ANNUAL REPORT

Magnesium and Magnesium Compounds

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1993

U.S. DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

PB95-111381

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Bruce Babbitt
Secretary

BUREAU
OF
MINES

September 1994

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COVER PHOTO:
A new 22.5-kilometer trench, constructed in 1993 by the Great Salt Lake Minerals Corp., feeds brines to the pump station at a 7,700-hectare pond system. In the ponds, brine is concentrated, and the precipitated minerals are separated into sulfate of potash, salt, magnesium chloride, and sodium sulfate. (Photo is courtesy of Great Salt Lake Minerals Corp.)

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PB95-111381

MAGNESIUM AND MAGNESIUM COMPOUNDS

By Deborah A. Kramer

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U.S. primary magnesium metal production declined slightly in 1993 and imports, primarily from Russia and Ukraine, provided an increased percentage of domestic demand. In addition, inventories of magnesium increased significantly from the low level at the end of 1992. These increases in inventories and imports prompted two of the three U.S. producers to announce cutbacks in production rates near the end of 1993. This oversupply situation was reflected in free market prices for primary magnesium during the year. Prices dropped steadily through the first three quarters of 1993 before rebounding slightly during the last 3 months.

In the past few years, automobile manufacturers have begun designing magnesium alloy diecastings into future car models. Many of these new components have been introduced in the 1994 model year and as a result, consumption of primary magnesium for diecastings has increased significantly. This is expected to increase as magnesium continues to be specified by designers for more components.

In Europe, a producers' association filed an antidumping complaint alleging dumping of magnesium on the European market by the former U.S.S.R. Other countries, including Japan and India, also have suggested that magnesium exports from the former U.S.S.R. have adversely affected their magnesium production. Several magnesium production facilities in Japan and Europe were either shut down completely or closed for a short period during 1993. At the same time, construction of new facilities in Australia and Israel was proceeding on schedule.

U.S. production of magnesium compounds from all sources (magnesite, dolomite, seawater, brines, and olivine) continued to decline as it has each year since 1988. Domestic demand, however, increased by nearly 8%. The increase in demand was met primarily by increased imports, particularly caustic-calcined and dead-burned magnesia from China. U.S. producers were concentrating on increasing production of magnesium compounds for use in environmental applications such as acid neutralization.

DOMESTIC DATA COVERAGE

Data for magnesium metal are collected from two voluntary surveys of U.S. operations. Of the 113 companies canvassed for magnesium consumption data, 73% responded, representing 46% of the primary magnesium consumption shown in tables 4 and 6. Data for the 30 nonrespondents were estimated based on prior-year consumption levels and other factors.

Data for magnesium compounds were collected from one voluntary survey of U.S. operations. Of the 19 operations canvassed, 84% responded, representing 75% of the magnesium compounds shipped and used shown in table 13. Data for the three nonrespondents were estimated based on prior-year consumption levels and other factors.

BACKGROUND

Definitions, Grades, and Specifications

Primary magnesium metal contains a minimum of 99.8% magnesium. Magnesium-base alloys are named by the composition of the two chief alloying elements, each designated by a letter, and the approximate percentage of each alloying element. For example, AZ91 contains about 9% aluminum (A) and 1% zinc (Z), and HK31 contains about 3% thorium (H) and 1% zirconium (K). Other letters used in specifying magnesium alloys are E for rare-earth metals and M for manganese.

Magnesite, or magnesium carbonate ($MgCO_3$), has a theoretical magnesium content of 47.6%. Dolomite is a calcium carbonate-magnesium carbonate mineral ($CaCO_3 \bullet MgCO_3$) that has a theoretical magnesium content of 22%. Brucite, magnesium hydroxide [$Mg(OH)_2$], contains up to 69% magnesium, and olivine ($Mg_2Fe_2SiO_4$) contains up to 19% magnesium. Of these minerals, magnesite and dolomite are the largest sources of magnesium and magnesium compounds.

Seawater, brines, and bitterns represent vast sources of magnesium and magnesium compounds. In the United States, more than 60% of the magnesium compounds produced annually is recovered from seawater and brines, and 80% of the magnesium metal production capacity uses seawater or brines as a raw material.

Various magnesia products are made by calcining magnesium carbonate or magnesium hydroxide at different temperatures. Caustic-calcined magnesia, which is readily reactive with water, is calcined at temperatures up to 890° C. Dead-burned magnesia, also called refractory or sintered magnesia, is calcined at temperatures up to 1,450° C and is unreactive with water. Fused magnesia is produced at temperatures greater than 3,000° C. Magnesia produced from magnesite is generally called natural magnesia, and magnesia produced from seawater or brines is called synthetic magnesia.

Standards for magnesia, including chemical composition, bulk density, and particle size, generally are set by the consumer for a specific application. Refractory magnesia composition depends on the area of the furnace in which the material is to be used. Magnesia produced from magnesite can contain between 88% and 98% magnesia, with varying quantities of alumina, calcium, iron, and silica impurities. Synthetic magnesia normally is purer than natural magnesia, containing between 92% and 99.5% magnesia, with smaller quantities of the same impurities found in natural magnesia. Most fused magnesia contains greater than 94% magnesia.

Products for Trade and Industry

The principal use for magnesium metal, averaging greater than 50% of U.S. consumption annually, is as an alloying addition to aluminum. Magnesium improves the hardness and corrosion resistance of pure aluminum. Aluminum-magnesium alloys are used in a variety of applications, including automobiles, trucks, aircraft, appliances, and home siding. Two-piece beverage cans, containing about 2% magnesium, are the largest single use for these aluminum-magnesium alloys.

Magnesium and its alloys are used as structural components on automobiles, trucks, aircraft, computers, and power tools. Many of these applications use magnesium because of its light weight and ease of machinability. Magnesium is used in the iron and steel industry for external hot-metal desulfurization and in the production of nodular iron. Production of the nonferrous metals, beryllium, hafnium, titanium, uranium, and zirconium, involves the use of magnesium as a reducing agent. Anodes of magnesium are used for cathodic protection of underground pipe and water tanks. Small quantities of magnesium are used as a catalyst in producing organic compounds, as photoengraving plates, and in alloys other than aluminum.

Refractory magnesia represents the largest use of magnesium in compounds. Refractory magnesia is manufactured into bricks and other shapes, principally for linings in furnaces and auxiliary equipment used to produce iron and steel. Magnesia-base refractories also are used in furnaces in the cement, glass, and nonferrous metals industries.

Caustic-calcined magnesia is used in a variety of applications in the agricultural, chemical, construction, and manufacturing industries. Caustic-calcined magnesia is an important component of animal feed and fertilizer, providing essential nutrients for livestock and plant growth. In construction, caustic-calcined magnesia is used in special cements for industrial flooring and in lightweight insulating wallboard. In the chemical industry, it is used as a starting point for the manufacture of other magnesium salts. Special grades of caustic-calcined magnesia are used for pharmaceuticals, including antacids, toothpaste, milk of magnesia, and cosmetics. Magnesia is used to remove sulfur from flue gases and boiler fuels and is used for acid neutralization in process wastewater and in lubricating oils. Caustic-calcined magnesia is also important in manufacturing paper, rayon, and rubber.[1]

Other magnesium compounds are used in place of, or in addition to, caustic-calcined magnesia in many of the above applications. Magnesium hydroxide is used in the pulp and paper industry; magnesium sulfate is used for pharmaceuticals, animal feed, and fertilizers; and magnesium carbonate is used in the chemical, pharmaceutical, and rubber industries. Fused magnesia is used primarily for electrical insulation.

The principal use for olivine is as a foundry sand used in casting iron and steel components and some nonferrous metals. Olivine is used in smaller quantities for refractories, slag control in blast furnaces, and abrasives.[2]

Industry Structure

U.S. producers of magnesium and magnesium compounds are shown in tables 1 and 2. Two companies in the United States produce olivine—Applied Industrial Materials Corp. (AIMCOR) and Olivine Corp. AIMCOR operates two mines in North Carolina and Washington, and processing plants in Indiana, North Carolina, and Washington; Olivine operates one mine and one processing plant in Washington.

Electrolytic plants in Canada, Kazakhstan, Norway, Russia, Ukraine, and the United States represent 67% of the world magnesium metal production capacity (excluding the capacity in Kazakhstan, Russia, and Ukraine that is used exclusively for titanium metal production). Smaller thermal plants are in Brazil, Canada, China, France, India, Italy, Japan, Serbia and Montenegro, and the United States.

The largest magnesite production facilities in the world are in China, North Korea, and Russia. Together, these three countries account for 60% of the world magnesite production capacity. Japan and the United States account for 61% of the world's magnesium compounds production capacity from seawater or brines. Fused magnesia is produced in Australia, Canada, France, Israel, Japan, Mexico, the United Kingdom, and the United States.

Norway is the world's principal producer of olivine, and in addition to supplying its domestic needs, Norway is a major world supplier of olivine. Countries with smaller output include Austria, Italy, Japan, Mexico, Spain, Sweden, and the United States. *(See tables 1 and 2.)*

Geology

Magnesium is the eighth most abundant element and constitutes about

2% of the Earth's crust. It is the third most plentiful element dissolved in seawater, with a concentration averaging 0.13%. Although many minerals contain magnesium, magnesite, dolomite, brucite, and olivine are the only minerals from which magnesium compounds are recovered commercially.

Dolomite is a sedimentary rock commonly interbedded with limestone, which extends over large areas of the United States and is widespread throughout the rest of the world. Most dolomite occurrences are likely the result of replacement of calcium by magnesium in preexisting limestone beds. Magnesite primarily is found in four types of deposits—sedimentary beds, alterations of serpentine, vein fillings, and replacements of limestone and dolomite. Brucite is found in crystalline limestone and as a decomposition product of magnesium silicates associated with serpentine, dolomite, magnesite, and chromite. Olivine generally occurs as granular masses or disseminated grains or crystals and is a common constituent of basic igneous rocks such as basalt and gabbro. Dunite is an olivine-rich rock.[3]

Technology

Processing.—**Metal.**—Two thermal processes currently are in use to recover magnesium metal from dolomite—the Pidgeon process and the Magnetherm process. Both use the same basic chemistry, but the Pidgeon process uses an external heat source, and the Magnetherm process uses heat generated by the electrical resistance of the reactants. In the Pidgeon process, dolomite and ferrosilicon are formed into briquettes and heated in a retort under a vacuum. Magnesium oxide in the dolomite reacts with the ferrosilicon to produce magnesium vapor, which is cooled and condensed in a separate section of the retort. Plants in Canada, Italy, and Japan use this process to recover magnesium.

