	--	--	--	--
Tunisia	6	19	--	--	--	--
United Kingdom	130	1,575	147	1,009	221	1,159
Total[2]	1,015	4,365	955	3,197	1,362	4,138
Wrought:						
Canada	(1)	62	--	--	--	--
China	--	--	--	--	9	21
France	--	--	19	90	--	--
Germany, Federal Republic of	(1)	1	(1)	3	1	9
Japan	2	40	3	60	1	17
United Kingdom	4	104	3	124	6	440
Other	1	5	(1)	6	(1)	7
Total[2]	7	212	25	283	18	495

[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. import duties for indium

Item	TSUS No.	Most favored nation (MFN)		Non-MFN
		Jan. 1, 1986	Jan. 1, 1987	Jan. 1, 1986
Unwrought, waste, and scrap	628.45	0.2% ad valorem	Free	25.0% ad valorem.
Wrought indium	628.50	4.3% ad valorem	3.6% ad valorem	45.0% ad valorem.
Indium compounds	423.96	.6% ad valorem	Free	25.0% ad valorem.

WORLD REVIEW

World production declined from that of 1985. Major world refiners included Cominco in Canada; MHO in Belgium; Penarroya in France and Italy; Nippon Mining Co. Ltd., Dowa Mining Co. Ltd., and Mitsui Mining & Smelting Co. Ltd. in Japan; Minero Perú Comercial S.A. in Peru; Mining and Chemical Products Ltd. in the United Kingdom; and Government metallurgical complexes in China and the U.S.S.R.

TECHNOLOGY

Transparent, conductive films of indium oxide or indium-tin oxide found use as conductive patterns for liquid crystal displays and truck and plane windshield heaters. Although transparent to visible light, these films reflect infrared light and became useful as energy saving coatings for residential and commercial windows and high-efficiency sodium lamps.[20]

Promising applications included indium phosphide semiconducting crystals used to make solid-state lasers and light detectors[21] and copper-indium-selenium alloy films used in solar cells.[22] As the development of fiber-optic technology continued, it was discovered that minimum transmission losses occurred at longer infrared wavelengths. Semiconductors containing indium showed high promise for working as light emitters and detectors in this range.[23]

RHENIUM[24]

Rhenium was processed by one domestic firm in 1986. Consumption of rhenium remained about the same as that of 1985 at 13,000 pounds. Imports for consumption of ammonium perrhenate and rhenium metal increased from 8,268 pounds in 1985 to 17,683 pounds in 1986. The major use continued to be bimetallic platinum-rhenium catalysts to produce low-lead and lead-free gasoline. The price of rhenium metal increased from $300 per pound in 1985 to $350 per pound in 1986, and the price of ammonium perrhenate remained level at $200 per pound.

Domestic Data Coverage.—Domestic mine production data for byproduct rhenium are developed by the Bureau of Mines from a single voluntary survey of U.S. porphyry-copper-molybdenum operations. Of the seven operations to which a survey request was made, all responded, representing 100% of the total production shown in table 12.

Table 12.—Salient U.S. rhenium statistics

(Pounds of contained rhenium)

	1982	1983	1984	1985	1986
Mine production[1]	11,200	8,100	8,600	10,500	10,900
Recovered[2]	W	W	W	W	W
Consumption[e]	5,900	8,800	10,200	13,000	13,000
Imports for consumption of rhenium metal	176	623	1,962	4,943	5,495
Imports for consumption of ammonium perrhenate	5,193	5,947	4,754	3,325	12,188
Stocks, Dec. 31	W	W	W	W	W

[e]Estimated. 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.

DOMESTIC PRODUCTION

Rhenium is contained in molybdenite (MoS_2) concentrates, which are produced as a byproduct of porphyry copper ores from seven mines in the Southwestern United States. Mine production in table 12 was calculated to be the rhenium content of MoS_2 concentrates.

Cyprus Minerals Co. was the only domestic producer to recover rhenium in 1986.

CONSUMPTION AND USES

Domestic consumption of rhenium remained level in 1986 at about 13,000 pounds. The largest consumers of rhenium were the manufacturers of catalysts for the petroleum industry. Platinum-rhenium bimetallic reforming catalysts are used by the petroleum industry to produce low-lead and lead-free high-octane gasoline. These catalysts compete with monometallic platinum catalysts and with other bimetallic catalysts that are used in the reforming process. Although the rhenium content ranges from 0.25% to 0.9%, by weight, the majority of these catalysts contain 0.3% rhenium and 0.3% platinum, using alumina as the support medium.

