MAGNESIUM

By Deboarh A. Kramer

Domestic survey data and tables were prepared by Jesse J. Inestroza, statistical assistant, and the world production table was prepared by Ronald L. Hatch, lead international data coordinator.

U.S. magnesium production in 2000 dropped by 23% from that of 1999. Much of the production decline came in the second half of the year and was attributed to high energy costs in the Pacific Northwest, which affected Northwest Alloys Inc.'s Addy, WA, primary magnesium plant and a cell relining project that was occurring at the Magnesium Corp. of America (Magcorp) Rowley, UT, plant. The shortfall in domestic production was replaced by imports, which, in 2000, reached their highest level, surpassing the 1999 record high. Canada, China, Russia, and Israel, in descending order, were the principal import sources. China supplied mostly magnesium alloys to the United States, Israel and Russia primarily supplied pure magnesium, and Canada supplied both. Aluminum alloying remained the largest use for magnesium in the United States, and although diecasting remained the second largest use for primary magnesium in the United States, 2000 consumption declined significantly, which was attributed to the overall decline in the U.S. economy.

Noranda Magnesium Inc. began commercial operation of its 63,000-metric-ton-per-year (t/yr) plant in the third quarter of 2000 and planned to have the plant fully operational by the first quarter of 2001. Development work continued on other proposed magnesium plants throughout the world, with the most activity in Australia. If all the plants for which completion dates have been announced are constructed, there would be an additional 96,000 t/yr of capacity in Australia onstream by 2003; 103,000 t/yr in Australia by 2004; 60,000 t/yr in Congo (Brazzaville) by 2005; and 80,000 t/yr in Australia by 2006. If other plants proposed in Australia, Canada, Iceland, and the Netherlands are built, there will be an additional 430,000 t/yr of primary magnesium capacity by the end of the decade.

Legislation and Government Programs

The International Trade Administration (ITA) conducted 5-year sunset reviews of the countervailing and antidumping duties for magnesium from Canada, as is required by the Uruguay Round of Agreements Act. The final determinations in these investigations were that revocation of the order would most likely lead to continuation or recurrence of the duties. For the countervailing duty for pure and alloy magnesium, the likely subsidy was 1.84% ad valorem for Norsk Hydro Canada Inc. and 4.48% ad valorem for all others. The ITA determined that the dumping margin for pure magnesium would be 21.00% ad valorem for Norsk Hydro Canada and all others, the amount at which the duty was originally set (U.S. Department of Commerce, 2000d, e). These sunset decisions may have an adverse effect on Noranda Magnesium. The company completed its 63,000-t/yr primary magnesium plant in Quebec in the third quarter of 2000 and planned to sell the magnesium in the United States. Until the company receives a new shipper review from the ITA, if it requests one, the Magnola plant will be required to pay the antidumping and countervailing duties established for "all others" in these sunset reviews. The

Magnesium in the 20th Century

In 1900, all the magnesium metal used in the United States was imported, mostly from Germany. It was not until 1914, when imports were cut off because of the start of World War I, that the first magnesium extraction plant was built in the United States by General Electric Co. At that time, the principal use for magnesium was in munitions, because it created a bright white light when it was burned, and small quantities were used in flash photography. With the end of World War I, requirements for magnesium decreased, but as new civilian uses were developed, such as use as a scavenger and deoxidizer and as an alloying addition to other metals, production grew steadily. The establishment of the national defense program in 1939, which emphasized the importance of magnesium alloys for aircraft and munitions applications, and the outbreak of World War II soon after, led to a huge increase in magnesium production and consumption in the United States. Between 1940 and 1943, the U.S. Government constructed 13 magnesium plants, and U.S. magnesium production reached its peak in 1943 at 167,000 metric tons. Although most of the plants that had been constructed to supply magnesium for defense needs were closed after World War II, ownership in a few was retained by the Government, and these were reactivated in 1950 during the Korean conflict. In the 1960s and 1970s, U.S. production and use of magnesium grew as use of aluminum grew; magnesium's principal application was as an alloying addition to aluminum. Of particular importance was the introduction of the aluminum beverage can in 1958 and its eventual dominance over steel in this application by about 1980.

By 2000, only two magnesium production plants were operating in the United States, with a total capacity of 83,000 metric tons per year, and imports again supplied a significant portion of the U.S. demand. Magnesium recycled from old magnesium and aluminum alloy scrap also supplied a significant portion of U.S. demand. Aluminum alloying was the largest application for primary magnesium, with about 53%, but structural magnesium alloy components, particularly diecastings, have grown to account for about 23% of the total primary magnesium consumed in the United States. Smaller quantities of magnesium were used for desulfurization of iron and steel and as a reducing agent for other nonferrous metals, such as titanium and beryllium.

company could not participate in the June sunset review process because it was not shipping commercial quantities of magnesium to the United States at that time. Through the NAFTA Secretariat, the government of Quebec appealed the final sunset reviews for the antidumping duty on pure magnesium and the antidumping and countervailing duty orders on magnesium alloy that were completed in July. A decision on the appeals was scheduled to be completed by June 15, 2001, (NAFTA Secretariat, [undated], General information, accessed November 7, 2000, at URL http://www.nafta-sec-alena.org/english/index.htm).

In September, the ITA also completed its administrative reviews of countervailing duties for pure and alloy magnesium from Canada for the 1998 calendar year. For this period, the countervailing duty was established at 1.38% ad valorem for magnesium imported into the United States from Norsk Hydro Canada. The ITA also determined that Norsk Hydro Canada had not sold commercial quantities of magnesium into the United States in a 3-consecutive-year period, so the company did not qualify for revocation of the antidumping duty (U.S. Department of Commerce, 2000c). The ITA also began an investigation of countervailing duties for calendar year 1999.

The International Trade Commission (ITC) revoked the antidumping duty order established in 1995 on magnesium imported from Russia because no interested party responded to the April 2000 request (U.S. International Trade Commission, 2000b). In an expedited 5-year review of the antidumping duty established for pure magnesium from China, the ITC determined that revocation of the duty likely would lead to continuation or recurrence of material injury. Therefore, the antidumping duty of 108.26% ad valorem will remain in effect (U.S. International Trade Commission, 2000a).