In the Magnetherm process, calcined dolomite, ferrosilicon, and alumina are heated under a vacuum. Alumina reduces the melting point of the slag produced by the dolomite-ferrosilicon reaction to make resistance heating practical. Magnesium vapor is cooled and condensed in a condensing chamber. The Magnetherm process is used in plants in Brazil, France, Japan, Serbia and Montenegro, and the United States.

Electrolytic recovery of magnesium requires a magnesium chloride feedstock that normally is prepared from seawater or brines. Two types of magnesium chloride can be made—hydrous and anhydrous. In the preparation of hydrous magnesium chloride, used by Dow Chemical Co., magnesium hydroxide is precipitated from seawater by the addition of dolomitic limestone. Adding hydrochloric acid to the magnesium hydroxide produces a neutralized magnesium chloride solution. This solution is dehydrated until it contains about 25% water and then is fed directly to electrolytic cells.

Magnesium Corp. of America (MagCorp) and Norsk Hydro A/S of Norway use an anhydrous magnesium chloride feed for their electrolytic cells. MagCorp uses solar evaporation initially to concentrate magnesium chloride brines from the Great Salt Lake. After adding calcium chloride to precipitate sulfate impurities and removing boron by solvent extraction, the brine is concentrated further and dehydrated in a spray dryer. The resulting powder is purified, concentrated, prilled, and dehydrated to produce anhydrous magnesium chloride.[4] Norsk Hydro starts with concentrated magnesium chloride brine. The brine is purified, concentrated, prilled, and dehydrated to produce anhydrous magnesium chloride.

Electrolytic cells used to recover magnesium from either hydrous or anhydrous magnesium chloride differ from company to company, and most information about cell design and operating conditions usually is not disclosed. Essentially, magnesium chloride fed to an electrolytic cell is broken down into magnesium metal and chlorine gas by direct current at 700° C. Magnesium is removed from the cell and cast into ingots, and the chlorine gas is recycled or sold.

Magnesium International Corp. developed a one-step process for producing anhydrous magnesium chloride that was demonstrated at Magnesium Co. of Canada Ltd.'s (MagCan) plant, which opened in 1990 and closed in 1991. Reacting magnesite with chlorine gas in the presence of carbon monoxide in a packed-bed reactor at 900° C produces magnesium chloride and carbon dioxide. Liquid magnesium chloride collects at the bottom of the reactor and is tapped periodically for transfer to electrolytic cells.[5] This process was not proven on a commercial scale.

Nonmetal.—Preparing either caustic-calcined or dead-burned magnesia from magnesite involves crushing the magnesite to various sizes, depending on the type of material to be produced. After crushing, magnesite is beneficiated; the degree of beneficiation depends on the quality of the ore and its ultimate end use. Lower quality ore often requires heavy-media separation, magnetic separation, and flotation to remove impurities. High-quality ore may require only screening and hand sorting to produce a material of acceptable quality. Caustic-calcined magnesia is produced in shaft kilns, multiple-hearth furnaces, or rotary kilns. Dead-burned magnesia is produced in rotary or shaft kilns.

In producing synthetic magnesia, seawater or brines are treated either with a small quantity of lime or sulfuric acid to remove dissolved carbon dioxide. Then calcium hydroxide, in the form of lime or dolime, is added to precipitate the dissolved magnesium as magnesium hydroxide. The resulting slurry is thickened and vacuum-filtered to yield a filter cake containing about 50% magnesium hydroxide. The filter cake can be directly calcined to produce caustic-calcined or dead-burned magnesia, or it can be calcined and pelletized before dead-burning to give specific size and density characteristics.

Fused magnesia is produced by fusion of high-grade magnesite or caustic-calcined synthetic magnesia in an electric arc furnace. After fusion, the material is crushed, inspected to remove any unfused magnesia, and crushed further in a ball mill.

Recycling.—Magnesium scrap is in forms similar to those of other nonferrous metals. New scrap comes in forms such as castings, drippings, drosses, gates, runners, and turnings. Old scrap primarily comes from old aircraft parts and discarded consumer products, such as lawnmower decks, chainsaw housings, and hand tools. The diecasting industry traditionally is the largest source of scrap magnesium.

Sorted scrap is charged into a steel crucible, which is heated to 675° C. As the scrap at the bottom begins to melt, more scrap is added. The liquid magnesium on the bottom is covered with a flux to inhibit surface burning. After any alloying elements are added and melting is complete, molten magnesium is transferred to ingot molds by either hand ladling, pumping, or tilt pouring.[6]

Economic Factors

Costs to produce magnesium metal vary greatly, depending upon the feed material and the process used. Operating costs for magnesium production range from $309 to $2,283 per ton, with energy costs as the largest component of the total operating cost. A weighted average operating cost was estimated to be $1,122 per ton. Total production costs from seawater sources were lower than from brines or dolomite sources. Magnesium compound operating costs also vary depending upon source material and processing techniques. Operating costs range from $24 to $425 per ton for magnesium compound production, with seawater as the most costly source. The weighted average operating cost for magnesium compounds production from all sources was $288 per ton. Energy costs also represent the largest component of total operating costs.[7]

Analysts at Commodities Research Unit (CRU) evaluated the direct operating costs of magnesium plants that operated during 1991. The operating cost curve showed that about one-half of the producers had direct operating costs less than $1.00 per pound of magnesium, and about 20% of the production was at direct operating costs above $1.25 per pound. In their cost estimates, CRU evaluated capital and operating costs for a 60,000-ton-per-year greenfield magnesium plant constructed in Australia. Capital costs were estimated at $470 million, with a 20% rate of return on investment over a 10-year life of the loan. In addition, operating costs were estimated to be $1.76 per pound in constant 1990 dollars, with most of the costs being capital charges resulting from the rate of return on investment and loan life. If the rate of return was lowered to 10% and the life of the loan was extended to 20 years, capital change would drop by one-half.[8]

Tariffs for magnesium and magnesium compounds are shown in table 3. Depletion allowance for magnesium chloride from domestic or foreign sources is 5%. Magnesium carbonate and dolomite have depletion allowances of 14% from domestic and foreign ores. Depletion allowances for other ores are brucite, 10% (domestic and foreign), and olivine, 22% domestic and 14% foreign. *(See table 3.)*

ANNUAL REVIEW

Magnesium

Legislation and Government Programs.—On August 16, the United States-Canada Binational Secretariat upheld findings by the Department of Commerce that Norsk Hydro Canada Inc. was dumping magnesium on the U.S. market. The panel, established by the United States-Canada Free Trade Agreement, also affirmed the countervailing duty determinations, except on two issues. The panel was unclear on why Commerce conducted a disproportionality analysis on an enterprise-by-enterprise basis rather than on an industry-by-industry basis. The panel also stated that Commerce's appropriate allocation period for grants to Norsk Hydro for pollution control equipment must be explained to be consistent with preceding binational panel cases. Commerce explanations of the two issues were due within 30 days of the findings.[9] After remanding the final antidumping duty determination to Commerce on August 16, the United States-Canada Binational Secretariat affirmed Commerce's redetermination on October 6. As a result, the antidumping duty on pure magnesium from Canada was reduced from 31.33% ad valorem to 21% ad valorem. This reduction makes the total antidumping and countervailing duties on pure magnesium 28.65%.[10]

Because of responses received in response to a request for administrative review, the Department of Commerce was initiating administrative reviews of antidumping and countervailing duty determinations made against Norsk Hydro Canada Inc. For antidumping duties assessed on pure magnesium, the review will cover the period from November 20, 1991, through July 31, 1993. For countervailing duties, the review period for pure and alloy magnesium is from December 6, 1991, to December 31, 1992. Commerce intended to issue the final results of these reviews by August 31, 1994.[11]

On October 16, Russia was added to the list of countries that can export their goods into the United States under the Generalized System of Preferences (GSP). Counties that are designated GSP countries can export goods either free of tariffs or at substantially reduced rates. For magnesium, Russia's exports into the United States became duty free with GSP status.

Production.—U.S. primary magnesium production in 1993 declined by 4% from the 1992 level. In contrast, producer stocks of magnesium metal increased significantly from the low level at yearend 1992 as imports supplied a greater share of domestic demand.

In September, Northwest Alloys Inc. announced that it would idle two of its primary magnesium furnaces at its plant in Addy, WA, for retrofitting. The furnaces were expected to be down for about 3 months, and according to industry estimates, production will be reduced by about 2,700 to 2,800 tons. Northwest Alloys reportedly has built up inventories and can satisfy existing contracts.[12] At the beginning of October, Dow Magnesium announced a magnesium production cutback of about 30%. The cutback was expected to take place in two phases; the first would occur before the end of 1993, and the second would occur in January 1994. Fourth quarter 1993 production losses were estimated to be about 3,000 to 4,000 tons. Approximately 20% of the company's work force will be affected by the closure. Dow cited the entrance of countries from the former U.S.S.R. into the world market as the principal reason for the closure.[13] *(See table 4.)*

Consumption and Uses.—Dow Magnesium announced that its direct-chill continuous magnesium caster came on-stream in November and that it was supplying T-bars to large aluminum customers on a trial basis. Although the caster was not intended to increase Dow's production levels, it was expected to eliminate some production bottlenecks. Dow initially will offer the T-bars in three sizes—250-pound, 500-pound, and 1,000-pound, and the company plans eventually to offer 500-pound and 750-pound round billets. A second caster was expected to be operational in January 1994. Dow is the only U.S. producer of the direct-chill-cast T-bars, which the company claims have a smoother surface and a lower likelihood of pockets than conventionally cast magnesium ingots.[14]

The automotive industry continued to be a main target area for increasing magnesium usage resulting in announcements of new magnesium alloy components and increases in diecasting capacity to meet the growing demand. Port City Diecasting in Muskegon, MI, planned to complete construction on a 1,200-square-meter magnesium diecasting facility in the summer. The company, which has been casting aluminum and zinc, is installing two 600-ton cold-chamber diecasting machines dedicated to magnesium. About one-half of Port City's current customers are with the automotive industry, and the company expects to have the same product mix with magnesium.[15]

Magnesium Products of America Inc., a subsidiary of Canada's Meridian Technologies Inc., plans to install three 3,000-ton magnesium diecasting machines in its new facility in Eaton Rapids, MI; the total number of high-pressure casting machines was scheduled to be 12 or 13, ranging in size from 800 tons to 3,000 tons. This new plant was expected to be in operation in September.[16]

Because of increased demand for large die-cast magnesium components, Lunt Manufacturing planned to begin construction of a second 6,000-square-meter magnesium casting facility near Chicago, IL, in 1993. The company currently operates an 8,000-square-meter facility with 12 diecasting machines.