Of the three basic types of bimetallic reforming catalysts, the semiregenerative type accounted for about 60% of the total reforming capacity. This type of catalyst requires process shutdown for regeneration at specified intervals. Cyclic and other types (nonregenerative, continuous, and moving-bed systems) accounted for 10% and 9%, respectively, of the total reforming capacity. An estimated 80% of the total reforming capacity employed platinum-rhenium catalysts. Other applications of reforming platinum-rhenium catalysts include the production of benzene, toluene, and xylenes.

About 10% of the total consumption of rhenium was used in the form of powder or alloys. The major portion of rhenium used in these forms was contained in tungsten-rhenium and molybdenum-rhenium alloys. When alloyed with other metals, rhenium improves their mechanical and electrical properties, acid and heat resistance, wear and corrosion resistance, and durability. Rhenium was used in manufacturing thermocouples, ionization gauges, electron tubes and targets, metallic coatings, semiconductors, heating elements, high-temperature nickel-based alloys, vacuum tubes, mass spectrographs, and electromagnets.

PRICES

The price of rhenium remained level during the year. The price of ammonium perrhenate was $200 per pound and the average price of rhenium metal was about $350 per pound.

FOREIGN TRADE

U.S. imports for consumption of rhenium totaled 17,683 pounds, an increase of 114% over those of 1985. Ammonium perrhenate imports totaled 12,188 pounds of metal content. This represented a 267% increase from those of 1985. The value of ammonium perrhenate imports was about $2.1 million. About 69% of the imports of ammonium perrhenate originated from Chile and 16% from the Federal Republic of Germany. Imports of rhenium metal totaled 5,495 pounds, which represented an 11% increase over those of 1985. The value of these imports totaled $2.6 million.

Table 13.—U.S. import duties for rhenium materials

Item	TSUS No.	Most favored nation (MFN)[1] Jan. 1, 1986	Most favored nation (MFN)[1] Jan. 1, 1987	Non-MFN Jan. 1, 1986
Unwrought metal	628.9000	3.9% ad valorem	3.7% ad valorem	25% ad valorem.
Wrought metal	628.9500	5.9% ad valorem	5.5% ad valorem	45% ad valorem.
Ammonium perrhenate	417.4520	3.2% ad valorem	3.1% ad valorem	25% ad valorem.
Perrhenic acid	416.4540	4.4% ad valorem	4.2% ad valorem	Do.

Table 14.—U.S. imports for consumption of ammonium perrhenate, by country

(Rhenium content)

Country	1984 Quantity (pounds)	1984 Value (thousands)	1985 Quantity (pounds)	1985 Value (thousands)	1986 Quantity (pounds)	1986 Value (thousands)
Chile	3,379	$740	2,918	$611	8,360	$1,463
Germany, Federal Republic of	564	131	407	58	1,978	348
Other[1]	811	181	--	--	1,850	338
Total	4,754	1,052	3,325	669	12,188	2,149

[1]Includes Belgium-Luxembourg, Brazil, Italy, Japan, and the Netherlands.

Source: Bureau of the Census.

Table 15.—U.S. imports for consumption of rhenium metal, by country

Country	1984 Gross weight (pounds)	1984 Value	1985 Gross weight (pounds)	1985 Value	1986 Gross weight (pounds)	1986 Value
Chile	--	--	3,300	$825,000	3,150	$2,014,000
France	2	$920	--	--	--	--
Germany, Federal Republic of	1,836	423,032	1,424	337,662	1,904	432,000
Italy	100	19,500	--	--	--	--
United Kingdom	2	417	193	54,065	441	171,000
Other[1]	22	5,590	26	8,378	--	--
Total	1,962	449,459	4,943	1,225,105	5,495	2,617,000

[1]Includes Haiti, Sweden, and Switzerland.

Source: Bureau of the Census.

WORLD REVIEW

World production of rhenium was estimated to be 40,000 pounds, exclusive of U.S. production. Rhenium was recovered from byproduct MoS_2 concentrates from porphyry copper deposits in Canada, Chile, 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.