At the request of Magcorp, the ITA initiated a countervailing duty investigation of pure magnesium from Israel and antidumping duty investigations of pure magnesium from China, Israel, and Russia. The principal material under concern in these investigations is pure magnesium in granular or powder form, which was specifically excluded from earlier antidumping investigations on magnesium from China and Russia. Antidumping duties for other forms of pure magnesium from China and Russia were established in 1995 and remain in effect. This was the first investigation of magnesium imported from Israel. In its preliminary review, the ITA determined that conditions in the magnesium industry have changed since the initial duties were established, and it is appropriate to include granules and powder in the investigations (U.S. Department of Commerce, 2000a, b).

On April 24, 2001, the ITA announced preliminary dumping determinations on U.S. imports of magnesium from China, Israel, and Russia. The preliminary dumping duties on imports from China were determined to be 8.76% ad valorem for Minmetals Precious & Rare Minerals Import and Export/China National Nonferrous Metals Industry Trading Group Corp. and 305.56% for all other companies in China. For Israel, the preliminary dumping duty was determined to be 12.68% ad valorem for Dead Sea Magnesium Ltd. (DSM), and for Russia, the preliminary dumping duty was determined to be 0% ad valorem. The investigation period for China and Russia was April 1, 2000, though September 30, 2000, and the investigation period for Israel was October 1, 1999, through September 30, 2000. The ITA's final determinations are scheduled to be announced by July 9, 2001, for the duties for Russia and Israel and by September 12, 2001, for the duties for China. If these duty determinations are upheld, importers of magnesium from China and Israel will be required to post a bond equal to the percentage margin of dumping (U.S. Department of Commerce, 2001a, b, c).

The U.S. Environmental Protection Agency (EPA) is planning to collect information on sulfur hexafluoride (SF_6) emissions from companies that produce or cast magnesium. The data collection is part of the EPA's SF_6 Emission Reduction Partnership for the Magnesium Industry, which is one of the agency's voluntary programs that contribute to the overall reduction of greenhouse gas emissions. By joining the partnership, a firm agrees to report an estimate of its SF_6 emissions to the EPA annually. The International Magnesium Association will act as the third party by assembling the data and transmitting it to the EPA to protect individual company proprietary data (U.S. Environmental Protection Agency, 2000).

In November, the EPA held an international conference on emission reduction strategies for SF_6. This conference brought together the electric utility and magnesium industries to discuss and learn about a wide array of issues relating to the use, handling, and management of SF_6. Topics particular to the magnesium industry that were discussed included potential replacements for SF_6, SF_6 recycling, and SF_6 leak detection. Presented papers, poster papers, and PowerPoint presentations from the conference were made available at URL http://www.epa.gov/highgwp1/sf6/agenda.html.

One of the replacements that is being investigated is boron trifluoride (BF_3). Hatch Associates, Mississauga, Ontario, Canada, developed a method of in-line generation of BF_3 that minimizes the need to purchase and store the material as a compressed gas, which can be expensive and hazardous. The company claimed that the patented generation process, called MagShield, protects molten magnesium from oxidation, as well as SF_6, with lower consumption rates, at a lower cost, with fewer workplace emissions, and with no fluoride hazardous waste products generated (Revankar and others, 2000).

Production

In 2000, U.S. primary magnesium production declined by 23% from that of 1999 (table 1). Some of the production decrease can be attributed to rising energy costs, particularly in the Pacific Northwest. Aluminum production in this area has also declined, resulting in reduced need for magnesium for aluminum alloying. This mostly affected Northwest Alloys' plant in Addy, WA. In addition, Magcorp had some of its electrolytic cells offline beginning in the fall, because the company was installing new electrolytic technology that should reduce chlorine emissions. Magcorp expected to complete the installation by the fall of 2002 at a cost of $35 million (U.S. Securities and Exchange Commission, September 11, 2000, Renco Metals Inc.—Form 10-Q, accessed June 12, 2001, via URL http://www.sec.gov/edgar.shtml). Because only two plants remain operating, the U.S. Geological Survey (USGS) can no longer publish U.S. production data to avoid disclosing company proprietary data.

Consumption

Aluminum alloying remained the largest end use for primary and secondary magnesium (tables 3, 4). Reported consumption of primary magnesium for aluminum alloying was 53% of the total. Diecasting was the second largest application with 23% of the total reported consumption, and desulfurization of iron and steel ranked third with 12% of the total. In addition to primary magnesium, significant quantities of secondary magnesium are used in iron and steel desulfurization reagents. The total primary magnesium consumed in the United States in 2000 declined by 21% from that of 1999; much of this decline was recorded in the diecasting sector. Although this application continues to be a growth area for magnesium metal consumption, the drop in 2000 was attributed to the overall slowdown in the U.S. economy.

Data for magnesium metal are collected from two voluntary surveys of U.S. operations by the USGS. Of the 81 companies canvassed for magnesium consumption data, 59% responded, representing 40% of the primary magnesium consumption listed in tables 1 and 3. Data for the 33 nonrespondents were estimated based on prior-year consumption levels and other factors. One large nonrespondent accounted for 38% of the 60% of the nonresponse total quantity.

The use of magnesium in automotive applications is continuing to grow. The magnesium content of the 2000 model year North-American-produced vehicles was estimated to be 3.63 kilograms (kg) (8 pounds), a 15% increase from the 1999 model year average of 3.17 kg (7 pounds). Ford Motor Co. planned to continue this growth trend by including magnesium instrument panel support beams in its F-series pickup trucks for the first time. This application was estimated to consume between 5,900 and 8,200 t/yr of magnesium, with each part weighing between 6.8 and 8.2 kg (15 and 18 pounds) each. These would substitute for steel beams in the trucks. Although no specific target year was set for the truck conversion, Ford was beginning to install magnesium alloy instrument panel support beams in the 2001 models of its Explorer sport-utility vehicle (SUV) (Wrigley, 2000d).

Ford announced that it would convert the valve covers on its Triton truck engines to magnesium from plastic, beginning in the 2003 or 2004 model year. The valve covers, which will be made out of AZ91D, will weigh about 3.2 kg (7 pounds). The main reasons for substituting magnesium for plastic are to reduce oil leaks and to improve noise, vibration, and harshness. Ford estimated that about 800,000 engines per year will be used in its pickup trucks, SUVs, and vans, which would consume about 2,500 t/yr of magnesium alloy (Wrigley, 2000b).