Borg-Warner Corp. plans to increase its production of magnesium alloy four-wheel-drive transfer cases by more than 100%, to a level of more than 500,000 units annually, within 3 years. Production of the additional cases will require nearly 3,000 tons of magnesium annually. The transfer cases are among the largest automotive parts made of magnesium, and Borg-Warner expected to shift to a production ratio of 90% magnesium-10% aluminum within 3 years.[17]

Chrysler Corp. announced that it would incorporate magnesium steering wheel armatures on its new economy car models, which were scheduled to be introduced early in 1994. It is estimated that this application will consume about 200 to 250 tons of magnesium annually. Chrysler's components will be manufactured by Gibbs Die Casting Corp., Henderson, KY, the same company that manufactures steering wheel diecastings for Ford Motor Co.[18] Ford also is investigating the potential for magnesium steering wheels for the 1996 models of another of its product lines. Ford currently uses magnesium steering wheels on several platforms. This application was estimated to represent 800 to 900 tons of magnesium alloy consumption per year.

Chrysler also reportedly finalized plans to use magnesium steering columns and mounting brackets in its minivans beginning in 1996. Total annual magnesium requirements for these parts were estimated to be about 1,000 tons annually. Suppliers for the die-cast parts were Magnesium Products Ltd. in Canada and U.S. manufacturer Diemakers Inc.[19]

Ford and General Motors Corp. (GM) were investigating the use of magnesium alloy seat risers in place of conventional steel units in two truck lines for the 1996 model year. These applications could consume more than 3,000 tons of magnesium alloy annually. Replacement of the steel part with magnesium alloy diecasting is projected to reduce the part weight from 3.6 to 4.5 kilograms to 0.9 to 1.1 kilograms.[20]

GM reportedly was completing plans for instrument panel support beam applications that could require about 5,000 tons of magnesium per year. The new components, which were scheduled to be introduced over a 2-year period beginning in late 1995, were expected to replace steel stampings in three vehicle lines. With a weight of 15 kilograms, the magnesium components were estimated to replace more than 17,000 tons of steel in GM's midsize and standard-size vans and C-body luxury cars.[21]

U.S.-based Rossborough Manufacturing was finalizing a joint venture with the East Slovak Steel Co. to construct a blending plant to produce magnesium-base desulfurization powders in Slovakia. Rossborough planned to expand the plant as demand for desulfurization increases in Eastern Europe.[22]

Dynacast Inc. reportedly acquired the assets of Lone Star Die Casting Corp., New Braunfels, TX, a major supplier of aluminum and magnesium diecastings for garden tools.[23]

IBM Corp. announced that it was producing a small pen-base notebook computer with magnesium cases. Because of magnesium's light weight, the material was chosen to reduce the case mass and make the computer easier to carry.[24]

A review of structural magnesium applications highlighted changes in the past 30 years. In 1966, more than 50 applications for magnesium were cited in 13 areas; by 1988, only 23 applications in 7 areas were cited. Reductions in the number of applications occurred in aerospace and nonindustrial machinery in particular. However, automotive and sporting good applications have increased.[25] *(See tables 5 and 6.)*

Stocks.—Producers' stocks of primary magnesium at yearend 1993 increased to 17,827 tons, more than three times the level at yearend 1992 of 5,863 tons. Stocks of magnesium metal and alloy held by consumers increased to 7,772 tons at yearend 1993 from 7,274 tons at yearend 1992. Consumer stocks of secondary magnesium also increased to 388 tons at yearend 1993 from 356 tons at yearend 1992.

Markets and Prices.—Magnesium prices quoted in trade journals generally decreased steadily through the first three quarters of 1993 before beginning to rise again. The Metals Week U.S. transaction price quotation declined from a range of $1.46 to $1.53 per pound at the beginning of the year to $1.36 to $1.46 by the end of the second quarter. Beginning in July, Metals Week began publishing two primary magnesium prices—the U.S. spot Western price and the U.S. spot dealer import price. The spot Western price would only reflect North American producer-consumer transactions, while the spot dealer import would reflect the price of imported magnesium, delivered, duty paid. These two quotations would replace the U.S. transaction price, which was a weighted average of all transactions.

The Metals Week U.S. spot dealer import price range was quoted at $1.22 to $1.48 per pound at the beginning of the third quarter, and this range dropped steadily to a low of $1.13 to $1.18 per pound by mid-September. By yearend, this price range had increased slightly to $1.17 to $1.21 per pound.

The Metals Week U.S. spot Western price was estimated at $1.45 to $1.46 from the beginning of July through mid-November. From that point, the range widened to $1.43 to $1.46 and remained at that level until yearend.

At the beginning of 1993, Metals Week's quoted European free market price range was $2,400 to $2,500 per ton. The range declined to reach a low for the year of $1,975 to $2,050 by the beginning of September and rose to $2,250 to $2,325 per ton by the end of the year.

Metal Bulletin's free market price quotation also trended downward through the first three quarters of 1993. At the beginning of 1993, the price range was quoted at $2,500 to $2,550 per ton. By mid-September, the quoted range had decreased to $1,950 to $2,050 per ton. This range rose to reach $2,220 to $2,300 per ton by the end of the year.

Foreign Trade.—Exports of magnesium in 1993 declined by 25% from the 1992 level. Canada, Japan, and the Netherlands were the principal destinations. Imports of magnesium increased significantly, with imports from Canada, Russia, and Ukraine making up the bulk of the total. *(See tables 7 and 8.)*

World Review.—In early September, Euroalliages, a European producer association, filed an antidumping suit against magnesium imports from the former U.S.S.R. The European Commission accepted the complaint in October, which alleged that magnesium from the Commonwealth of Independent States was dumped at a margin of 123%. Russian producers stated that the low prices of the magnesium appearing on the European market were from illegal exports and did not correspond to producer prices. Other countries, including Japan and India, also claimed that exports from the former U.S.S.R. were having an adverse effect on their magnesium production.[26]

According to the International Magnesium Association (IMA), world magnesium inventories at the end of 1993 were 42,400 tons, a 44% increase from the yearend 1992 level of 29,500 tons. *(See tables 9, 10, and 11.)*

Australia.—The Australian Federal and Queensland State Governments were jointly funding a feasibility study to construct a magnesium diecasting facility in Gladstone, near Queensland Metals Corp.'s (QMC) proposed magnesium plant. The study represented a strategy for adding value to QMC's magnesite deposit.

Canada.—Meridian Technologies, a Canadian-based magnesium diecaster, reportedly completed two agreements to expand its market into Europe. The company announced an agreement in principle with Stahlschmidt & Maiworm Technics GmbH to develop, produce, and sell magnesium wheels in Germany. Meridian Technologies also signed a Heads of Agreement with Italy's Teksid, with the objective of setting up a European diecasting operation. Teksid, which produces iron and aluminum castings, would provide European contacts and market knowledge to Meridian Technologies.[27]

Magnesium Products installed two 800-ton cold-chamber diecasting machines at its Strathroy, Ontario, facility and began operating a 2,200-ton caster to bring the total casting capacity at the plant to 7,000 tons per year. The company also completed construction at its Eaton Rapids, MI, plant and was planning a June 1994 startup.[28]

France.—Because of high inventory levels, Pechiney announced that it would close two-thirds of its 17,000-ton-per-year primary magnesium production capacity in November 1993, earlier than the company's normal winter closure. Pechiney originally was scheduled to shut down production completely between Christmas and the beginning of March. With the high inventory levels, the company could supply its customers' needs despite the closure. Closure of the plant during the winter, which was initiated last year and occurred during January and February only, was originally intended to reduce electric power costs.[29]

Israel.—At the end of June, Israel's Dead Sea Works (DSW), a subsidiary of Israel Chemicals Ltd. (ICL), announced that it had signed a $9 million contract with a consortium of companies and research institutes in the Commonwealth of Independent States to purchase electrolytic cell technology using carnallite as a feed material. In March, ICL's board of directors had approved a $366 million investment for the plant and a new 110-megawatt power station. The new plant will be at the southern tip of the Dead Sea in the town of Sdom. By mid-July, two Israeli engineering firms had begun work on the engineering, construction, procurement, and management for the planned 25,000-ton-per-year magnesium plant, scheduled to be completed in 1995. If expansion is warranted, construction of a second 25,000-ton-per-year phase is scheduled for 1998. A foundation stone-laying ceremony was held on October 19.[30]

Japan.—Japanese magnesium producer Ube Industries Ltd. reportedly signed a formal agreement with an unidentified partner in China to take dolomite feedstock under a long-term agreement. Previously, Ube Industries had long-term agreements with suppliers in the Republic of Korea and Taiwan and made spot purchases from China. Ube Industries was estimated to require between 80,000 and 100,000 tons of dolomite per year.[31]

Japan Metal & Chemicals (JMC) reportedly liquidated its 5,000-ton-per-year primary magnesium plant in December, after it had been idle for more than 1 year. The plant was originally opened in 1987 and has been closed since mid-1992. Furnace problems were cited as the original reason for closure, but because of increased imports from China and the former U.S.S.R. and appreciation of the yen, the plant has remained closed. JMC announced that it would continue to market magnesium through remelting ingot consigned from Northwest Alloys Inc.[32]