Canada.—The Island Copper Mine in British Columbia continued to be the sole producer of rhenium in Canada.

Chile.—Chilean recovery of rhenium was estimated at 12,500 pounds, the largest amount produced by a market economy country.

SCANDIUM[25]

Production of refined scandium in the United States in 1986 was estimated to be essentially the same as that of 1985. Most of the scandium processed in the United States was derived as a byproduct from previously mined ores and concentrates. Demand for scandium for use in laser crystals and special-use light bulbs, its principal markets, was also essentially the same as that of 1985. Scandium-containing synthetic garnet crystals were important components in high-energy lasers being developed for defense and commercial applications.

Domestic Data Coverage.—Domestic production data for scandium are estimated by the Bureau of Mines on the basis of discussions with domestic producers and processors.

DOMESTIC PRODUCTION

Byproduct scandium-bearing ore and concentrate from three mines were processed in 1986. Scandium was recovered by Baldwin Metal Processing Co. from residual fluorite screenings accumulated at a now inactive fluorite mine at Crystal Mountain, MT, and by Boulder Scientific Co. from tungsten concentrates derived from the processing of molybdenum ores at AMAX Inc.'s Climax Mine, Climax, CO. However, AMAX's byproduct tungsten operation at Climax was closed in June, reportedly as a result of low prices and an oversupply of tungsten on the market.

Scandium was also refined by Sausville Chemical Co. Inc. from a scandium concentrate produced at Westinghouse Electric Corp.'s uranium recovery facility at Bingham Canyon, UT. The scandium concentrate, a byproduct, along with uranium, of copper ore mined by Kennecott at its Bingham Canyon Mine, was last produced in August 1985, when the recovery plant was closed, reportedly as a result of weak prices for uranium. Westinghouse sold its uranium and scandium operations at Bingham Canyon to Energy Fuels Nuclear Inc. in September 1986. Reopening of the operation by Energy Fuels was scheduled for February of 1987.

Refined scandium products were produced domestically by Baldwin Metal Processing Co., Phoenix, AZ; Boulder Scientific Co., Mead, CO; Research Chemicals Div. of Nucor Corp., Phoenix, AZ; and Sausville Chemical Co. Inc., Garfield, NJ.

CONSUMPTION AND USES

Estimated domestic consumption of scandium in 1986 was 51 kilograms of equivalent scandium oxide, an increase of 1 kilogram from the revised 1985 estimated consumption of 50 kilograms. The major use for scandium was in high-energy laser crystals of gadolinium-scandium-gallium garnets (GSGG) doped with various elements. GSGG laser crystals are reportedly twice as efficient as yttrium-aluminum garnets (YAG) as a lasing medium. Laser applications for GSGG are in communications and high-energy applications such as hydrogen fusion research and antimissile defense systems. Using narrow width lasing beams, GSGG lasers were also used to etch semiconductors.

Scandium is used in high-intensity mercury vapor lights to produce a highly efficient, near-sunlight color emission that is used for indoor and nighttime color television transmission. Approximately 3 to 5 milligrams of scandium is added per bulb.

The radioactive isotope scandium-46 was used as a tracing agent in petroleum cracking refineries and in crude oil wells after cementing and fracturing.

Small amounts of scandium metal reportedly were used in semiconductors, while minor amounts found use in petroleum catalysts.

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, $11,500; 99.995% purity, $12,500; and 99.999% purity, $15,500.[26] Scandium metal prices varied considerably depending on purity and amount.

FOREIGN TRADE

No trade data were available for scandium as an individual item of trade. However, analysis of small shipments of high value from probable scandium import sources suggested that about 1 kilogram of scandium oxide was imported from the United Kingdom in 1986.

WORLD REVIEW

Countries that recovered scandium in 1986 included Australia, China, the U.S.S.R., and the United States. Scandium was processed from imported materials in France, Japan, and the United Kingdom. The U.S.S.R. has historically been a major source of high-purity scandium oxide.