Ford also planned to convert the cam covers on some of its truck engines from plastic to magnesium. Beginning with the 2003 model year, Ford will convert the cam covers on its 5.4-liter Triton V-8 engine to AZ91D, and the next model year, the company planned to convert the covers on the 6.8-liter Triton V-10 engine. Estimated magnesium consumption of the cam covers on both engines is about 3,200 t/yr. Spartan Light Metal Products Inc. and Intermet Corp. were expected to be the diecasters for the cam covers. The covers were switched from plastic to magnesium because magnesium has greater creep resistance than the existing plastic covers, and Ford expected that this will lead to fewer service problems (Wrigley, 2000c). With additional parts, such as instrument panel support beams and four-wheel-drive transfer case covers, planned for conversion to magnesium, Ford planned to increase its total magnesium consumption to 78,000 metric tons (t) by the 2004 model year from about 21,000 t in the 2001 model year. Most of the new applications for magnesium will be in the company's SUVs and light-duty trucks (Wrigley, 2000g).

General Motors Corp. (GM) also announced that it would be using about 12 kg (27 pounds) of magnesium alloy diecastings on its new crossover vehicle, the Chevrolet Avalanche, beginning with the 2001 model. The Avalanche is a new type of vehicle that combines the passenger cabin of the Chevrolet Suburban SUV with the cargo box common to pickup trucks. Magnesium components in the new vehicle include four-wheel-drive transfer cases, instrument panel beams, pedal bracket supports, alternator brackets and covers, and the steering wheel armatures (Wrigley, 2000e). In addition, GM was planning to use magnesium alloy support beams in the 2002 models of its new Cadillac roadster model (American Metal Market, 2000).

Lunt Manufacturing Co. entered into a multiyear agreement with GM to manufacture one-piece magnesium alloy instrument panel support beams for the automaker. GM planned to replace the 25-kg (55-pound) steel beams in its 2002 model medium-duty trucks with the magnesium alloy ones, which weigh between 10 and 11 kg (22 and 25 pounds) each. This application was expected to consume 500 to 570 t/yr of alloy AM60. Lunt Manufacturing is only the fourth company in North America that can produce these one-piece beams and will manufacture the components at its Hampshire, IL, facility (Wrigley, 2000j).

For the new 2001 models, North American auto manufacturers were expecting to average between 3.9 and 4.1 kg (8.5 and 9 pounds) of magnesium components per vehicle, a 12.5% increase from the 2000 average. Most of the increase would result from the use of existing part applications in new models. All of the "Big Three" U.S. auto manufacturers (GM, Ford, and DaimlerChrysler Corp.) are using magnesium alloy diecastings in some of their automobiles, trucks, and SUVs. The principal magnesium components will continue to be instrument panel support beams, engine cam covers, four-wheel-drive transfer cases, steering column and pedal bracket supports, and steering wheel armatures (Wrigley, 2000a).

Magnesium also has potential for other automotive applications. GM is interested in a metal hydride fuel cell system using powdered magnesium alloy for its new Precept vehicle, a high-mileage vehicle that uses a combination of electric motors and a small diesel engine. The Precept is the result of the Partnership for a New Generation of Vehicles, a consortium backed in 2000 by $250 million in Federal funding and $980 million from GM, Ford, and DaimlerChrysler. The magnesium-alloy-metal hydride fuel system was developed by Energy Conversion Devices Inc.'s subsidiary Ovionics Battery Co. Because the hydrogen is stored as a solid rather than as a gas or liquid, the need for large storage tanks is eliminated (Wrigley, 2000i; Energy Conversion Devices Inc., [undated], Ovonic hydrogen generation, accessed at URL http://www.ovonic.com/hydrogen/technology.html).

Magnesium also was being used for large components in concept and limited-production vehicles. BMW AG of Germany equipped its Z22 concept car with a cast magnesium cylinder block. Saleen Inc., a specialty vehicle manufacturer based in California, created a high-performance, light-metals-intensive production car called the S7. Magnesium is used in engine components in the vehicle, along with such materials as beryllium and titanium. Only 300 to 400 vehicles were expected to be produced over the 4-year production run (Light Metal Age, 2000). DaimlerChrysler was also using significant quantities of magnesium in its ESX3 concept hybrid-electric family vehicle. Magnesium components were substituted for steel as a radiator enclosure, as an instrument panel support beam, and as A pillars (Wrigley, 2000f).

The Swiss ferroalloys producer Xstrata AG announced that it reached an agreement to acquire the Magnesium Services International fluxless magnesium recycling technology, which produces secondary magnesium diecasting alloys using 100% scrap as the feed material. As a result, Xstrata has begun a feasibility study on the construction of a 25,000-t/yr magnesium recycling plant in the Midwestern United States (Platt's Metals Week, 2000g).

TAC Manufacturing Inc., a subsidiary of the Japanese firm Tokai Rika Co., announced that it would install magnesium casting equipment at its existing facility in Jackson, MI, to produce magnesium steering wheel locks. The cost of the new equipment was estimated to be about $10 million. The company already supplied steel and zinc automotive parts to Toyota Motor Corp.'s auto manufacturing plants in the United States. The company planned to sell the magnesium parts to Toyota, as well as other U.S. manufacturing firms (Furukawa, 2000b).

Stocks

Producers' yearend 2000 stocks of primary magnesium declined slightly from those at yearend 1999; these data cannot be reported to avoid disclosing company proprietary data. Consumer stocks of primary and alloy magnesium increased to 7,550 t at yearend 2000 from 6,980 t at yearend 1999. Yearend 2000 consumer stocks of secondary magnesium increased to 2,360 t from the 1999 level of 783 t (revised).

Prices

Quoted magnesium prices declined during 2000, reflecting the oversupply of magnesium in the world market. The Metal Bulletin free market price range for pure magnesium started the year at $2,450 to $2,550 per metric ton and dropped to $1,900 to $2,000 per metric ton by yearend. The China free market price range declined from $1,520 to $1,570 per metric ton to $1,300 to $1,310 per metric ton by yearend.

Platt's Metals Week's European free market price decreased from a range of $2,250 to $2,350 per metric ton at the beginning of the year to $1,800 to $2,000 per metric ton by yearend. The Platt's Metals Week U.S. spot western price dropped from a range of $1.40 to $1.45 per pound at the beginning of 2000 to $1.23 to $1.30 per pound at yearend. The Platt's Metals Week U.S. spot dealer import price decreased from a range of $1.25 to $1.32 per pound at the beginning of the year to $1.05 to $1.15 per pound by yearend.