Kawasaki Steel Corp. in Japan announced that it is testing a desulfurization process using magnesium; this company would be the first Japanese steel producer to use magnesium. This could increase the world magnesium desulfurization market significantly.[33]

Japan's Kobe Steel finished installing production equipment at its new aluminum and magnesium alloy casting plant in Daian. The casting shop was expected to be completely operational by December.[34]

Norway.—Hydro Magnesium reportedly was conducting a preliminary study to build a magnesium recycling plant near Herøya, Norway. The proposed plant would have a capacity of 10,000 tons per year and would be the first magnesium recycling plant in Norway. To encourage European automakers to use magnesium, the plant would melt scrap returned from diecasters and return it in ingot form. Completion of the study was scheduled for the second or third quarter of 1993.[35]

Saudi Arabia.—A feasibility study conducted for the Gulf Organization for Industrial Consultancy, an offshoot of the Gulf Corporation Council (GCC), suggested constructing a 10,000-ton-per-year primary magnesium plant in the Persian Gulf area. (The six Arab nations that form the GCC are Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates.) The study said that Saudi Arabia would be a likely location for the new plant, but both Oman and Qatar could be possible locations. Annual magnesium demand in the six nations was estimated to be 3,000 tons, but was expected to increase to 10,000 tons by 2000. Cost for building the new magnesium plant was calculated to be $85 million, and because of inexpensive fuel costs in the area, the consultancy estimated that the cost of producing 1 ton of magnesium would be $2,880.[36]

Ukraine.—In Ukraine, the Government introduced export duties on a variety of metals and raw materials. Included in these materials is magnesium, which has an export duty of 30% of the sale price, effective June 1, 1993. Previously, the country had no export duty on magnesium.[37] In May, Alusuisse-Lonza Trading Group reportedly signed an agreement with Kemo Komplex in Ukraine to market its Kalusch 99.9% magnesium in most areas of the world. Kemo Komplex was expected to continue to market magnesium in Europe, and its agreement with Alusuisse-Lonza would improve its marketing, transportation, and storage arrangements.[38]

Current Research.—Researchers at the U.S. Bureau of Mines have developed a process to vacuum distill magnesium and zinc from aluminum alloys as an alternative to chlorination. Distillation is considered more environmentally benign than chlorination, and the metals are produced as byproducts that can be recycled. Bench-scale tests have shown lower than expected distillation rates at 850° C, but commercial operations could use induction heating at higher temperatures to improve distillation rates.[39]

The International Magnesium Association's annual magnesium conference highlighted developments in several areas of magnesium and magnesium alloy technology. Topics covered in papers presented at the 1993 conference included advancements in magnesium alloy diecasting technology, alloy development and improvements, desulfurization advances, and magnesium alloy recycling.[40]

Researchers at the Universidad Nacional Autonoma de Mexico studied the effects of microstructure and alloying elements on the efficiency of sacrificial magnesium anodes. From the results of their investigations, the researchers found that by controlling the quantity of second-phase, iron-rich particles at grain boundaries, anode efficiency was improved.[41]

As part of a broad research program aimed at the characterization and development of magnesium and magnesium alloy composites, researchers at Laval University investigated different methods of producing magnesium and magnesium alloy composites reinforced with silicon carbide. Two methods of powder metallurgy processing and one method of ingot metallurgy processing were investigated. In the first powder metallurgy method, mechanical alloying using a low-energy ball mill to form composite particles is followed by hot pressing and hot extrusion. The second powder metallurgy method used simple dry mixing of the particles, followed by hot pressing and hot extrusion. In ingot metallurgy, a fluxless melting technology is used. The researchers found that the best combination of properties, including crack initiation and propagation behavior, was achieved with the low-energy mechanical alloying.[42]

Magnesium Compounds

Production.—Because of decreases in the demand for domestically produced refractory magnesia, production of dead-burned magnesia and magnesium hydroxide declined in 1993. Other magnesium compound production increased slightly.

Dow announced that it had expanded the magnesium hydroxide production capacity at its Ludington, MI, plant to 125,000 tons per year, an increase of 30,000 tons from the prior capacity level. This increase in capacity was driven by anticipated growth in acid neutralization applications for magnesium hydroxide.[43] Martin Marietta Magnesia Specialties reportedly completed a new facility at its Manistee, MI, location for producing FlowMag® slurry products use in wastewater neutralization applications. The company also received a patent on its FlowMag granular product, used to remove heavy metals from industrial-process effluent. To reduce costs and to broaden its product line, Martin Marietta began importing magnesite from China in 1993.[44] *(See table 12.)*

AIMCOR announced that it planned to sell its Metals/Minerals Group, including its olivine operations. The company has hired investment bankers Bowles Hollowell Connor & Co. to find a buyer for the group as a whole or separate buyers for the minerals division and the metals division.[45]

Consumption and Uses.—Dead-burned magnesia refractories for use in metal, cement, and glass production furnaces continued to be the primary application for magnesium compounds in the United States, representing about 66% of the total U.S. demand for magnesium compounds.

In 1993, agricultural applications (animal feed and fertilizer) were the dominant use for caustic-calcined magnesia, accounting for 35% of U.S. shipments. Chemical processing was the next largest segment, with 18% of total shipments. The following categories, with the individual components in parentheses in declining order, were the other end-use sectors for caustic-calcined magnesia: metallurgical (refractories, water treatment, electrical, and stack-gas scrubbing), 16%; manufacturing (rayon, rubber, fuel additives, and pulp and paper), 13%; construction (oxychloride and oxysulfate cements and general construction), 5%; pharmaceuticals and nutrition (medicinal and pharmaceutical, sugar, and candy), 4%; and unspecified uses, 9%.

Magnesium carbonate was used principally as a chemical intermediate and in medicines and pharmaceuticals. Magnesium hydroxide was used mainly in the chemical industries, water treatment, and pulp and paper. Magnesium sulfate was used mostly in pharmaceuticals and animal feed.

Magnesium chloride was used mainly in oxychloride cements. Magnesium chloride brines were used principally for road dust and ice control.

Foundry uses were the largest application for olivine in the United States, accounting for 60% of consumption of domestically produced material. Refractory applications consumed 26% of U.S. olivine shipments, sand blasting and other abrasive applications accounted for 7%, and slag control accounted for the remaining 7% of U.S. olivine consumption. *(See table 13.)*

Markets and Prices.—Most quoted magnesium compound prices at yearend 1993 were significantly higher than prices at the end of 1992. Magnesium hydroxide prices in particular increased almost 25%, which was mainly a result of the increased interest in the material in environmental applications.

U.S. olivine prices, quoted in Industrial Minerals, were $62 to $109 per ton for foundry grade and $50 to $79 per ton for aggregate material. All prices were quoted f.o.b. mine or plant. *(See table 14.)*

Foreign Trade.—Trade data for olivine are not reported separately by the Bureau of the Census. Some data on olivine are available from a computer service, the Port Import/Export Reporting Service (PIERS). PIERS reports data on materials that are transported by ship. According to this source, the United States imported 136,478 tons of olivine from Norway in 1993. Exports of olivine from the United States totaled 1,859 tons. Peru, with 43% and Chile, with 33% of the total, were the principal recipients. Australia, Italy, the Republic of Korea, New Zealand, and Taiwan were the other destinations. *(See tables 15, 16, 17, and 18.)*

World Review.—In Europe, the refractory magnesia market has undergone significant changes in the past few years. Western Europe has been a large producer and significant exporter of dead-burned magnesia, but recently imports have supplied up to 35% of the area's needs. For first-grade refractory magnesia, domestic sources in Greece, Ireland, Italy, the Netherlands, and the United Kingdom traditionally supplied most of western Europe's requirements, but closures in Greece, Italy, and the United Kingdom changed this. With the opening of the Qmag plant in Australia, this country is emerging as a major supplier to western Europe.[46]

Australia.—Queensland Metals Corp. (QMC) and ICI Australia Ltd. reportedly signed an agreement that formally establishes the Enviromag joint venture in May. The 50-50 joint venture was incorporated as Enviromag (Marketing) Pty. Ltd. The company planned to market magnesium hydroxide for environmental markets throughout the world.[47] QMC also reached an agreement in principle with a European group to join the 50-50 Flamemag joint venture, for which the primary objective is to identify to lowest cost process capable of producing a wide range of magnesium hydroxides from magnesite. QMC planned to construct a large pilot plant in Europe, to be operational by the second half of 1994.

China.—At the Liaoning Magnesite Refractory Co., a two-stage froth flotation process was developed to eliminate talc and other minerals from magnesite. By using this process, the magnesite concentrate may be upgraded to contain less than 1.5% silica. A two-stage calcining process also was developed to produce high-purity dead-burned magnesite. By using the high-purity raw material, the company has produced magnesia-carbon, magdol-carbon, direct-bonded magnesite-chrome, and magnesite-alumina refractory bricks. With the process improvements, these refractories have shown improved service performance in several iron and steel- and cement-making applications.[48]

Greece.—To improve the quality of both caustic-calcined and dead-burned magnesite, Grecian Magnesite S.A. commissioned a new petroleum coke facility and a new research and development laboratory. The company also was involved with several outside partners in developing new dead-burned refractory materials. The other magnesite producer, Magnomin Gemco S.A., switched from producing only caustic-calcined magnesite to a 50-50 mix of caustic-calcined and dead-burned magnesite over the past few years. Magnomin was involved in improving product quality through its research and development program, which involved evaluation of the effects of particle size of dead-burned magnesite and assessing the advantages of vertical shaft kilns.[49]

To make itself more attractive to potential buyers, Fimisco reportedly restarted magnesia refractories production in late 1993 from stockpiles of raw materials that the company had on hand. The company was put under Alpha Finance A.E. and was being privatized during 1993, although there were no offers for Fimisco during the first round of privatization. Mining, Trading & Manufacturing Ltd. (MTM), a Greek magnesite producer whose operations have been closed since 1988, also was undergoing privatization under the auspices of Alpha Finance. MTM's operations consisted of an open pit and underground mine, prebeneficiation and beneficiation facilities, and two shaft kilns.[50]