TECHNOLOGY

Researchers at the Ames Laboratory, Materials Preparation Center, in Ames, IA, developed a method to upgrade scandium oxide of 98% purity to oxide of 99.999% purity in kilogram quantities. Using ion exchange chromatography, scandium oxide was separated from impurities at 96° C with ammonium hydroxethylethylenediaminetriacetate (HEDTA) as the eluting agent. Scandium was stripped from the ion exchange columns using ammonium acetate and precipitated as scandium oxalate. The oxalate was then filtered and ignited at 900° C to produce a high-purity scandium oxide suitable for use in laser crystals.[27]

SELENIUM[28]

Domestic production decreased substantially in 1986 as one of the three copper refineries with capacity for production of byproduct selenium was idle. Both imports and exports increased to record-high levels, and net imports increased substantially.

Selenium was used principally as a photoreceptor in office copiers and as a decolorizer of container glass. A relatively new material, ternary copper indium diselenide, has shown promise as a photovoltaic device because of its excellent thermal stability and high short circuit current density.

Domestic Data Coverage.—Domestic data for selenium are developed by the Bureau of Mines from a voluntary survey of U.S. operations. The two domestic refiners of selenium responded to a survey of their stocks, primary refined production, and shipments of selenium to consumers. Data are withheld to avoid disclosing company proprietary data.

Table 16.—Salient selenium statistics

(Kilograms of contained selenium unless otherwise specified)

	1982	1983	1984	1985	1986
United States:					
Production, primary refined	242,996	353,860	253,598	W	W
Shipments to consumers	307,610	374,030	224,401	W	W
Exports, metal, waste and scrap	117,267	93,368	122,929	154,122	161,007
Imports for consumption	347,329	297,029	376,946	400,658	462,646
Apparent consumption	537,672	577,691	478,418	W	W
Stocks, yearend, producer[1]	254,210	152,790	139,159	W	W
Dealers' price, average per pound, commercial-grade[2]	$3.53	$3.87	$9.02	$6.00-$10.25	$3.95-$7.20
World: Refinery production	[r]1,118,617	[r]1,322,992	1,378,660	[p]1,175,868	[e]1,073,984

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Granular selenium, a semirefined form of selenium, is included in stocks.
[2]Metals Week.

Legislation and Government Programs.—Public Law 96-510, Superfund, was enacted in order to raise revenue for the Superfund by taxing various substances considered to be toxic. The tax was scheduled to expire on September 30, 1985. However, legislation was introduced in both Houses of Congress to extend the program beyond that date. Selenium was added to the list to be taxed.

DOMESTIC PRODUCTION

Most primary selenium was recovered from anode slimes generated in the electrolytic refining of copper. Selenium also was believed to have been recovered from lead slimes and nonferrous flue dusts.

Primary selenium was recovered from both domestic and imported materials at two U.S. copper refineries: Asarco at Amarillo, TX; and Phelps Dodge Refinery Corp. at El Paso, TX. Selenium-bearing copper slimes from other domestic copper refiners were either shipped to the above refineries or exported for processing.

High-purity selenium metal and various selenium compounds were produced from commercial-grade metal by the two copper refineries and other processors.

Scrap xerographic materials containing selenium were exported to Canada and the United Kingdom for processing to recover selenium.

Standard commercial-grade selenium averaging 99.5% selenium was produced as powder, available in several mesh sizes, or as small lumps or shot. High-purity selenium containing 99.99% selenium or better was marketed as pellets or sticks. Specifications for pigment-grade selenium powder generally required a selenium content of 99.8%. Other forms of selenium available included selenium dioxide, ferroselenium, sodium selenite, and sodium selenate.

CONSUMPTION AND USES

Consumption of refined selenium in its major end uses decreased for the second consecutive year. Estimated consumption of selenium by end-use category was electronic and photocopier components, 35%; glass manufacturing, 30%; pigments and chemicals, 25%; and other, including metallurgy and agriculture, 10%.

The major electronic use of selenium was as a photoreceptor in plain paper electrophotographic copiers.

The U.S. automobile and construction industries contributed to a strong demand for selenium-containing pigments. These pigments, which range in color from light orange to maroon, depending on the selenium content, have good heat stability and are important colorants for plastics, glass, and ceramics. The primary use of selenium in the glass industry in 1986 was in container glass, where it was used to decolor the yellow-green tint imparted by ferrous ions. Also, selenium was used in architectural plate glass, where it was used in combination with cobalt oxide and iron oxide to reduce solar heat transmission.