Foreign Trade

Total magnesium exports for 2000 were about 18% lower than those in 1999 (table 5). Canada (63%), the Netherlands (12%), and Mexico (8%) were the main destinations. Imports for consumption in 2000 were slightly higher than those in 1999 (table 6), and continued to reach new high levels. Canada (40%), China (24%), Russia (15%), and Israel (9%) were the principal import sources in 2000. Russia, Israel, and Canada, in descending order, were the principal sources of imported metal. Canada and China were the principal sources of imported alloys.

World Review

According to figures published by the International Magnesium Association (IMA), world magnesium shipments in 2000 were 367,000 t, which was slightly lower than those of 1999. The data, however, are not exactly comparable; in 1999, the IMA includes shipments of recycled diecasting scrap by the primary producers, and these data were not included in 2000. Aluminum alloying, with 45% of total shipments, was the largest end-use category for magnesium, followed by diecasting with 30% and desulfurization with 14%. Yearend 2000 world inventories increased slightly to 46,500 t representing an estimated 45 days of supply, based on the previous 12 months of shipments (International Magnesium Association, 2001).

After an investigation that began in June 1999, the European Commission recommended an antidumping duty of 63.4% on imports of magnesium from China. This was a significant increase from the 31.7% that has been in effect since 1998 (Platt's Metals Week, 2000e). The Chinese producers were expected to appeal this duty, although several producers reportedly sold magnesium at prices lower than the Chinese Magnesium Association's minimum reference price of $1,500 per metric ton (Platt's Metals Week, 2000c).

Australia.—In March, Australian Magnesium Corp. Ltd. (AMC) completed its feasibility study on construction of a new magnesium plant in Stanwell, Queensland. The study estimated that capital costs for a 96,000-t/yr plant would be $759 million and that operating costs would be between 58.1 and 63.8 cents per pound. (The range in operating cost is based solely on varying exchange rates between Australian and U.S. dollars.) Under a restructuring proposal, Queensland Metals Corp. Ltd. (QMC) will acquire Normandy Mining Ltd.'s 50% interest in AMC in exchange for 225 million shares of QMC. Once a commitment to commercialization of the AMC magnesium plant is made, these shares will be distributed to Normandy's shareholders (Queensland Metals Corp. Ltd., March 28, 2000, AMC feasibility study completed, accessed April 25, 2000, via URL http://www.normandy.com.au; Queensland Metals Corp. Ltd., April 5, 2000, AMC ownership optimised, accessed April 25, 2000, via URL http://www.normandy.com.au).

AMC entered into an alliance with VAW Aluminium AG to develop a magnesium engine block in hopes of providing additional funding for AMC's proposed magnesium plant. If the magnesium engine block is commercialized, AMC would be VAW's exclusive supplier of magnesium alloy for the first 5 years of production. AMC already has a 45,000-t/yr offtake agreement with Ford that provides much of the financing for its pilot plant (Metal Bulletin, 2000a). The company also received all governmental and environmental approvals for the construction of a commercial plant and expected that the plant would come onstream in 2003 (Metal Bulletin, 2000b).

Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Queensland government each planned to contribute $A50 million to assist Australia's fledgling magnesium industry. CSIRO's contribution would assist in the commercialization of AMC's process technology, and the Queensland government's contribution would be used to develop a light-metals industry precinct in Stanwell. The Stanwell Energy Park was expected to be developed over the next decade to include magnesium production, diecasting, chemical, and associated service industries (Australian Magnesium Corp. Ltd., November 14, 2000, $100 million

Federal & Queensland government commitment, accessed December 9, 2000, via URL http://www.austmg.com). AMC also planned to outsource its research and development activities to CSIRO as part of a 4-year agreement. The new agreement covered two major research areas—improving primary magnesium process technologies and developing new value-added applications and improved methods for producing magnesium components, such as alloys, casting, melt, and recycling systems (Australian Magnesium Corp. Ltd., December 7, 2000, AMC to contract CSIRO in research & development alliance, accessed December 9, 2000, via URL http://www.austmg.com).

Pima Mining NL reported that it raised $3.5 million for further development of a proposed magnesium plant by placing 18.2 million shares to institutional investors. The company, through its 80%-owned SAMAG Ltd. subsidiary, planned to construct a 52,500-t/yr primary magnesium plant in Port Augusta, South Australia, using technology acquired from Dow Chemical Co. SAMAG was in the final stages of selecting design engineers and construction contractors. An earlier feasibility study for the project indicated that the capital cost for the plant would be $375 million, and the operating cost would be less than 60 cents per pound of magnesium (Metal Bulletin, 2000j).

In May, SAMAG began trial mining of its magnesite deposit in South Australia. The company planned to mine about 2,000 t of ore for trial leaching tests. The company selected Port Pirie as the site for its proposed 52,500-t/yr magnesium plant because of its existing infrastructure (the Pasminco zinc smelter is located at the same site), rail link between Port Pirie, and the location of the magnesite raw material near Leigh Creek. Initial investment in the plant was expected to begin in 2001, with commercial production scheduled for 2004 (Metal Bulletin, 2000k).

SAMAG purchased the Myrtle Springs and Huandot magnesite deposits from Unimin Australia Ltd., which increased SAMAG's total magnesite resources in the Leigh Creek area in the Northern Territory to 579 million metric tons. This magnesite would provide additional resources for its planned magnesium plant (Pima Mining NL, November 28, 2000, SAMAG purchases additional magnesite resources, accessed January 8, 2001, at URL http://www.pima.com.au/temp.asp?t=asx28nov00). The company also entered into a long-term sales agreement with Germany's ThyssenKrupp Metallurgie GmbH for all of SAMAG's proposed output of magnesium metal and alloys. The agreement allowed SAMAG to receive a guaranteed base price that is sufficient to service the project's debt finance requirements (Pima Mining NL, November 16, 2000, SAMAG signs metal sale agreement with German industrial giant Thyssen Krupp, accessed November 28, 2000, at URL http://www.pima.com.au/temp.asp?t=asx16nov00).