India.—India Rayon announced that it was beginning a project to produce 50,000 tons per year of high-purity refractory magnesia from seawater. This plant will be India's first seawater magnesia plant. Commercial production was expected to begin in early 1995. Refractories Consulting and Engineering, an Austrian firm, was providing technology for the project, and India Rayon was planning to import a part of the plant and equipment required for the project.[51]

In June, Dalmia Magnesite Corp. announced that it was closing its mines in Tamil Nadu for at least 2 months. Before the closure, the company had been working at reduced levels because of poor market conditions. Because of reduced import duties for magnesite, implemented in February, less costly imports from Australia, Brazil, China, North Korea, and Turkey have increased to supply a greater share of the country's demand.[52]

Khaitan Hostombe Spinels reportedly was constructing a $100 million plant in Salem, Tamil Nadu, to produce sintered magnesia and magnesia-chrome clinker. The new 34,000-ton-per-year plant, scheduled to be completed by the third quarter of 1994, will supply domestic consumers, substituting for material that previously was imported.[53]

Israel.—In October, the new 13,000-ton-per-year fused magnesia plant at Mishor Rotem was inaugurated. This $23 million plant is operated by Tateho Dead Sea Fused Magnesia Co., a joint venture between Japan's Tateho Chemical Industries Co. Ltd. and Israel's Dead Sea Periclase Ltd. Preliminary product specifications indicated that the fused magnesia contained 99.5% MgO and 0.5% CaO, with a specific gravity greater that 3.5 grams per cubic centimeter. Initial plant operations will focus on fine tuning process parameters and determining if more than one grade of fused magnesia will be produced.[54]

Jordan.—The Arab Potash Co. Ltd. (APC) planned to build a 3.6-ton-per-day pilot magnesia plant at Safi, the company's existing site. Refractories Consulting & Engineering will supply the equipment and technology for the $1 million plant, which was scheduled to be completed by the beginning of 1994. Magnesium chloride for the plant will be extracted from the brines that APC already uses as a source of potassium chloride. Depending on the results of the pilot tests, APC may decide to construct a 100,000-ton-per-year plant at the same site.[55]

Netherlands.—Billiton Refractories BV was put up for sale by its parent company Royal Dutch/Shell Group after negotiations between Gencor Ltd. and the Shell Group fell through because Billiton did not fit into Gencor's activities. Although many companies were rumored as possible buyers for Billiton, negotiations were not expected to be completed by yearend. Billiton Refractories operates a 100,000-ton-per-year dead-burned magnesia plant in Veendam.[56]

Turkey.—To reform its large state-owned enterprises, Turkey targeted some of its operations for closure and some for privatization. Two of the country's largest magnesite operations—Kümas Kütahya Manyezit and Konya Krom Manyezit—were scheduled for privatization. Kümas was separated from its parent, Çitosan, in 1992, was offered for sale in March 1993, and the bidding was closed in May. One of Turkey's private-sector magnesite companies, Magnesit AS, was one of two companies that bid on Kümas. Konya remained under the umbrella of Çitosan, but was undergoing a major modernization and automation program scheduled to be finished by the end of 1994.[57]

Magnesit began recovering crude magnesite from waste dumps at its mines in June after extensive design studies and testing. The recovery was initiated in 1992 and uses magnetic separation rather than heavy-media separation to recover the magnesite. Original estimates of output were 85,000 tons of crude magnesite per year.[58]

United Kingdom.—U.S.-based J. E. Baker Co. announced an agreement with Redland PLC to acquire the manufacturing plants of Steetly Refractories Ltd. in January. Steetly has two facilities in Worksop and Dudley. The acquisition of the magnesia refractories operations will complement J. E. Baker's dolomite refractories operations in the United States and will enhance the company's international position. *(See tables 19, 20, and 21.)*

Current Research.—Science Ventures Inc. announced that it had developed a leaching process to remove unwanted magnesium from dolomitic phosphate ores as marketable magnesium oxide. In the process, called the P^3 process, sulfuric acid is added to the ore to maintain a pH range of 4.0 to 4.4 and carbon dioxide is continuously removed by boiling the solution. In a second step, lime is added to the solution to precipitate magnesium hydroxide. The process was developed because the magnesium content of dolomitic phosphate ores increases solution viscosity and precipitates on equipment used in the manufacture of phosphoric acid.[59]

OUTLOOK

Magnesium producers throughout the world, but especially in the United States, have targeted the automotive industry as a potential growth market for magnesium. Within the past 15 years, through the introduction of high-purity diecasting alloys, the average magnesium content of a North American automobile has increased from 0.5 kilogram to 2.3 kilograms. As a result, production of magnesium diecasting has increased significantly. Steady growth in this area is likely, as automobile manufacturers continue to announce new applications for magnesium diecastings in future car, truck, and van models.

Other large applications for magnesium, aluminum alloying and iron and steel desulfurization, are likely to be areas of slow growth for magnesium consumption. These markets are fairly mature in the United States. In aluminum alloying, most of the magnesium is used for beverage cans, which generally grow only with increases in population. Although iron and steel desulfurization has had a large growth rate in the past decade, most of the U.S. market already has been captured from calcium carbide. Growth in the desulfurization market only will come as additional metal requires desulfurization, not as a result of substitution done in the past.

The most important influence on world supply of magnesium has been exports from Kazakhstan, Russia, and Ukraine appearing on the world market. In 1993, Russia and Ukraine were responsible for a 470% increase in U.S. primary magnesium imports from the 1992 figure. The IMA also reported that there was a significant increase in imports from the former U.S.S.R. to Europe and Japan. Most of this material was used for aluminum alloying and desulfurization. The European producers already have filed an antidumping suit against these magnesium imports, and press reports indicated that antidumping suits may be filed in the United States and Japan. U.S. producers have cited these increased imports as reasons for closing parts of their plants. World inventories also have shown a significant increase from 1992 levels. The outcome of the European antidumping suit and resolution of potential antidumping actions in the rest of the world will have a significant impact on the world supply of magnesium.

Production and demand for magnesium compounds in the United States were expected to remain relatively stable over the new few years, but the proportion of magnesia used as refractories was expected to continue to decrease. Technological changes in steel production have had a deleterious effect on the consumption of specific refractories. Open-hearth furnaces have been replaced by electric arc furnaces and basic-oxygen steelmaking. Although the trend to electric arc furnaces has reduced the overall demand for refractories, high-quality basic refractories (including magnesia-base refractories) are needed for the body of the furnace. At the same time, improvements in refractories technology resulted in increased longevity. There will still be a demand for magnesia refractories, but producers will continue to work to produce higher quality material that is needed by their customers.

Although refractories are the principal use for magnesia, environmental applications, such as flue gas desulfurization and water treatment, are being investigated as growth areas for magnesia and other magnesium compounds. Any increase in demand for other magnesium compounds is expected to be offset by the decline in refractories demand, leading to a stagnant demand for magnesium compounds in the United States.

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TABLE 1

U.S. MAGNESIUM METAL PRODUCERS, BY LOCATION, RAW MATERIAL, AND PRODUCTION CAPACITY, IN 1993

Company	Plant location	Raw material	Annual capacity (metric tons)
The Dow Chemical Co.	Freeport, TX	Seawater	90,000
Magnesium Corp. of America	Rowley, UT	Lake brines	35,000
Northwest Alloys Inc.	Addy, WA	Dolomite	35,000
Total			160,000

TABLE 2

U.S. MAGNESIUM COMPOUND PRODUCERS, BY RAW MATERIAL SOURCE, LOCATION, AND PRODUCTION CAPACITY, IN 1993

Raw material source and producing company	Location	Capacity (metric tons of MgO equivalent)	Products
Magnesite: Premier Services Inc.	Gabbs, NV	100,000	Caustic-calcined and dead-burned magnesia.
Lake brines:			
Great Salt Lake Minerals Corp.	Ogden, UT	90,000	Magnesium chloride and magnesium chloride brines.
Reilly Industries Inc.	Wendover, UT	45,000	Magnesium chloride brines.
Well brines:			
The Dow Chemical Co.	Ludington, MI	214,000	Magnesium hydroxide.
Martin Marietta Magnesia Specialties Inc.	Manistee, MI	275,000	Caustic-calcined and dead-burned magnesia.
Morton International	do.	10,000	Magnesium carbonate, magnesium hydroxide, and caustic-calcined magnesia.
Seawater:			
Barcroft Co.	Lewes, DE	5,000	Magnesium hydroxide.
The Dow Chemical Co.	Freeport, TX	20,000	Magnesium chloride.
Marine Magnesium Co.	South San Francisco, CA	15,000	Magnesium carbonate, magnesium hydroxide, and caustic-calcined magnesia.
National Refractories & Minerals Corp.	Moss Landing, CA	165,000	Magnesium hydroxide and caustic-calcined and dead-burned magnesia.
Premier Services Inc.	Port St. Joe, FL	50,000	Caustic-calcined and dead-burned magnesia.
Total		989,000	

TABLE 3

U.S. IMPORT DUTIES

Item	HTS No.	Most favored nation (MFN) Jan. 1, 1993	Non-MFN Jan. 1, 1993
Magnesium:			
Unwrought magnesium	8104.11.0000	8.0% ad valorem	100% ad valorem.
Unwrought magnesium alloys	8104.19.0000	6.5% ad valorem	60.5% ad valorem.
Magnesium waste and scrap	8104.20.0000	Free	Free.
Wrought magnesium	8104.90.0000	14.8 cents per kilograms on Mg content + 3.5% ad valorem	88 cents per kilogram on Mg content + 20.0% ad valorem.
Magnesium compounds:			
Crude magnesite	2519.10.0000	Free	$10.33 per ton.
Dead-burned and fused magnesia	2519.90.1000	0.4 cent per kilogram	1.7 cents per kilogram.
Caustic-calcined magnesia	2519.90.2000	$2.07 per ton	$20.70 per ton.
Other magnesia	2519.90.5000	Free	15.4 cents per kilogram.
Calcined dolomite	2518.20.0000	6% ad valorem	30% ad valorem.
Kieserite, natural	2530.20.1000	Free	Free.
Epsom salts, natural	2530.20.2000	3.7% ad valorem	20% ad valorem.
Magnesium hydroxide and peroxide	2816.10.0000	3.1% ad valorem	25% ad valorem.
Magnesium chloride	2827.31.0000	1.5% ad valorem	5% ad valorem.
Magnesium sulfate	2833.21.0000	3.7% ad valorem	20% ad valorem.

