MAGNESIUM

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Magnesium is the eighth most abundant element in the Earth's crust and the third most plentiful element dissolved in seawater. Magnesium metal is recovered from seawater and well and lake brines, as well as from such minerals as dolomite, magnesite, and carnallite.

Magnesium metal production declined significantly in 1999, mostly because the 1998 closure of Dow Chemical Co.'s primary magnesium plant, which, with 65,000 metric tons per year (t/yr) of capacity, was the largest U.S. producer. As demand for magnesium continued to increase in the United States, the shortfall in domestic production was replaced by imports, which, in 1999, were record high. Canada, China, Russia, and Israel, in descending order, were the principal import sources. Canada and China supplied mostly magnesium alloys to the United States; Israel and Russia primarily supplied pure magnesium. Aluminum alloying remained the largest use for magnesium in the United States, but diecasting continued to show strong growth, accounting for about one-third of the total magnesium consumed.

Work continued on new magnesium projects that had been announced since 1997. Several feasability studies were completed on plants planned in Australia recovering magnesium from magnesite and asbestos tailings, which indicated that magnesium potentially could be recovered at an operating cost of $0.60 to $0.62 per pound. A feasibility study completed on a plant in Congo (Brazzaville) indicated that magnesium could be produced from carnallite at a 60,000-t/yr plant at an operating cost of $0.55 per pound. In Canada, one plant that will recover magnesium from asbestos tailings is due on-stream in 2000, and several others are being evaluated. If all the new primary magnesium capacity is installed, by 2005, about 500,000 metric tons (t) of annual capacity could be added to the world's present capacity.

Dr. Lloyd Pidgeon, the inventor of the magnesium production process than bears his name, passed away in December 1999. The Pidgeon process was developed in the late 1930's and subsequently was used by five magnesium plants in the United States during World War II. One Pidgeon plant was constructed in Canada in 1942, and this plant is operated today by Timminco Metals Ltd (Light Metal Age, 2000).

Legislation and Government Programs

In its administrative review of the antidumping order on pure magnesium from Norsk Hydro Canada Inc., the International Trade Administration (ITA) found that no dumping margins existed for the period August 1, 1996, to July 31, 1997, and no dumping margins existed for the period of August 1, 1997, to July 31, 1998. ITA also determined the Norsk Hydro Canada did not sell magnesium in sufficient quantities in a 3-year period to support its request for revocation of the duties, so it does not qualify for revocation of the duty order for pure magnesium (U.S. Department of Commerce, 1999d, e).

In September, the ITA issued its final determination of countervailing duties for magnesium imported into the United States from Norsk Hydro Canada. The countervailing duty for pure and alloy magnesium was established at 2.02% ad valorem for calendar year 1997 (U.S. Department of Commerce, 1999c). The ITA also began administrative reviews of the afore-mentioned antidumping and countervailing duty determinations in October; antidumping duties for pure magnesium are to be reviewed for August 1, 1998, to July 31, 1999, and counter-vailing duties for pure and alloy magnesium are to be reviewed for calendar year 1998. The results are expected by August 31, 2000 (U.S. Department of Commerce, 1999b).

The International Trade Commission began 5-year reviews of the antidumping and countervailing duties on pure and alloy magnesium from Canada in August. The purpose of the review was to determine whether revocation of the duties would likely lead to a recurrence of material injury to the domestic industry (U.S. International Trade Commission, 1999).

In June, the ITA received a request to review the antidumping duty on pure magnesium from China. The period to be reviewed is May 1, 1998, to April 30, 1999. The ITA expects to publish final results by May 31, 2000 (U.S. Department of Commerce, 1999a).

Production

In 1999, U.S. primary magnesium production declined significantly from that in 1998 because of the closure of Dow's 65,000-t/yr magnesium plant in November 1998 (table 1). 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. Closure of Dow's plant reduced U.S. production capacity by 45%.

Following the closure of its plant, Dow announced plans to license various parts of its magnesium technology. Technology licenses were available for cell feed, electrolytic cells, metal casting, and products and applications. Dow liquidated its remaining inventory in the first quarter of 1999 (Platt's Metals Week, 1999h).