The Council for Minerals Technology (Mintek) of South Africa planned to test a new magnesium production process at a pilot plant that was scheduled to start operation by yearend. The new process is a derivative of the Magnetherm process in which dolomite is reduced with ferrosilicon and alumina to produce magnesium vapor. In Mintek's process, the process is carried out at atmospheric pressure at about 1,700° C compared with operating at a vacuum at 1,550° C to 1,600° C for the Magnetherm process. By operating at atmospheric pressure, rather than in a vacuum, the reduction process can be carried continuously, rather than as a batch process, which may have economic advantages. Mintek planned to evaluate the process for 3 to 6 months before deciding if it is suitable for commercial-scale development and estimated that a 50,000-t/yr plant would require a capital investment of $200 to $250 million (Metal Bulletin, 2000l). Immediately after this announcement, Mintek signed a technology license agreement with Australia's Mt. Grace Resources NL, whereby Mt. Grace Resources would fund the demonstration project and, if test work was successful, use the process to recover magnesium from its Batchelor magnesite deposit in the Northern Territory. Mt. Grace Resources planned to test the new process along with the Heggie aluminothermic process to determine which would be the more economically attractive (Mt. Grace Resources NL, October 6, 2000, Mintek magnesium production technology licence and project option agreement, accessed October 17, 2000, at URL http://www.mtgrace.com/releases/oct_6_2000.html).

In October, Mt. Grace Resources began bulk magnesite mining operations at its Batchelor magnesium project. The company planned to mine and stockpile 2,000 t of magnesite to provide sample material for test work. An ore parcel was scheduled to be sent to Mintek in Johannesburg in January 2001 for testing (Mt. Grace Resources NL, October 30, 2000, Mt[.] Grace Resources mines ore at Batchelor, accessed November 8, 2000, at URL http://www.mtgrace.com/releases/oct_30_2000.html). Mt. Grace Resources planned to complete a 50,000-t/yr magnesium plant by 2004.

Golden Triangle Resources NL produced its first magnesium metal in November. The company is using serpentinite tailings from the former Woodsreef Mine in New South Wales as feedstock. Golden Triangle also announced the development of a new electrolysis system, for which it has applied for a patent. According to the company, the new system will combine magnesium chloride dehydration, electrolyte purification, and electrolysis in one apparatus. Additionally, the apparatus will include the preparation of magnesium alloys. The new electrolytic system, which was developed by the Joint Israeli-Russian Laboratory for Energy Research at Ben Gurion University, will also have the added advantage of significant energy savings in the magnesium production process (Golden Triangle Resources NL, November 28, 2000, Re: Revolutionary new magnesium electrolyzer, accessed January 8, 2001, at URL http://www.goldentriangle.com.au/28Nov00.htm). Golden Triangle Resources planned to construct an 80,000-t/yr plant by 2006.

Canada.—In spite of a fire in one of the four electrolytic cells on August 12, Noranda Magnesium planned to open its Magnola magnesium plant in Quebec by the first quarter of 2001. Noranda produced its first magnesium metal late in October, and 2 out of 24 electrolytic cells had been commissioned. When the 63,000-t/yr plant opens, it will be the first in the world to use asbestos tailings as a raw material for magnesium production (Platt's Metals Week, 2000h; Canada Newswire, October 25, 2000, Noranda produces first magnesium metal, accessed October 31, 2000, at URL http://newswire.ca/releases/October2000/25/c6547.html).

Cassiar Magnesium Inc. (formerly Cassiar Mines & Metals Inc.) expected to complete a feasibility study on its planned magnesium project by the end of 2000. The company hopes to construct a 90,000-t/yr primary magnesium facility in British Columbia by 2003. Cassiar Magnesium planned to present the study results to Aluminium of Korea Ltd. (Koralu), with which it has a memorandum of understanding for an initial investment. If, after assessing the study results, Koralu opts to fund the $600 million project, it would have the option to acquire a 65% stake in the plant (Metal Bulletin, 2000d).

Meridian Technologies Inc. was planning to construct its second magnesium diecasting facility in Strathroy, Ontario, which would bring the company's total number of facilities to four. In addition to the two plants in Ontario, Meridian operates plants in Eaton Rapids, MI, and Verres, Italy. Capacity at the new facility is estimated to be 5,000 t/yr of AZ91D and the AM series of alloys (Wrigley, 2000h).

China.—Norsk Hydro A/S announced that it would build a magnesium alloy facility in China. Production capacity of the plant will be 5,000 t/yr, and it will use magnesium produced in China as the feed material. Norsk Hydro planned to have the plant, which will be located in Xian, operational by early 2001. Alloy ingot produced at the plant was expected to be marketed to Norsk Hydro's customers throughout the world (Norsk Hydro A/S, April 20, 2000, Hydro Magnesium goes to China, accessed April 21, 2000, via URL http://www.hydro.com). In addition, Norsk Hydro Magnesiumgesellschaft mbH planned to build a magnesium anode facility in China at the same site. Initial production capacity was expected to be 400 t/yr, perhaps expanding to 800 t/yr. The principal market for the anodes is hot-water heaters in China and Southeast Asia. No timetable was given for plant startup (Norsk Hydro A/S, April 25, 2000, Magnesium in China—Step two, accessed July 7, 2000, via URL http://www.hydro.com).

Because of pollution problems and weak prices, many small magnesium plants in Henan and Shanxi Provinces closed by September. Some of the larger plants were expected to close for a short period to make process upgrades to reduce pollution. The Chinese magnesium export market was reported to be slow, particularly to countries in Europe because of the potential of higher antidumping duties (Metal Bulletin, 2000e). In spite of the world oversupply and plant closures, Chinese magnesium producers continued to announce production expansions at some plants. Yinguang Magnesium Industry Group's new 5,000-t/yr expansion was expected to be completed in December; this would bring the plant's total capacity to 20,000 t/yr of magnesium and magnesium alloy. Shanxi Top Magnesium Co. planned to increase its capacity by yearend 2000 to about 10,000 t/yr from 7,200 t/yr (Platt's Metals Week, 2000j).

The Ningxia Magnesium Metal Works was declared bankrupt in September. Production at the 1,400-t/yr plant had stopped in March 1999, and the state was planning to auction off the plant once the final auditing was complete (Platt's Metals Week, 2000a). Tongxiang Magnesium Industry Co. halved its magnesium output for the second half of 2000, according to company officials. The cutback, to 1,000 metric tons per month (t/mo) from 2,000 t/mo, was in response to declining prices. Tongxiang exported most of its product to Japan and to the Republic of Korea (Platt's Metals Week, 2000i).