PRICES

The New York dealer price for commercial-grade selenium, quoted by Metals Week on a weekly basis, ranged from $3.95 to $7.20 per pound, compared with a range of $6.00 to $10.25 in 1985.

FOREIGN TRADE

Exports increased to a record-high level of 161,000 kilograms, mainly because of larger quantities exported to Colombia, Japan, the Republic of Korea, Malaysia, and the Netherlands. Imports for consumption of selenium also increased to a record-high level, 462,646 kilograms.

Table 17.—U.S. exports of selenium metal, waste and scrap, by country

Country	1984		1985		1986	
	Quantity (kilograms, contained selenium)	Value	Quantity (kilograms, contained selenium)	Value	Quantity (kilograms, contained selenium)	Value
Argentina	1,089	$10,200	1,179	$22,750	2,907	$44,163
Australia	--	--	962	29,220	--	--
Belgium-Luxembourg	322	5,141	--	--	--	--
Brazil	254	8,100	650	10,400	319	5,099
Canada	2,462	39,365	2,207	40,595	324	5,171
Chile	5,517	24,313	--	--	--	--
Colombia	7,831	198,864	894	22,660	7,387	144,870
France	1,758	38,173	318	5,075	1,011	16,150

Table 17.—U.S. exports of selenium metal, waste and scrap, by country —Continued

Country	1984 Quantity (kilograms, contained selenium)	1984 Value	1985 Quantity (kilograms, contained selenium)	1985 Value	1986 Quantity (kilograms, contained selenium)	1986 Value
Germany, Federal Republic of	13,769	$139,413	7,861	$126,793	--	--
India	--	--	68	4,765	--	--
Italy	--	--	1,456	20,015	1,883	$21,835
Jamaica	91	3,000	--	--	--	--
Japan	27,255	186,992	36,951	289,592	42,875	245,381
Korea, Republic of	--	--	45	1,800	10,165	52,265
Malaysia	--	--	--	--	4,802	76,752
Mexico	1,799	28,750	19,265	308,481	15,231	237,033
Netherlands	6,822	82,744	7,711	106,360	19,421	180,238
Norway	--	--	236	6,760	--	--
Philippines	--	--	18,144	42,000	17,178	43,486
Portugal	--	--	91	1,950	272	3,350
Switzerland	7,983	71,060	4,990	75,350	2,984	32,763
Thailand	499	11,000	--	--	--	--
United Kingdom	45,480	739,450	51,096	316,177	34,200	342,461
Venezuela	--	--	--	--	48	1,446
Total[1]	122,929	1,586,565	154,122	1,430,743	161,007	1,452,463

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

Source: Bureau of the Census.

Table 18.—U.S. imports for consumption of selenium, by class and country

Class and country	1984 Quantity (kilograms, contained selenium)	1984 Value	1985 Quantity (kilograms, contained selenium)	1985 Value	1986 Quantity (kilograms, contained selenium)	1986 Value
Unwrought and waste and scrap:						
Belgium-Luxembourg	47,483	$1,084,424	63,353	$1,572,220	86,143	$2,736,960
Canada	130,317	2,786,063	111,927	2,353,429	130,038	2,386,721
Chile	3,498	64,015	7,500	153,902	3,000	42,118
Costa Rica	--	--	--	--	362	11,940
German Democratic Republic	--	--	45	14,743	--	--
Germany, Federal Republic of	23,364	402,088	5,550	126,877	205	9,496
Japan	46,074	1,904,155	72,609	2,056,694	87,858	1,958,821
Korea, Republic of	--	--	--	--	2,000	19,852
Netherlands	2,755	64,610	15,239	30,851	3,680	61,216
Peru	2,994	32,605	--	--	--	--
Philippines	5,000	59,525	16,748	243,747	10,000	86,200
Sweden	1,032	26,258	100	3,750	--	--
United Kingdom	80,844	964,306	66,434	910,947	97,408	1,501,694
Yugoslavia	--	--	--	--	5,000	43,572
Total	343,361	7,388,049	359,505	7,467,160	425,694	8,858,590
Selenium dioxide:						
Belgium-Luxembourg	35	529	--	--	8	1,011
Germany, Federal Republic of	5,598	121,704	6,916	164,471	5,405	113,472
Sweden	71	4,500	--	--	--	--
United Kingdom	29	1,586	--	--	142	3,114
Total	5,733	128,319	6,916	164,471	5,555	117,597
Selenium salts:						
Belgium-Luxembourg	--	--	567	29,839	--	--
France	6,399	6,397	--	--	--	--
Korea, Republic of	4,429	6,197	4,847	4,962	1,626	2,662
Taiwan	50	400	--	--	--	--
United Kingdom	193	6,821	7,000	114,959	650	7,798
Total	11,071	19,815	12,414	149,760	2,276	10,460
Sodium selenite:						
Canada	460	17,223	42	2,090	4	1,648
Germany, Federal Republic of	1,154	28,745	3,013	80,091	14,987	125,108
Japan	450	29,592	1,058	29,575	230	15,917
Spain	1,150	20,939	--	--	--	--
United Kingdom	9,968	249,974	13,835	332,551	10,931	258,425
Total	13,182	346,473	17,948	444,307	26,152	401,098