Magnesium Corp. of America (MagCorp) has experienced delays in its cell upgrade program at its Rowley, UT, primary magnesium facility. Originally scheduled for completion by the end of 2000, the upgrading program is not expected to be completed until mid-2001 or 2002. Prototype cell work was expected to be completed by early 1999, but is still continuing because of technological problems. MagCorp also has installed new scrubbers to meet new HCl emission standards (Platt's Metals Week, 1999m).

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 44% of the total. Diecasting was the second-largest application, with 32% of the total reported consumption, and desulfurization of iron and steel ranked third, with 7% of the total. In addition to primary magnesium, significant quantities of secondary magnesium are used in iron and steel desulfurization reagents. Although consumption of primary magnesium for diecasting increased from that in 1998, a significant portion of the increase shown in table 4 resulted from several companies reporting data to the USGS for the first time. The 1999 data more accurately represent the diecasting industry than do the 1998.

Data for magnesium metal are collected from two voluntary surveys of U.S. operations by the USGS. Of the 84 companies canvassed for magnesium consumption data, 64% responded, representing 53% of the primary magnesium consumption listed in tables 1 and 3. Data for the 30 nonrespondents were estimated on the basis of prior-year consumption levels and other factors.

The 1999 models of North American-built family vehicles contained about 3.18 kilograms (kg) (7.0 pounds) of magnesium per vehicle, 0.23 kg (0.5 pound) more than the 1998 models. New magnesium parts applications are the principal reason for the gain in magnesium consumption; however, some of the increase comes from existing part applications, such as instrument panel and drive-line components, that are being used in more models. General Motors Corp.'s (GM) 1999 model sport utility vehicles (SUV's), however, contain 11.8 to 12.7 kg (26 to 28 pounds) of magnesium per vehicle, a record for SUV's. Total consumption of magnesium in GM's SUV's is estimated to be 3,850 t, based on an annual production volume of 400,000 vehicles. Magnesium applications include instrument panel/pedal bracket supports, alternator brackets, four-wheel-drive transfer-case covers, and steering wheel armatures (Wrigley, 1999f).

GM signed a contract with Missouri-based Diemakers Inc. to produce the die-cast magnesium steering column support brackets for four of its midsize cars. About 1,800 t of magnesium alloy AM60 will be required annually for this application. Diemakers already had been selected to produce magnesium instrument panel support beams for GM's redesigned 2000 Cadillac DeVille models (Wrigley, 1999a).

GM plans to switch from steel to magnesium alloy instrument panel support beams in the 2000 models of its Pontiac Bonneville, Oldsmobile Aurora, and Buick Le Sabre standard-size automobiles; total production of the automobiles is estimated to be 320,000 annually. The support beams will be cast in one piece from alloy AM60 by Magnesium Products Ltd. of Strathroy, Ontario, Canada, and will replace beams that were assembled from several steel components. GM expects that the one-piece assembly will eliminate the rattles and squeaks that often occurred with multipiece assemblies (Wrigley, 1999d). For the 2003 model year, GM decided to install cross-car instrument panel beams made of magnesium in its Pontiac Grand Prix cars. The magnesium alloy AM60 beams will replace steel components and are estimated to consume about 1,300 t of magnesium alloy per year. Norsk Hydro A/S will supply the magnesium alloy for the application (Wrigley, 1999e).

Ford Motor Co. announced several new applications for magnesium in its cars, trucks, and SUV's. Ford plans to incorporate magnesium instrument panel beams in the 2001 and 2002 models of its standard- and compact-size SUV's. Magnesium alloy AM60 for the beams will be supplied by Norsk Hydro and will be die-cast by Meridian Technologies Inc. The beams will require more than 4,000 t of magnesium alloy annually (Wrigley, 1999c). Ford also plans to convert transfer cases on its four-wheel-drive vehicles back to magnesium alloy from aluminum in the 2001 model year. The company also is planning to convert valve covers on most of its North-American-built engines to magnesium alloy from other materials. The two conversion projects are expected to add about 9,000 t to North American consumption of die-cast magnesium alloy (Wrigley, 1999b).

Harvard Industries Inc. announced that it would close its Hayes-Albion diecasting plant in Ripley, TN, at the end of August 1999. The company, which emerged from chapter 11 bankruptcy in 1998, had tried to sell the plant, but reportedly had no acceptable offers. The Tennessee plant makes magnesium alloy parts for automotive applications (Platt's Metals Week, 1999i).