An official from the Chinese Magnesium Association stated that China planned to construct a 50,000-t/yr magnesium plant in Qinghai by 2005 using the salt lake resources in the area as feedstock. New plant construction would be funded by the Government and by Minhe Magnesium Co., which operated a 7,000-t/yr magnesium plant in the province (Platt's Metals Week, 2000b). This plant, if constructed, would be China's largest individual plant.

Czech Republic.—Magnesium Elektron, a unit of the Luxfer Group, selected a site northwest of Prague to build a 10,000-t/yr secondary magnesium plant. An unoccupied manufacturing plant was located at the site, and Magnesium Elektron planned to refurbish the building for use as a magnesium recycling plant. The new plant, which will use magnesium alloy scrap from Germany as its feedstock to produce casting alloys, is expected to begin commercial operation in mid-2001 at an initial operating capacity of 7,500 t/yr. The finished product will be exported to German customers, and the plant will gradually ramp up its capacity to 10,000 t/yr by 2002, with an option to increase to 20,000 t/yr if the market warrants it (Metal Bulletin, 2000h).

Israel.—The Board of Directors of Israel Chemicals Ltd. approved the transfer of a majority stake (65%) in DSM from Dead Sea Works Ltd. to Israel Chemicals, the parent company, at a cost of $66.3 million; Volkwagen AG of Germany owns the remaining 35%. Israel Chemicals also would absorb DSM's $111 million in bank debts (Platt's Metals Week, 2000f).

In March, DSM was qualified by DaimlerChrysler to supply magnesium alloys AZ91D, AM50A, and AM60B for use by all of the company's diecasters and was in the initial stages of negotiating with GM to supply it with magnesium alloys. DSM also was in the process of increasing production at the facility in 2000 to 30,000 t of magnesium metal and 24,000 t of magnesium alloys, and the company was proceeding with the construction of its direct-chill caster for producing magnesium T-bar ingot (Platt's Metals Week, 2000d).

Japan.—Japan's Nippon Kinzoku Co. Ltd. completed a 2,400-t/yr magnesium recycling plant in Kitakami, Iwate Prefecture, that was expected to begin commercial production in January 2001. The completion of this plant raised the company's total recycling capacity to 8,000 t/yr. Nippon Kinzoku operated three other magnesium recycling plants in Japan (Furukawa, 2000a).

Netherlands.—A preliminary feasibility study on the Antheus Magnesium Development Programme Delfzijl proposed magnesium plant in the Netherlands was completed. The study was for a combined magnesium smelter, diecasting plant, and recycling plant, all at the same location. Projected capacity of the magnesium smelter would be 15,000 t/yr, with potential expansion to 30,000 t/yr. With the projected sale of excess chlorine generated at the plant, operating costs for the plant were estimated to be about 60 cents per pound. A feasibility study was expected to be completed by early 2001, and a decision on plant construction was expected by the end of 2001 (Brooks, 2000).

Russia.—Russia's Uralasbest, the country's largest asbestos producer, announced that it planned to construct a 50,000-t/yr primary magnesium plant using tailings from the company's asbestos production as its magnesium source. Uralasbest reportedly has constructed a pilot plant based on technology developed at the Solikamsk magnesium plant to recover the magnesium from the tailings, which contain about 24% magnesium. The cost of building a commercial-scale plant was estimated to be about $300 million, and the regional government was planning to issue recommendations on the proposal (Interfax Mining & Metals Report, 2000b).

The European Bank for Reconstruction and Development planned to grant $95 million to the Solikamsk magnesium plant by the end of 2000. The grant was targeted toward increasing magnesium production by 100% in 2001. In 1999, Solikamsk produced 9,000 t of primary magnesium and 9,200 t of magnesium alloys (Interfax Mining & Metals Report, 2000a).

Serbia and Montenegro.—The 5,000-t/yr primary magnesium plant in Serbia reportedly restarted production at the end of 1999. The plant had been shut down because of the NATO bombing in the area. Although small quantities of magnesium were produced, it was uncertain whether commercial quantities of magnesium would be produced again (Metal Bulletin, 2000i).

Taiwan.—Norsk Hydro and Taiwan's CS Aluminium Corp. were discussing the construction of a magnesium recycling plant in Taiwan. Although the project was in the planning stage and no details were disclosed, the project was expected to collect magnesium diecasting scrap from Taiwanese firms and recover it in the form of high-purity alloys (Metal Bulletin, 2000f).

Taiwan's Sheng Yu Steel Co. announced that it would complete construction of a magnesium alloy casting plant in Pingnan by early 2001. The plant will produce magnesium alloy covers for computer laptops, digital cameras, and electronic appliances (Metal Bulletin, 2000c).

Ukraine.—MMD-Mineral hoped to restart the Kalush magnesium plant, which had been idle since 1998. The 10,000-t/yr plant had operated using byproduct magnesium chloride salt from a nearby fertilizer operation as its raw material before it closed because of lack of raw material and high operating costs. MMD-Mineral planned to use bischofite ($MgCl_2 \cdot 6H_2O$), which it extracted at a nearby operation, as an alternative raw material source and use technology similar to that used by DSM in Israel. Much of the magnesium plant was owned by the Ukrainian Government, and tender for the magnesium plant, which needed about a $50 million investment for refurbishment, was expected sometime in 2001 (Metal Bulletin, 2000g).

Current Research and Technology

Noranda developed a new family of magnesium alloys with elevated temperature properties equal to or better than those of the magnesium alloy AE42, which can be sold at a lower cost. Unlike AE42, which normally is used in aerospace applications and contains expensive rare earth elements, the new alloys contain magnesium, 5% aluminum, an unspecified quantity of strontium, which is added to improve heat resistance, and a small quantity of manganese, which is added for corrosion resistance. According to Noranda, these alloys demonstrated excellent creep and mechanical properties between 150° C and 175° C and had salt-spray resistance equivalent to that of AZ91D and of the AM series of magnesium alloys. Because of the enhanced properties, the new alloys could be suitable for automotive applications such as automatic transmission casings, engine fan components, oil pumps, and oil pans (Advanced Materials & Processes, 2000b; Pierre Labelle, Mihriban Pekguleryuz, Don Argo, Mike Dierks, Todd Sparks, and Ted Waltematte, [2001], Heat resistant magnesium alloys for power train applications, accessed June 18, 2001, at URL http://www.my.noranda.com/NR/rdonlyres/00001d27cvfandndmjmzqeci/HeatResistantMgAlloys1.pdf).