Table 18.—U.S. imports for consumption of selenium, by class and country —Continued

Class and country	1984 Quantity (kilograms, contained selenium)	1984 Value	1985 Quantity (kilograms, contained selenium)	1985 Value	1986 Quantity (kilograms, contained selenium)	1986 Value
Other selenium compounds:						
Canada	--	--	1,105	$3,394	--	--
Germany, Federal Republic of	13	$1,548	22	1,443	338	$10,351
Japan	2,574	133,671	1,588	81,559	--	--
Netherlands	42	482	--	--	--	--
Sweden	170	2,107	123	1,398	--	--
United Kingdom	800	33,400	1,037	44,072	2,631	152,070
Total	3,599	171,208	3,875	131,866	2,969	162,421
Grand total	376,946	8,053,864	400,658	8,357,564	462,646	9,550,166

Source: Bureau of the Census; figures adjusted by Bureau of Mines.

Table 19.—U.S. import duties for selenium

Item	TSUS No.	Most favored nation (MFN) Jan. 1, 1986	Most favored nation (MFN) Jan. 1, 1987	Non-MFN Jan. 1, 1986
Selenium metal	632.40	Free	Free	Free.
Selenium dioxide and salts	420.50, 420.52	do	do	Do.
Sodium selenite and other selenium compounds	421.625, 420.54	3.9% ad valorem.	3.7% ad valorem.	25% ad valorem.

WORLD REVIEW

Estimated refinery production of selenium in the market economy countries decreased about 9% from the 1985 level and was slightly higher than the estimated demand of about 1,000 metric tons.

Table 20.—Selenium: World refinery production, by country[1]

(Kilograms, contained selenium)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Belgium[e]	60,000	60,000	[r]65,000	[r]65,000	70,000
Canada[3]	222,000	266,000	[e]354,000	361,000	334,000
Chile	23,011	43,869	25,450	50,037	40,000
Finland	10,020	11,172	16,975	[e]17,000	17,000
India	5,351	3,684	[e]4,000	[e]4,000	4,000
Japan	410,490	433,122	464,524	496,835	[4]426,567
Mexico	29,000	24,000	44,000	42,000	40,000
Peru	[r]23,973	[r]19,514	20,758	14,506	[4]12,012
Sweden	27,000	42,000	68,000	60,000	70,000
United States	242,996	353,860	253,598	W	W
Yugoslavia	42,323	43,720	[e]45,000	[e]46,000	45,000
Zambia[5]	22,453	22,051	17,355	19,490	[4]15,405
Total	[r]1,118,617	[r]1,322,992	1,378,660	1,175,868	1,073,984

[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 9, 1987.

[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]Refinery output from all sources, including imported materials and secondary sources.

[4]Reported figure.

[5]Data for fiscal year ending Mar. 31. In addition to refined selenium produced, Zambia exported significant quantities of selenium contained in anode slimes.

TELLURIUM[29]

Domestic consumption, imports, and production decreased from the 1985 levels. Estimated world refinery production was essentially the same as that of 1985. Mercury-cadmium-tellurium (MCT) has become one of the most important semiconductors for defense and space applications; it is the principal photosensitive material used in infared detector systems.