Stocks

Producers' yearend 1999 stocks of primary magnesium declined significantly from those at yearend 1998, but can not be reported to avoid disclosing company proprietary data. Consumer stocks of primary and alloy magnesium decreased to 6,980 t at yearend 1999 from 10,100 t (revised) at yearend 1998. Yearend 1999 consumer stocks of secondary magnesium increased to 1,010 t from the 1998 level of 485 t (revised).

Prices

Quoted magnesium prices did not change significantly during the year. The Metal Bulletin free market price range for pure magnesium started the year at $1,900 to $2,150 per metric ton and increased to $2,420 to $2,500 per metric ton by yearend. Much of this increase resulted from a change in the composition of the price. In August, Metal Bulletin removed the price of magnesium from China as one of the elements in its free market calculation. After this change, the free market price jumped by about $300 per metric ton. Metal Bulletin began quoting a price for Chinese magnesium separately; in

August, this price was quoted at $1,500 to $1,550 per metric ton. By yearend the price range had increased slightly to $1,520 to $1,570 per metric ton.

Platt's Metals Week's European free market price decreased slightly from a range of $2,300 to $2,450 per metric ton at the beginning of the year to $2,250 to $2,350 per metric ton by yearend. The Platt's Metals Week U.S. spot western price dropped slightly from a range of $1.52 to $1.62 per pound at the beginning of 1999 to $1.40 to $1.55 per pound at yearend. The Platt's Metals Week U.S. spot dealer import price decreased from a range of $1.30 to $1.35 per pound at the beginning of the year to $1.25 to $1.32 per pound by yearend.

Foreign Trade

Total exports of magnesium and its alloys were 18% lower than those in 1998 (table 5). Canada (73%) and the Netherlands (8%), were the primary destinations. Imports for consumption of magnesium and its alloys set a new record-high level of more then 90,000 t; this was 10% higher than the level in 1998. Canada (42%), China (19%), Russia (16%), and Israel (13%) were the main sources (table 6). Most of the imports from Canada and China were magnesium alloy, and most of the imports from Israel and Russia were pure magnesium.

World Review

According to figures published by the International Magnesium Association, world magnesium shipments in 1999 were 376,000 t, a 4% increase from those of 1998. Aluminum alloying, with 43% of total shipments, was the largest end-use category for magnesium followed by diecasting with 36%, and desulfurization with 11%. Yearend 1999 world inventories increased slightly to 45,900 t representing an estimated 45 days of supply, based on the previous 12 months of shipments (International Magnesium Association, 2000).

In September, the European Commission (EC) began a review of antidumping measures that it had instituted on magnesium imported from China. The EC had set a duty of the difference between the c.i.f. Europe price of the Chinese magnesium and the minimum import price of 2,622 euros ($2,777) per metric ton. European parties that were related to a Chinese exporter were to pay a duty of 31.7% ad valorem. These duties have been in effect since November 1998, but the French magnesium producer, Pechiney S.A., claimed that even with these duties, import prices for Chinese magnesium have remained below the minimum import price. By yearend, no decision had been reached (Metal Bulletin, 1999c).

Australia.—In Australia, development continued on a number of new magnesium projects. Five new projects have been proposed for the country. The four that are the most likely to be developed would add a total of 272,000 t of annual capacity; most of these plants are scheduled for commercial production to begin in 2003 or 2004.

Australian Magnesium Corp. produced the first magnesium test ingot at its demonstration plant near Gladstone, Queensland, in September. The company plans to study and refine its patented production technology within 6 months. Based on continued success with its production technology, Australian Magnesium plans to complete construction of a 90,000-t/yr plant by 2002, with commercial production scheduled for 2004 (Platt's Metals Week, 1999b).

Hatch Associates Ltd. of Canada completed a feasibility study on Samag' Ltd.s proposed 52,000-t/yr magnesium plant in Port Augusta, South Australia. Results of the study indicate that capital costs for the plant would be $375 million, and the cash cost of production would be $0.60 per pound. Samag is 80% owned by Pima Mining NL and 20% by Resource Finance Corp., both Australian-based firms. The company plans to use technology it licensed from Dow to produce magnesium from magnesite from the Leigh Creek deposit (estimated indicated and inferred resources of 516 million metric tons [Mt], grading 42% MgO). Samag plans to have funding and offtake agreements by June 2000, with initial production scheduled for 2003 (Metal Bulletin, 1999f).