Source: U.S. International Trade Commission.

TABLE 4
SALIENT MAGNESIUM STATISTICS

(Metric tons unless otherwise specified)

	1989	1990	1991	1992	1993
United States:					
Production:					
Primary magnesium	152,066	139,333	131,288	136,947	132,144
Secondary magnesium	51,200	54,808	50,543	57,045	58,890
Exports	56,631	51,834	55,160	r51,951	38,815
Imports for consumption	12,289	26,755	31,863	r11,844	37,248
Consumption, primary	105,226	96,108	91,872	93,827	100,571
Price per pound	$1.63	$1.43-$1.63	$1.43	$1.46-$1.53	[1]$1.43-$1.46
World: Primary production	r344,447	r355,237	r341,000	r306,381	e283,944

eEstimated. rRevised.

[1]Yearend Platt's Metals Week U.S. spot western price.

TABLE 5
MAGNESIUM RECOVERED FROM SCRAP PROCESSED IN THE UNITED STATES, BY KIND OF SCRAP AND FORM OF RECOVERY

(Metric tons)

	1989	1990	1991	1992	1993
KIND OF SCRAP					
New scrap:					
Magnesium-base	3,951	3,992	4,867	4,539	3,221
Aluminum-base	19,278	19,432	18,192	21,652	25,092
Total	23,229	23,424	23,059	26,191	28,313
Old scrap:					
Magnesium-base	4,269	4,277	4,443	4,220	4,323
Aluminum-base	23,702	27,107	23,041	26,634	26,254
Total	27,971	31,384	27,484	30,854	30,577
Grand total	51,200	54,808	50,543	57,045	58,890
FORM OF RECOVERY					
Magnesium alloy ingot[1]	4,494	4,290	4,604	W	W
Magnesium alloy castings	795	857	1,043	923	1,091
Magnesium alloy shapes	635	301	158	329	413
Aluminum alloys	43,125	46,807	41,606	48,619	51,587
Zinc and other alloys	W	W	3	3	2
Other[2]	2,151	2,553	3,129	7,171	5,797
Total	51,200	54,808	50,543	57,045	58,890

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

[1]Includes secondary magnesium content of both secondary and primary alloy ingot.

[2]Includes chemical and other dissipative uses and cathodic protection, as well as data indicated by symbol "W."

TABLE 6
U.S. CONSUMPTION OF PRIMARY MAGNESIUM, BY USE

(Metric tons)

Use	1989	1990	1991	1992	1993
For structural products:					
Castings:					
Die	5,627	7,479	7,532	8,920	10,949
Permanent mold	811	875	750	853	746
Sand	1,017	724	575	450	397
Wrought products:					
Extrusions	6,712	7,848	6,387	6,435	7,433
Other[1]	2,941	3,096	2,415	2,408	2,438
Total	17,108	20,022	17,659	19,066	21,963
For distributive or sacrificial purposes:					
Alloys:					
Aluminum	53,821	45,060	45,809	41,003	46,498
Other	9	8	9	10	10
Cathodic protection (anodes)	5,474	5,421	4,976	4,852	4,723
Chemicals	594	800	695	739	653
Iron and steel desulfurization	10,463	9,853	10,895	13,611	12,525
Nodular iron	1,635	1,424	1,074	W	W
Reducing agent for titanium, zirconium, hafnium, uranium, beryllium	10,798	8,989	6,071	8,209	9,092
Other[2]	5,324	4,531	4,684	6,337	5,107
Total	88,118	76,086	74,213	74,761	78,608
Grand total	105,226	96,108	91,872	93,827	100,571

W Withheld to avoid disclosing company proprietary data; included in "Other."
[1]Includes sheet and plate and forgings.
[2]Includes scavenger, deoxidizer, and powder.

TABLE 7
U.S. EXPORTS OF MAGNESIUM, BY COUNTRY

Country	Waste and scrap		Metal		Alloys (gross weight)		Powder, sheets, tubing, ribbons, wire, other forms (gross weight)	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1992:								
Argentina	—	—	384	$906	—	—	70	$420
Australia	7	$15	2,975	5,447	—	—	117	517
Belgium	—	—	7	96	15	$88	86	541
Brazil	—	—	338	718	—	—	41	104
Canada	2,097	[r]4,798	4,041	9,967	1,035	2,766	819	4,067
Ghana	—	—	138	360	—	—	—	—
India	—	—	124	335	—	—	45	388
Iran	—	—	450	1,496	—	—	—	—
Japan	11	22	10,996	26,690	59	289	1,174	4,928
Korea, Republic of	—	—	444	1,084	103	715	6,749	2,049
Mexico	295	668	354	949	58	212	201	741
Netherlands	76	240	13,940	41,108	43	129	1,907	5,591
Taiwan	—	—	349	758	10	33	42	570
United Kingdom	10	164	91	592	28	295	139	563
Venezuela	—	—	481	913	1	7	2	5
Other	([1])	([1])	[r]712	[r]4,802	[r]121	[r]831	[r]766	[r]3,883
Total	2,496	5,907	35,824	96,221	1,473	5,365	12,158	24,367
1993:								
Argentina	—	—	119	311	1	9	50	273
Australia	—	—	2,990	5,661	22	42	163	708
Belgium	—	—	1,664	5,498	85	276	419	1,308
Brazil	3	22	190	442	([2])	15	36	112
Canada	1,956	4,484	5,514	15,417	1,140	3,528	726	3,337
Ghana	—	—	100	313	—	—	—	—
India	—	—	110	330	—	—	3	26
Iran	—	—	10	32	—	—	—	—
Japan	—	—	7,451	19,250	188	1,120	331	2,407
Korea, Republic of	16	24	177	519	158	1,119	4,941	1,596
Mexico	24	55	325	923	220	917	370	1,281
Netherlands	—	—	7,488	19,815	12	37	595	1,797
Taiwan	6	32	—	—	7	42	2	25
United Kingdom	2	19	19	306	6	97	210	766
Venezuela	—	—	25	75	3	38	—	—
Other	—	—	336	2,960	111	979	491	5,136
Total	2,007	4,636	26,518	71,852	1,953	8,219	8,337	18,772

[r]Revised.
[1]Revised to zero.
[2]Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 8

U.S. IMPORTS FOR CONSUMPTION OF MAGNESIUM, BY COUNTRY

Country	Waste and scrap		Metal		Alloys (magnesium content)		Powder, sheets, tubing, ribbons, wire, other forms (magnesium content)	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1992:								
Brazil	—	—	40	$110	—	—	—	—
Canada	1,049	$722	548	1,514	3,144	$11,312	344	$913
China	—	—	370	930	57	248	—	—
France	—	—	111	291	1	58	([1])	3
Germany	83	86	—	—	([1])	11	([1])	35
Kazakhstan	—	—	—	—	209	486	—	—
Mexico	87	63	97	289	—	—	988	3,247
Netherlands	137	120	—	—	—	—	([2])	—
Norway	—	—	—	—	([1])	2	1	2
Russia	561	1,179	1,930	5,122	77	209	—	—
Taiwan	31	31	—	—	—	—	—	—
Ukraine	—	—	692	1,871	—	—	—	—
United Kingdom	274	442	([1])	4	324	1,787	3	70
Other	[r]203	[r]178	[r]456	[r]899	27	432	([1])	11
Total	2,425	2,821	4,244	11,030	3,839	14,545	1,336	4,281
1993:								
Brazil	—	—	1,075	2,694	—	—	—	—
Canada	517	742	802	2,391	5,459	18,964	102	458
China	1	3	1,148	2,748	919	2,393	—	—
France	—	—	60	192	6	189	—	—
Germany	162	137	38	87	6	16	1	20
Kazakhstan	—	—	—	—	323	865	—	—
Mexico	1,076	1,376	—	—	—	—	1,328	3,937
Netherlands	451	510	50	103	([1])	3	([1])	5
Norway	—	—	—	—	269	861	36	116
Russia	272	463	16,639	35,831	773	1,638	1	6
Taiwan	140	132	—	—	38	98	—	—
Ukraine	—	—	4,223	8,577	17	40	—	—
United Kingdom	300	422	132	295	252	1,933	1	78
Other	540	737	69	182	22	544	([1])	2
Total	3,459	4,522	24,236	53,100	8,084	27,544	1,469	4,622

[r]Revised.
[1]Less than 1/2 unit.
[2]Revised to zero.

Source: Bureau of the Census.

TABLE 9

WORLD ANNUAL PRIMARY MAGNESIUM PRODUCTION CAPACITY,[1] DECEMBER 31, 1993, BY CONTINENT AND COUNTRY

(Metric tons)

Continent and country	Capacity
North America:	
Canada	49,000
United States	160,000
Total	209,000
South America: Brazil	10,600
Europe:	
France	17,000
Italy	[2]10,000
Kazakhstan	[3]65,000
Norway	41,000
Russia	[3]95,000
Serbia and Montenegro	[2]7,000
Ukraine	[3]54,000
Total	289,000
Asia:	
China	10,000
India	1,500
Japan	8,300
Total	19,800
World total	528,400

[1]Includes capacity at operating plants as well as at plants on standby basis.
[2]Standby capacity only.
[3]Includes magnesium production capacity that is used exclusively for titanium production as follows: Kazakhstan, 40,000 metric tons; Russia, 35,000 metric tons; and Ukraine, 15,000 metric tons.