At Honda Motor Corp., researchers also developed a creep-resistant magnesium alloy for use in oil pans in the engines of Honda's hybrid cars. The new alloy ACM522 also uses a magnesium/5%-aluminum alloy as the basic constituent, but contains 2% calcium, 2% cerium mischmetal, and 0.3% manganese. This new alloy has creep resistance characteristics that are superior to AE42 and has resistance to both heat and corrosion that are similar to those of aluminum alloy A384. Magnesium oil pans made from this alloy are 35% lighter than the aluminum ones that they replace (Kioke and others, 2000).

Researchers at Pacific Northwest National Laboratories and Thixomat Inc. developed a casting process for a series of magnesium-zinc-aluminum-calcium alloys that demonstrates high creep resistance at temperatures up to 175° C. Although this family of alloys has demonstrated improved high-temperature properties, it has exhibited castability problems when it is die-cast. To alleviate this problem, the alloys were cast by the Thixomolding process, then evaluated for creep resistance, moldability, and tensile and compressive strengths. Thixomolding is a patented high-speed injection molding of semisolid thixotropic alloys, which yields high-quality, net-shape magnesium components (Advanced Materials & Processes, 2000c).

Scientists at Wright-Patterson Air Force Base were developing new aluminum-magnesium-scandium alloys for aerospace applications to replace titanium in certain components. By developing high-temperature aluminum alloys, the cost and lead time for the parts could be reduced. Magnesium is present in the alloys because of its strengthening capability. The alloys were in the initial stages of development (Advanced Materials & Processes, 2000a).

Researchers at Bar-Ilan University in Israel announced the construction of the first rechargeable battery based on magnesium. According to the researchers, the new battery can be charged more than 2,000 times and produces up to 1.3 volts of power, which is similar to existing rechargeable batteries. Although magnesium batteries already exist, they are used mostly in military applications and are not rechargeable. By using electrolyte solutions based on magnesium organohaloaluminate salts and $Mg_xMo_3S_4$ (where x is between zero and one) cathodes, the researchers can produce a battery that is about the size of a computer monitor. The new batteries were expected to be commercially available within a year and to be used as uninterrupted power supplies for computer networks affected by power outages (Aurbach and others, 2000).

The French producer of magnesium casting systems Brochot SA developed a new casting wheel designed to minimize surface oxidation when casting magnesium and magnesium alloys. The company applied for a patent of its design, which was adapted from the design of a casting wheel for aluminum systems. By redesigning the points at which the molten metal is delivered to the casting wheel, metal turbulence is reduced, thus minimizing the surface area available for oxidation. In addition, Brochot has replaced the SF_6 protective cover gas with a patented mixture of carbon dioxide, argon, and xenon (Brown, 2000).

Ford was sponsoring research, through the Department of Commerce's Advanced Technology Program, to develop an innovative magnesium diecasting process to be used to cast large components from magnesium alloys. The objective of the 4-year project was to develop a multiport injection "hot runner" system for introducing magnesium into die cavities at a controlled temperature and flow rate. The new process is expected to increase yields and reduce scrap by 10%, thus lowering diecasting production costs (National Institute of Standards, October 2000, Cost-reduced magnesium die castings

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TABLE 1
SALIENT MAGNESIUM STATISTICS 1/

(Metric tons unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Production:					
Primary magnesium	133,000	125,000	106,000	W	W
Secondary magnesium	71,200	80,200 r/	77,100	86,100 r/	82,300
Exports	40,500	40,500	35,400	29,100	23,800
Imports for consumption	46,600	65,100	82,500	90,700	91,400
Consumption, primary	102,000	100,000	107,000	131,000	104,000
Yearend stocks, producer	17,400	13,100	13,500	W	W
Price per pound 2/	$1.70-$1.80	$1.60-$1.70	$1.52-$1.62	$1.40-$1.55	$1.23-$1.30
World, primary production	378,000 r/	383,000 r/	397,000 r/	342,000 r/	368,000 e/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to no more than three significant digits, except prices.
2/ Source: Platt's Metals Week.

TABLE 2
U.S. MAGNESIUM METAL PRODUCERS, BY LOCATION, RAW MATERIAL, AND PRODUCTION CAPACITY IN 2000

Company	Plant location	Raw material	Annual capacity (metric tons)
Magnesium Corp. of America	Rowley, UT	Lake brines	43,000
Northwest Alloys Inc.	Addy, WA	Dolomite	40,000
Total			83,000

TABLE 3
MAGNESIUM RECOVERED FROM SCRAP PROCESSED IN THE UNITED STATES, BY KIND OF SCRAP AND FORM OF RECOVERY 1/

(Metric tons)

	1999	2000
KIND OF SCRAP		
New scrap:		
Magnesium-base	11,200	12,800
Aluminum-base	40,700 r/	39,400
Total	52,000 r/	52,200
Old scrap:		
Magnesium-base	7,720	7,300
Aluminum-base	26,500 r/	22,800
Total	34,200 r/	30,100
Grand total	86,100 r/	82,300
FORM OF RECOVERY		
Magnesium alloy ingot 2/	W	W
Magnesium alloy castings	5,130	6,870
Magnesium alloy shapes	670	196
Aluminum alloys	68,000 r/	62,400
Zinc and other alloys	2	--
Other 3/	12,300	12,800
Total	86,100 r/	82,300

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other." --Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes secondary magnesium content of secondary and primary alloy ingot.
3/ Includes chemical and other dissipative uses and cathodic protection, and data indicated by symbol W.