Golden Triangle Resources NL contracted with Bateman Brown & Root to conduct comparative feasibility studies on constructing an 80,000-t/yr magnesium plant using two different raw material sources—magnesite from its Main Creek deposit in Tasmania or serpentinite tailings from its Woodsreef operation in New South Wales. The Main Creek resource consists of 47.4 Mt of magnesite, grading 43.4% MgO, and the Woodsreef resource consists of 24.2 Mt, grading 38.3% MgO. According to the study results, which were announced in March, the proposed plant would have a capital cost of $421 million and an operating cost of $0.62 per pound using magnesite as a raw material, and a capital cost of $436 million and an operating cost of $0.60 per pound using serpentinite as a raw material (Golden Triangle Resources NL, March 16, 1999, Media release, accessed June 2, 2000, at URL http://www.goldentriangle.com/au/16Mar99.htm). In May, the company selected the Latrobe Valley in Victoria as a site for its proposed plant (Metal Bulletin, 1999e). In September, Golden Triangle signed an agreement with Hazelwood Power and HRL Technology Pty. Ltd. to exchange information to evaluate the synergies between Hazelwood's magnesium-from-coal flyash project and Golden Triangle's investigations on recovering magnesium from serpentinite. As a result of the agreement, and the lower operating cost for the Woodsreef project, Golden Triangle decided to concentrate on the Woodsreef project and terminate its agreement with Savage Resources Ltd. to develop the Main Creek magnesite deposit (Golden Triangle Resources NL, September 13, 1999, Media release, accessed June 2, 2000, at URL http://www.goldentriangle.com/au/13Sep99.htm).

Mt. Grace Resources NL announced that it would continue developing its Batchelor magnesite mine in the Northern Territory following an agreement to license Magnesium Development International's Heggie production technology. Mt. Grace plans to develop the project in stages, beginning in June 2000, and reach full capacity of 50,000 t/yr by 2004. Inferred magnesite resources for the project are 20.7 Mt, grading 42% MgO, but the company plans further drilling to more accurately delineate the deposit (Platt's Metals Week, 1999n).

Financial negotiations between Crest Magnesium NL and

Glencore International AG of Switzerland collapsed in September. Glencore was to provide financing for Crest's proposed 95,000-t/yr magnesium plant in Bell Bay, Tasmania. Part of the reason for the collapse was that Glencore wanted 99% equity in the proposed plant and Crest wanted to retain at least 10% equity (Gomez, 1999). In addition, Crest's partner in the project, Multiplex Constructions Pty. Ltd., withdrew from the project in October. Multiplex held the right to take up to 60% of the plant. These two factors likely will delay the project, which was scheduled to begin construction by January 2000 and completed by December 2002 (Platt's Metals Week, 1999o).

Anaconda Nickel Ltd. announced that it is considering plans to invest in magnesite resources that it has in Western Australia, with the eventual goal of constructing a magnesium metal plant. The magnesite resources are near the company's Murrin Murrin nickel-cobalt project that Anaconda recently commissioned. Drilling at the site indicates that the magnesium content of the ore approaches 28% in specific areas (Platt's Metals Week, 1999c). According to the company's 1999 annual report, Kaiser Engineering completed a scoping study for a 100,000-t/yr plant to produce magnesium metal that shows positive economics with a capital investment of A$1 billion (Anaconda Nickel Ltd., 2000, 1999 annual report, accessed June 21, 2000, via URL http://www.anaconda.com.au/default.htm).

***Canada.*—**On January 19, an explosion at Norsk Hydro Canada Inc.'s Becancour, Quebec, magnesium plant injured four workers, but the plant lost only 1 day's worth of metal production. The explosion, however, idled the company's direct chill caster, which is the only one in the world that can direct-chill cast the T-bars that are the preferred product used for alloying by the aluminum industry. The "T" shape provides ease of handling by forklifts, and direct-chill casting minimizes pockets in the metal that can trap moisture and increase the risk of explosions. Instead of repairing or replacing the caster that was damaged during the explosion, Norsk Hydro Canada will produce a new large magnesium sow to replace the T-bar ingots, citing cost and employee safety as the reasons not to replace the caster. Unlike traditional sows, however, the new sow will not have a cavity. The 113- to 680-kg (250- to 1,500-pound) sows will be available in the "T" shape. Norsk Hydro Canada planned to have prototype products available by the end of October 1999 for testing (Platt's Metals Week, 1999k).