TABLE 10

MAGNESIUM: WORLD PRIMARY PRODUCTION, BY COUNTRY[1]

(Metric tons)

Country	1989	1990	1991	1992	1993[e]
Brazil[e]	6,200	[r]8,700	7,800	7,300	9,700
Canada	[r, e]7,000	26,726	35,512	[e]25,700	23,300
China[e]	[r]3,500	[r]5,900	[r]8,600	[r]10,000	12,000
France	14,600	[r, e]14,000	[e]14,000	[r]13,700	13,000
Italy	[r]5,768	5,725	[r]3,919	[r]1,211	—
Japan	8,381	12,843	11,559	[r]7,119	7,500
Kazakhstan[e]	—	—	—	20,000	20,000
Norway	49,827	48,222	44,322	30,404	27,300
Russia[e, 2]	—	—	—	40,000	30,000
Serbia and Montenegro[3]	—	—	—	[e]4,000	—
Ukraine[e]	—	—	—	10,000	9,000
U.S.S.R.[e, 4]	91,000	88,000	80,000	—	—
United States	152,066	139,333	131,288	136,947	[5]132,144
Yugoslavia[3, 6]	6,105	5,788	[e]4,000	—	—
Total	[r]344,447	[r]355,237	[r]341,000	[r]306,381	283,944

[e]Estimated. [r]Revised.
[1]Table includes data available through July 14, 1994.
[2]Includes secondary.
[3]All production in Yugoslavia 1989-91 came from Serbia and Montenegro.
[4]Dissolved in Dec. 1991.
[5]Reported figure.
[6]Dissolved in Apr. 1992.

TABLE 11

MAGNESIUM: WORLD SECONDARY PRODUCTION, BY COUNTRY[1]

(Metric tons)

Country	1989	1990	1991	1992	1993[e]
Brazil[e]	1,500	1,600	1,600	1,600	1,600
Japan	20,270	23,308	17,158	12,978	[2]13,215
U.S.S.R.[e, 3]	8,000	7,500	7,000	6,500	6,000
United Kingdom[e, 4]	1,000	[r]900	[r]800	800	500
United States	51,200	[r]54,808	50,543	57,045	[2]58,890
Total	81,970	[r]88,116	[r]77,101	78,923	80,205

[e]Estimated. [r]Revised.
[1]Table includes data available through July 14, 1994.
[2]Reported figure.
[3]Dissolved in Dec. 1991; however, information is inadequate to formulate reliable estimates for individual countries.
[4]Includes alloys.

TABLE 12
SALIENT MAGNESIUM COMPOUND STATISTICS

(Thousand metric tons and thousand dollars)

	1989	1990	1991	1992	1993
United States:					
Caustic-calcined and specified magnesias:[1]					
Shipped by producers:[2]					
Quantity	135	135	154	130	131
Value	$39,529	$37,850	$48,074	[r]$36,781	$39,476
Exports, value[3]	$2,263	$1,406	$2,289	$2,404	$2,459
Imports for consumption, value[3]	$13,657	$13,957	$15,891	$12,309	$15,709
Refractory magnesia:					
Shipped by producers:[2]					
Quantity	348	335	296	291	268
Value	$97,673	$94,962	$85,292	$80,756	$77,716
Exports, value	$10,685	$19,709	$25,038	$22,257	$21,807
Imports for consumption, value	$38,555	$32,858	$30,209	$37,928	$48,673
Dead-burned dolomite:					
Sold and used by producers:					
Quantity	365	342	308	[r]302	315
Value	$28,294	$26,988	$25,736	$25,230	$26,218
World production (magnesite)	[r]11,953	[r]10,481	[r]9,813	[r]10,501	[e]10,136

[e]Estimated. [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.

TABLE 13
U.S. MAGNESIUM COMPOUNDS SHIPPED AND USED

	1992		1993	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Caustic-calcined[1] and specified (USP and technical) magnesias	130,118	[r]$36,781	131,207	$39,476
Magnesium hydroxide [100% $Mg(OH)_2$][1]	267,087	[r]64,445	252,471	61,585
Magnesium sulfate (anhydrous and hydrous)	37,889	13,919	42,687	13,974
Precipitated magnesium carbonate[1]	2,162	547	3,005	672
Refractory magnesia	290,558	80,756	268,275	77,716

[r]Revised.
[1]Excludes material produced as an intermediate step in the manufacture of other magnesium compounds.

TABLE 14
YEAREND MAGNESIUM COMPOUND PRICES

Material		Price
Magnesia, natural, technical, heavy, 85%, f.o.b. Nevada	per short ton	$232- $265
Magnesia, natural, technical, heavy, 90%, f.o.b. Nevada	do.	265
Magnesia, dead-burned	do.	330
Magnesia, synthetic technical	do.	366
Magnesium chloride, hydrous, 99%, flake	do.	290
Magnesium carbonate, light, technical (freight equalized)	per pound	$0.73- 0.78
Magnesium hydroxide, National Formulary, powder (freight equalized)	do.	.95- 1.05
Magnesium sulfate, technical (epsom salts)	do.	.16

Source: Chemical Marketing Reporter.

TABLE 15

U.S. EXPORTS OF CRUDE AND PROCESSED MAGNESITE, BY COUNTRY

Material and country	1992 Quantity (metric tons)	1992 Value (thousands)	1993 Quantity (metric tons)	1993 Value (thousands)
Caustic-calcined magnesia:				
Canada	—	—	142	$47
Colombia	255	$98	355	136
Germany	546	353	495	404
Mexico	359	103	543	243
Netherlands	1,482	801	865	573
United Kingdom	81	131	62	103
Venezuela	2,135	694	1,666	477
Other	r404	r224	325	476
Total	5,262	2,404	4,453	2,459
Dead-burned and fused magnesia:				
Brazil	685	764	288	292
Canada	38,605	14,595	40,696	14,262
France	1,887	508	67	23
Germany	2	525	2,162	689
Israel	1,457	756	906	524
Japan	532	101	37	7
Korea, Republic of	286	138	756	442
Mexico	1,251	459	1,300	546
Netherlands	150	56	461	170
Switzerland	1,000	368	—	—
Taiwan	307	136	119	82
Thailand	4,257	1,594	2,051	615
Venezuela	5,956	2,011	10,318	3,772
Other	r383	r246	686	383
Total	56,758	22,257	59,847	21,807
Other magnesia:				
Australia	296	369	491	551
Canada	5,545	2,687	6,508	2,568
Colombia	204	354	213	380
France	86	115	2,664	710
Germany	138	140	109	129
Italy	52	64	136	188
Korea, Republic of	191	174	165	144
Mexico	9,684	5,326	7,380	3,586
Netherlands	116	54	123	87
Spain	1,753	952	1,511	791
Taiwan	317	122	351	222
United Kingdom	82	105	301	175
Venezuela	227	113	1,349	513
Other	384	965	713	1,104
Total	19,075	11,540	22,014	11,148
Crude magnesite:				
Australia	81	86	72	96
Brazil	169	242	385	244
Canada	726	145	791	245
China	—	—	237	105

See footnotes at end of table.

TABLE 15—Continued
U.S. EXPORTS OF CRUDE AND PROCESSED MAGNESITE, BY COUNTRY

Material and country	1992 Quantity (metric tons)	1992 Value (thousands)	1993 Quantity (metric tons)	1993 Value (thousands)
Crude magnesite—Continued:				
Costa Rica	6	$3	1,998	$361
Germany	795	898	134	181
Italy	450	545	—	—
Korea, Republic of	789	316	819	231
Mexico	884	277	818	321
Netherlands	940	736	993	641
New Zealand	209	249	125	176
Panama	—	—	298	177
Spain	96	74	—	—
Taiwan	317	29	37	4
Other	[r]464	[r]614	683	225
Total	5,926	4,128	7,390	2,911
Calcined dolomite:				
Canada	2,695	529	1,864	403
Colombia	212	39	—	—
Mexico	5,761	1,290	7,155	1,624
Saudi Arabia	1,810	252	37	4
Trinidad and Tobago	3,887	507	4,031	605
Venezuela	5,037	642	513	124
Other	182	55	144	58
Total	19,584	3,314	13,744	2,818

[r]Revised.

Source: Bureau of the Census.

TABLE 16
U.S. EXPORTS OF MAGNESIUM COMPOUNDS

Year	Magnesium hydroxide and peroxide		Magnesium chloride (anhydrous and other)		Magnesium sulfate (natural kieserite and epsom salts)		Magnesium sulfate (other)	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1991	2,691	$4,190	2,995	$2,134	808	$497	2,419	$1,201
1992	2,280	4,411	3,941	2,348	436	333	2,929	1,161
1993	2,543	3,577	3,141	2,636	69	52	4,139	1,667

Source: Bureau of the Census.

TABLE 17

U.S. IMPORTS FOR CONSUMPTION OF CRUDE AND PROCESSED MAGNESITE, BY COUNTRY

Material and country	1992		1993	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Caustic-calcined magnesia:				
Canada	48,206	$9,507	42,830	$8,555
China	29,423	1,798	83,094	4,700
Greece	2,747	445	9,883	1,468
Japan	2,595	547	359	586
Slovakia[1]	—	—	4,488	400
Turkey	80	12	—	—
Total	83,051	12,309	140,654	15,709
Dead-burned and fused magnesia:				
Australia	263	136	1,327	583
Austria	10,199	4,127	13,624	6,069
Brazil	3,000	360	3,065	378
Canada	2,976	1,599	5,453	2,234
China	132,500	13,807	196,457	15,940
Czechoslovakia[2]	8,537	789	—	—
France	2,000	404	5	9
Germany	2,145	884	1,180	686
Greece	12,767	1,615	6,435	938
Ireland	—	—	4,334	1,594
Israel	12,168	5,121	16,248	6,882
Italy	2,500	558	—	—
Japan	2,465	2,152	7,934	3,467
Mexico	17,525	6,030	21,563	9,313
Other	[r]1,370	[r]346	1,696	580
Total	210,415	37,928	279,321	48,673
Other magnesia:				
Brazil	122	98	244	191
Canada	280	204	100	33
China	168	938	1,330	238
Israel	526	942	856	1,452
Japan	1,918	3,384	1,828	3,639
Netherlands	55	20	340	209
Tajikistan	107	219	—	—
Other	[r]108	[r]355	421	503
Total	3,284	6,160	5,119	6,265
Crude magnesite:				
China	804	83	109	43
Italy	2,163	230	38	12
Japan	338	249	144	167
Other	102	61	41	29
Total	3,407	623	332	251
Calcined dolomite:				
Austria	220	159	1,973	842

See footnotes at end of table.