TABLE 4
U.S. CONSUMPTION OF PRIMARY MAGNESIUM, BY USE 1/

(Metric tons)

Use	1999	2000
For structural products:		
Castings:		
Die	42,600	23,500
Permanent mold	6,100	5,430
Sand	481	527
Wrought products 2/	9,380	2,120
Total	58,600	31,600
For distributive or sacrificial purposes:		
Aluminum alloys	57,800	55,400
Cathodic protection (anodes)	70	98
Chemicals	W	W
Iron and steel desulfurization	9,440	12,200
Reducing agent for titanium, zirconium, hafnium, uranium, beryllium	1,730	1,520
Other 3/	3,650	3,570
Total	72,700	72,800
Grand total	131,000	104,000

W Withheld to avoid disclosing company proprietary data; included with "Other."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes extrusions, sheet and plate, and forgings.
3/ Includes nodular iron, scavenger, deoxidizer, and powder.

TABLE 5
U.S. EXPORTS OF MAGNESIUM, BY COUNTRY 1/

	Waste and scrap		Metal		Alloys (gross weight)		Powder, sheets, tubing, ribbons, wire, other forms (gross weight)	
Country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1999:								
Canada	16,400	$46,200	785	$2,720	1,850	$5,910	2,220	$8,180
Japan	10	25	564	1,840	88	474	292	2,030
Korea, Republic of	9	40	22	155	83	474	227	616
Mexico	33	87	238	642	94	439	1,200	3,430
Netherlands	5	14	2,340	5,730	20	42	35	203
United Kingdom	--	--	226	763	37	441	719	2,940
Other	43	144	618 r/	2,700 r/	594	3,500	303 r/	2,800 r/
Total	16,500	46,500	4,790	14,600	2,760	11,300	4,990	20,200
2000:								
Canada	6,290	17,100	2,700	7,680	4,930	16,400	957	6,310
Japan	--	--	537	1,740	233	1,520	200	3,400
Korea, Republic of	--	--	12	52	99	506	50	616
Mexico	57	142	31	106	118	686	1,710	5,540
Netherlands	6	14	2,650	7,000	78	166	162	970
United Kingdom	--	--	99	391	29	775	407	1,740
Other	46	195	1,270	3,240	533	3,300	575	5,430
Total	6,400	17,500	7,300	20,200	6,020	23,300	4,060	24,000

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF MAGNESIUM, BY COUNTRY 1/

Country	Waste and scrap Quantity (metric tons)	Waste and scrap Value (thousands)	Metal Quantity (metric tons)	Metal Value (thousands)	Alloys (magnesium content) Quantity (metric tons)	Alloys (magnesium content) Value (thousands)	Powder, sheets, tubing, ribbons, wire, other forms (magnesium content) Quantity (metric tons)	Powder, sheets, tubing, ribbons, wire, other forms (magnesium content) Value (thousands)
1999:								
Brazil	41	$14	120	$307	1,590	$4,390	4	$24
Canada	2,180	3,160	3,920	13,400	32,000	110,000	72	418
China	695	718	--	--	16,300	41,000	--	--
Israel	13	14	11,800	37,400	--	--	169	397
Kazakhstan	--	--	690	1,870	--	--	--	--
Mexico	--	--	61	146	436	1,420	296	1,020
Russia	--	--	10,000	23,800	4,700	15,300	--	--
United Kingdom	455	458	60	406	514	4,250	28	202
Other	3,390	3,330	232	677	988	3,540	25	202
Total	6,780	7,690	26,900	78,000	56,500	180,000	594	2,260
2000:								
Brazil	--	--	450	1,040	(2/)	9	--	--
Canada	6,450	12,800	3,100	10,100	25,700	82,100	1,740	6,710
China	508	548	244	322	21,100	41,800	106	351
Israel	13	6	6,320	18,900	2,110	11,900	--	--
Kazakhstan	--	--	1,340	3,390	--	--	--	--
Mexico	27	50	100	199	328	1,080	431	1,240
Russia	10	10	10,800	23,200	2,610	8,720	(2/)	3
United Kingdom	145	192	(2/)	3	954	5,920	3	237
Other	2,730	2,790	532	1,590	3,550	12,500	22	134
Total	9,890	16,400	22,900	58,700	56,300	164,000	2,300	8,670

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 7
WORLD ANNUAL PRIMARY MAGNESIUM
PRODUCTION CAPACITY, DECEMBER 31, 2000 1/ 2/

(Metric tons)

Country	Capacity
Brazil	12,000
Canada	64,000
China 3/	188,000
France	17,000
India	900
Israel	27,500
Kazakhstan	10,000
Norway	35,000
Russia	40,000
Serbia and Montenegro	5,000
Ukraine	15,000
United States	83,000
Total	497,000

1/ Includes capacity at operating plants, as well as at plants on standby basis.
2/ Data are rounded to no more than three significant digits; may not add to total shown.
3/ Total effective capacity, including many small plants at unknown locations.

TABLE 8
MAGNESIUM: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1996	1997	1998	1999	2000 e/
Primary production:					
Brazil e/	9,000	9,000	9,000	9,000	9,000
Canada e/ 3/	54,000	57,700	77,100	80,000 r/	80,000
China e/	73,100	75,990	70,500	120,000 r/	140,000
France e/	14,000	13,740 4/	14,000	14,000	14,000
Israel	100 r/ e/	7,000 r/	25,000 r/ e/	28,000 r/	34,000
Kazakhstan e/	9,000	8,972 4/	9,000	9,500	9,500
Norway	37,800 r/	34,200 r/	35,400 r/	35,000 r/ e/	35,000
Russia e/ 3/	35,000	39,500	41,500	45,000 r/	45,000
Serbia and Montenegro	2,500 e/	2,500 e/	3,965	1,203	1,200
Ukraine	10,000 e/	10,000 e/	5,043 r/	3 r/	3
United States	133,000	125,000	106,000	W	W
Total	378,000 r/	383,000 r/	397,000 r/	342,000 r/	368,000
Secondary production:					
Brazil e/	1,600	1,600	1,600	1,600	1,600
Japan	8,175	10,934	7,807	7,735 r/	7,800
U.S.S.R. e/ 5/	6,000	NA	NA	NA	NA
United Kingdom e/ 6/	1,000	1,000	1,000	500 r/	500
United States	71,200	80,200	77,100	86,100 r/	82,300 4/
Total	88,000	91,100	87,500	96,000 r/	92,200

e/ Estimated. r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.
1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.
2/ Table includes data available through July 21, 2001.
3/ Includes secondary.
4/ Reported figure.
5/ Dissolved in December 1991; however, information is inadequate to formulate reliable estimates for individual countries of the former U.S.S.R.
6/ Includes alloys.