Domestic Data Coverage.—Domestic tellurium refinery production data were provided to the Bureau of Mines by the sole domestic producer. Data are withheld to avoid disclosing company proprietary data.

Table 21.—Salient U.S. tellurium statistics[1]

(Kilograms, contained tellurium unless otherwise specified)

	1982	1983	1984	1985	1986
Refinery production	W	W	W	W	W
Shipments to consumers	W	W	W	W	W
Imports for consumption	16,602	11,829	35,383	30,050	13,935
Apparent consumption	45,978	56,639	107,311	W	W
Stocks, yearend, producer	W	W	W	W	W
Producer's price, per pound, yearend, commercial-grade	$10.00	$9.00	$11.00-$11.50	$10.00	$10.00

W Withheld to avoid disclosing company proprietary data.
[1]World refinery production for selected countries is given in table 24.

DOMESTIC PRODUCTION

Commercial-grade tellurium was recovered by Asarco, at Amarillo, TX, as a byproduct of electrolytic copper refining.

High-purity tellurium, tellurium master alloys, and tellurium compounds were produced by primary and intermediate processors from commercial-grade metal and tellurium dioxide.

Commercial grades of tellurium metal, containing a minimum of 99% or 99.5% tellurium, were marketed as minus 200-mesh powder, 1-pound ingots, or 5-pound slabs. Tellurium dioxide was sold as powder ranging from minus 40 mesh to minus 200 mesh and containing a minimum of 75% tellurium.

CONSUMPTION AND USES

Estimated consumption of tellurium by end-use category was iron and steel products, 60%; nonferrous metals, 25%; chemicals, including rubber manufacturing, 10%; and other, including xerographic and electronic applications, 5%.

Tellurium was used principally as an alloying metal in free-machining steels and free-machining copper alloys. The addition of up to 0.1% tellurium improves the machinability of steels; the addition of tellurium to copper alloys improves their corrosion resistance as well as their machinability.

Tellurium catalysts were used chiefly for the oxidation of a number of organic compounds, and to a lesser extent, for the hydrogenation of oils and in chlorination and dehydrochlorination processes. Telluride salts were used as an antioxidant in counteracting the formation of sludge in lubricating oils. Other tellurium compounds were used in germicides and fungicides and in the treatment of dermatitis. Tellurium was used as a glass-former in combination with other metal oxides, as a color additive in metal-finishing operations, and in time-delay explosive detonators. Photoconductive MCT was the most widely used infrared sensing material for thermal imaging devices in applications such as night vision and navigation systems. Such applications require detector-grade, 99.99999%-pure tellurium.

PRICES

The price for commercial-grade tellurium metal quoted by Asarco remained constant throughout 1986 at $10.00 per pound.

FOREIGN TRADE

Imports decreased by 54% from the 1985 level. Data on tellurium exports are not available.

Table 22.—U.S. imports for consumption of tellurium, by class and country

Class and country	1984 Quantity (kilograms, contained tellurium)	1984 Value	1985 Quantity (kilograms, contained tellurium)	1985 Value	1986 Quantity (kilograms, contained tellurium)	1986 Value
Unwrought and waste and scrap:						
Belgium-Luxembourg	4,003	$68,764	5	$5,878	21	$1,021
Canada	20,382	369,745	13,458	453,929	3,247	504,983
Germany, Federal Republic of	1,019	17,367	5	1,404	--	--
Japan	1,825	103,338	499	29,083	342	43,891
Netherlands	1,300	23,884	500	9,653	--	--
Peru	--	--	963	18,963	2,206	70,244
United Kingdom	5,892	105,026	4,999	107,398	4,082	175,543
Total	34,421	688,124	20,429	626,308	9,898	795,682
Compounds:						
Belgium-Luxembourg	724	21,112	726	15,381	5	1,277
Canada	200	5,753	73	1,904	--	--
Germany, Federal Republic of	23	3,408	51	3,369	--	--
Japan	--	--	82	10,900	29	7,161
Philippines	--	--	7,376	202,483	--	--
United Kingdom	14	6,572	17	5,536	163	76,545
Total	961	36,845	8,325	239,573	197	84,983
Salts:						
Germany, Federal Republic of	1	270	--	--	3,840	30,397
Netherlands	--	--	1,296	5,410	--	--
Total	1	270	1,296	5,410	3,840	30,397
Grand total	35,383	725,239	30,050	871,291	13,935	911,062

Source: Bureau of the Census.