TABLE 17—Continued

U.S. IMPORTS FOR CONSUMPTION OF CRUDE AND PROCESSED MAGNESITE, BY COUNTRY

Material and country	1992 Quantity (metric tons)	1992 Value (thousands)	1993 Quantity (metric tons)	1993 Value (thousands)
Calcined dolomite—Continued:				
Canada	23,610	$3,069	33,237	$3,509
Germany	54	12	19	9
Other	20	5	567	70
Total	23,904	[r]3,245	35,796	4,430

[r]Revised.
[1]Formerly part of Czechoslovakia.
[2]Dissolved in Dec. 1992.

Source: Bureau of the Census.

TABLE 18

U.S. IMPORTS FOR CONSUMPTION OF MAGNESIUM COMPOUNDS

Year	Magnesium hydroxide and peroxide		Magnesium chloride (anhydrous and other)		Magnesium sulfate (natural kieserite)		Magnesium sulfate (natural epsom salts)		Magnesium sulfate (other)	
	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)
1991	3,842	$6,355	7,184	$1,691	16,727	$596	107	$14	6,524	$1,265
1992	1,750	2,461	4,594	1,447	16,902	754	36	36	5,193	1,119
1993	1,773	1,826	5,323	1,742	20,157	1,040	138	154	6,652	1,376

Source: Bureau of the Census.

TABLE 19
WORLD MAGNESIUM COMPOUNDS ANNUAL PRODUCTION CAPACITY,[1] DECEMBER 31, 1993

(Thousand metric tons, MgO equivalent)

Country	Raw material				Total
	Magnesite		Seawater or brines		
	Caustic-calcined	Dead-burned	Caustic-calcined	Dead-burned	
North America:					
Canada	100	—	—	—	100
Mexico	—	—	10	150	160
United States	NA	NA	NA	NA	[2]989
Total	100	NA	10	150	1,249
South America: Brazil	45	146	—	—	191
Europe:					
Austria	90	565	—	—	655
France	—	—	30	—	30
Greece	100	140	—	—	240
Ireland	—	—	NA	NA	100
Italy	25	—	5	125	155
Netherlands	—	—	—	100	100
Norway	—	—	25	—	25
Poland	—	10	—	—	10
Russia	—	2,200	—	—	2,200
Serbia and Montenegro	40	200	—	—	240
Slovakia	26	700	—	—	726
Spain	135	70	—	—	205
Turkey	50	259	—	—	309
Ukraine	—	—	20	80	100
United Kingdom	—	—	NA	NA	200
Total	466	4,144	80	305	5,295
Africa:					
Kenya	NA	NA	—	—	170
South Africa, Republic of	4	80	—	—	84
Zimbabwe	NA	NA	—	—	2
Total	4	80	—	—	256
Asia:					
China	200	850	—	10	1,060
India	30	204	—	—	234
Israel	—	—	10	60	70
Japan	—	—	590	60	650
Korea, North	NA	NA	—	—	2,100
Korea, Republic of	—	—	—	50	50
Nepal	—	50	—	—	50
Total	230	1,104	600	180	4,214
Oceania: Australia	160	30	—	—	190
Grand total	1,005	5,504	690	635	11,395

NA Not available.

[1]Includes capacity at operating plants as well as at plants on standby basis.

[2]Includes capacity for production of magnesium chloride, magnesium chloride brines, magnesium carbonate, magnesium hydroxide, and caustic-calcined and dead-burned magnesia.

TABLE 20
MAGNESITE: WORLD PRODUCTION, BY COUNTRY[1]

(Metric tons)

Country	1989	1990	1991	1992	1993[e]
Australia[e]	55,000	60,000	100,000	820,000	800,000
Austria	1,204,942	1,179,162	[r]960,589	[r]995,347	1,000,000
Brazil[2] (beneficiated)	259,508	257,159	242,256	[e]250,000	250,000
Canada[e 3]	150,000	150,000	180,000	180,000	180,000
China[e]	2,600,000	[r]2,170,000	[r]1,650,000	[r]1,510,000	1,500,000
Colombia	20,425	19,300	18,768	[r]18,840	18,900
Czechoslovakia[4 5]	642,000	561,000	328,000	—	—
Greece	903,593	696,900	590,188	[e]250,000	250,000
India	479,530	544,000	[e]539,000	[e]550,000	500,000
Iran[6]	6,967	1,405	29,291	[r]36,165	40,000
Korea, North[e]	1,500,000	1,500,000	1,600,000	1,600,000	1,600,000
Mexico	[r]4,229	[r]579	[r]—	[r]—	—
Nepal	27,978	[e]25,000	[e]25,000	[e]25,000	25,000
Pakistan	8,750	4,274	5,191	[r]6,484	3,000
Philippines[e]	[7]4,796	700	700	700	700
Poland	24,133	23,300	[r]8,100	[r]12,900	14,000
Russia[8]	—	—	—	1,100,000	800,000
Serbia and Montenegro[9]	—	—	—	[r]185,000	185,000
Slovakia[4 10]	—	—	—	1,267,000	1,200,000
South Africa, Republic of	75,695	114,182	92,634	[r]60,085	60,000
Spain	[r]430,778	[r]444,350	[r e]445,000	[r e]400,000	400,000
Turkey (run of mine)	1,343,893	[r]845,124	[r]1,365,287	[r]1,224,900	1,300,000
U.S.S.R.[e 8 11]	1,825,000	1,600,000	1,400,000	—	—
United States	W	W	W	W	W
Yugoslavia[9 12]	[r]352,000	[r]252,000	210,000	—	—
Zimbabwe	33,423	32,639	23,295	[r]8,973	9,000
Total	[r]11,952,640	[r]10,481,074	[r]9,813,299	[r]10,501,394	10,135,600

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."
[1]Figures represent crude salable magnesite. In addition to the countries listed, Bulgaria produced magnesite, but output is not reported quantitatively, and available general information is inadequate for formulation of reliable estimates of output levels. Table includes data available through June 1, 1994.
[2]Series reflects output of marketable concentrates. Production of crude ore was as follows, in metric tons: 1989—1,385,565; 1990—1,432,741; 1991—879,477 (revised); 1992—880,000 (estimated); and 1993—880,000 (estimated).
[3]Magnesitic dolomite and brucite. Figures are estimated on the basis of reported tonnage dollar value.
[4]All production in Czechoslovakia from 1989-92 came from Slovakia.
[5]Dissolved on Dec. 31, 1992.
[6]Year beginning Mar. 21 of that stated. Figures for 1989 and 1990 are for magnesite; figures for 1991 and 1992 include 3,336 tons and 220 tons of huntite ($Mg_3Ca(CO_3)_4$), respectively.
[7]Reported figure.
[8]All production in U.S.S.R. from 1989-91 came from Russia.
[9]All production in Yugoslavia from 1989-91 came from Serbia and Montenegro.
[10]Formerly part of Czechoslovakia.
[11]Dissolved in Dec. 1991.
[12]Dissolved in Apr. 1992.

TABLE 21
MAGNESIUM SUPPLY-DEMAND RELATIONSHIPS

(Thousand metric tons of contained magnesium)

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
WORLD PRODUCTION											
United States:											
Nonmetal	567	574	420	412	464	573	513	499	442	[r]418	386
Metal	104	144	136	125	124	142	152	139	131	137	132
Total	671	718	556	537	588	715	665	638	573	[r]555	518
Rest of world:											
Nonmetal	4,777	4,676	4,807	5,009	4,905	4,756	[r]4,745	[r]4,321	[r]4,128	[r]4,327	[e]4,222
Metal	156	184	189	196	200	192	192	[r]216	[r]210	[r]169	[e]152
Total	4,933	4,860	4,996	5,205	5,105	4,948	[r]4,937	[r]4,537	[r]4,338	[r]4,496	[e]4,374
World total	5,604	5,578	5,552	5,742	5,693	5,663	[r]5,602	[r]5,175	[r]4,911	[r]5,051	[e]4,892
COMPONENTS AND DISTRIBUTION OF U.S. SUPPLY											
U.S. production:											
Nonmetal	567	574	420	412	464	573	513	499	442	[r]418	386
Primary metal	104	144	136	125	124	142	152	139	131	137	132
Secondary metal (old scrap)	23	24	24	23	23	28	28	31	27	31	31
Imports:											
Nonmetal	61	115	134	160	164	198	171	147	156	179	256
Metal	5	9	8	8	11	14	12	27	32	12	37
Industry stocks, metal, Jan. 1	42	25	32	39	39	28	25	26	26	27	13
Total U.S. supply	802	891	754	767	825	983	901	869	814	[r]804	855
Distribution of U.S. supply:											
Exports:											
Nonmetal	15	27	25	25	20	34	26	59	57	49	52
Metal	43	44	36	40	44	50	57	52	55	52	39
Industry stocks, metal, Dec. 31	25	32	39	39	28	25	26	26	27	13	26
Industrial demand[1]	719	788	654	663	733	874	792	732	675	[r]690	738
U.S. DEMAND PATTERN											
Nonmetal:											
Chemicals	105	131	127	171	155	202	188	174	187	[r]176	200
Refractories	508	531	402	376	453	535	470	413	354	[r]372	390
Total	613	662	529	547	608	737	658	587	541	[r]548	590
Metal:											
Cans and containers	19	23	23	22	39	39	42	45	42	40	38
Chemicals	7	8	5	3	2	1	1	1	1	1	1
Iron and steel desulfurization	NA	10	12	12	13	15	15	16	13	20	19
Iron and steel foundries	3	4	3	3	2	3	2	1	1	2	2
Machinery	34	29	22	27	19	20	17	20	21	25	20
Nonferrous metal production	6	9	12	9	5	11	12	11	7	9	10
Transportation	31	36	38	33	38	38	36	38	37	34	47
Other	6	7	10	7	7	10	9	13	12	11	11
Total	106	126	125	116	125	137	134	145	134	142	148
Total industrial demand	719	788	654	663	733	874	792	732	675	[r]690	738
Total U.S. primary demand[2]	696	764	630	640	710	846	764	701	648	[r]659	707
Total U.S. demand for primary metal[3]	83	102	101	93	102	109	106	114	107	111	117

[e]Estimated. [r]Revised. NA Not available.
[1]Sum of total nonmetal and total metal demands.
[2]Total U.S. demand less U.S. recovery from secondary metal.
[3]U.S. demand for metal less U.S. recovery from secondary metal.

13.57