Table 23.—U.S. import duties for tellurium

Item	TSUS No.	Most favored nation (MFN) Jan. 1, 1986	Most favored nation (MFN) Jan. 1, 1987	Non-MFN Jan. 1, 1986
Tellurium metal	632.48	0.5% ad valorem	Free	25% ad valorem.
Tellurium compounds and salts.	421.90, 427.12	3.9% ad valorem	3.7% ad valorem	Do.

Table 24.—Tellurium: World refinery production, by country[1]

(Kilograms, contained tellurium)

Country[2]	1982	1983	1984	1985[p]	1986[e]
Canada[3]	18,000	16,000	[e]21,000	19,000	16,000
Japan	62,800	54,800	64,500	[e]63,000	60,000
Peru	[r]19,565	[r]15,806	14,066	15,007	[4]9,815
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 9, 1987.

[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[30]

Although thallium was contained in ores mined in the United States, it was not recovered domestically as a marketable product in 1986. In other countries, thallium was recovered as a byproduct from flue dusts and residues collected in the smelting of copper, zinc, and lead ores. Domestic requirements for thallium were met by imports and withdrawals from stocks.

CONSUMPTION AND USES

Based on import data, the domestic consumption of thallium was estimated to be 4,000 pounds in 1986. The uses of thallium included gamma radiation detection equipment, additives for changing the refractive index and density of glass, low-temperature mercury-thallium alloy switches, high-density liquids, alloys, photosensitive devices, and radioactive isotopes for cardiovascular diagnostic procedures. The largest single use in the rest of the world continued to be as an ingredient in rodenticides; however, this use has been banned in the United States.

PRICES

Thallium metal was sold at various prices during the year depending on the purity. Metal traders reported that the price ranged from about $20 per pound for 99%-pure thallium metal to about $65 per pound for 99.999%-pure metal. Based on the average value per pound of metal imported into the United States, the price of thallium metal in 1986 was estimated to be about $30 per pound.

Table 25.—U.S. imports for consumption of thallium in 1986, by country

Country	Compounds			Unwrought and waste and scrap	
	Gross weight (pounds)	Content[1] (pounds)	Value	Gross weight (pounds)	Value
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	2,400	1,920	267,088	--	--
United Kingdom	10	8	2,250	--	--
Total	4,263	3,411	327,516	1,039	30,694

[1]Estimated by the Bureau of Mines.

Source: Bureau of the Census.

Table 26.—U.S. import duties for thallium

Item	TSUS No.	Most favored nation (MFN)		Non-MFN
		Jan. 1, 1986	Jan. 1, 1987	Jan. 1, 1986
Unwrought metal	632.50	0.6% ad valorem	Free	25% ad valorem.
Compounds	422.00	3.9% ad valorem	3.7% ad valorem	Do.

WORLD REVIEW

World production data for thallium are not available. However, Western European companies were thought to be the largest producers of thallium in 1986. World reserves of thallium contained in zinc ores were estimated to be approximately 800,000 pounds of thallium.

[1]Prepared by Neldon L. Jensen, physical scientist.

[2]U.S. Department of Agriculture. The Biologic and Economic Assessment of Pentachlorophenol, Inorganic Arsenic, Creosote. V. 1: Wood Preservatives. USDA Tech. Bull. 1658-1, Nov. 4, 1980, pp. 399-341.

[3]Prepared by W. Timothy Adams, physical scientist.

[4]Chemical Marketing Reporter. V. 229, No. 11, Mar. 17, 1986, p. 14.

[5]Prepared by Patricia A. Plunkert, physical scientist.

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[9]Where necessary, values have been converted from Belgian francs (BF) to U.S. dollars at the 1986 average exchange rate of BF44.672=US$1.00.

[10]Work cited in footnote 7.

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[21]Work cited in footnote 20.

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[24]Prepared by John W. Blossom, physical scientist.

[25]Prepared by James B. Hedrick, physical scientist.

[26]99.999%-pure oxide available from the Materials Preparation Center, 121 Metals Development Bldg., Ames Laboratory, Ames, IA 50011.

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[28]Prepared by Neldon L. Jensen, physical scientist.

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