The company also postponed the proposed expansion of its Becancour plant because the company was limiting its capital expenditure programs in 1999. The expansion, which was originally announced in June 1997, would add 25,000 t of annual capacity by 2000. This expansion has been delayed by 1 to 2 years, depending on Norsk Hydro's financial situation (Platt's Metals Week, 1999j).

Canada's Cassiar Mines & Metals Inc. signed a memorandum of understanding with the South Korean firm Aluminium of Korea Ltd. (Koralu), which is a subsidiary of the Hyundai Group, to enter into a joint venture at Cassiar's proposed 90,000-t/yr magnesium-from-asbestos-tailings plant in British Columbia. Under terms of the agreement, Koralu will acquire a 35% interest in Cassiar and will be entitled to buy as much magnesium as it needs. Koralu's initial investment in the joint venture will be $25 million, with an option to increase its stake in Cassiar to 65% by providing additional funding. A feasibility study on the proposed plant is planned to be completed by 2000, and if the pilot-plant stage can be bypassed, commercial production will begin in 2003 (Metal Bulletin, 1999a).

Production at Noranda Inc.'s 58,000-t/yr Magnola facility in Quebec is scheduled to begin in the second half of 2000.

***China.*—**At a meeting of the China Magnesium Association, officials announced that they plan to penalize producers that export magnesium at prices lower than their production costs, and authorities are considering establishing an export licensing system to control exports. The association also looked at ways to address the pollution problem including shutting down plants that fail to comply with national environmental protection standards. China's total magnesium production in 1999 is estimated to be between 80,000 and 90,000 t, about the same as in 1998, although the total number of plants operating is about 50 to 60 of the 120 total. Many of the country's smaller plants stopped producing in 1998 when the price was low. A few years ago, when the price was high, as many as 400 primary magnesium plants were operating (Platt's Metals Week, 1999e). China also plans to control magnesium expansion projects by banning bank loans on projects with capacities of less than 3,000 t/yr (Platt's Metals Week, 1999d).

The Ningxia Metal Magnesium Works closed in March to restructure and increase production capacity by 1,000 t/yr, to bring the total plant capacity to 2,400 t/yr. The company did not receive state funds of $360,000 to $600,000 to restructure on schedule in May, so the plant remain closed (Platt's Metals Week, 1999q).

Another magnesium producer in China, Chaoyang Rich Magnesium Co. Ltd., closed its 4,000-t/yr primary plant, ostensibly in response to poor prices. According to the company, the current magnesium price of $1,600 per metric ton does not cover its production costs, which are $1,900 per metric ton. The company will concentrate on producing alloys and powder, and does not plan to reopen its primary ingot production line until prices increase (Platt's Metals Week, 1999f).

In contrast, several magnesium producers in China announced plans to increase production capacity for magnesium and magnesium alloys in 1999. By mid-June, Wenxi Xindi Magnesium Industries planned to increase primary magnesium capacity to 4,500 t/yr from its present level of 3,700 t/yr (Platt's Metals Week, 1999s). Xindi Magnesium Industries Co. planned to increase production of magnesium alloys to 2,000 t from 100 t. The company installed a new production line, which began operating in October 1998 (Platt's Metals Week, 1999t).

***Congo (Brazzaville).*—**In June, a feasibility study completed for Magnesium Alloy Corp.'s proposed 60,000-t/yr magnesium plant in Congo (Brazzaville) indicated that magnesium could be produced at an operating cost of $0.55 per pound, assuming electrical rates of $0.16 per kilowatt hour. Because of the favorable study results, Magnesium Alloy began the last detailed work needed to move the project forward, including detailed engineering work, environmental impact studies, and drilling of solution mining production wells. Magnesium Alloy plans to solution-mine the magnesium salts using technology provided by Germany's Preussag AG and recover the magnesium through electrolysis (Platt's Metals Week, 1999r).

Germany.—A consortium of three aluminum firms in Germany has set up a new company, MR Magnesium-Recycling GmbH, to recover magnesium from scrap and residues. The decision was made to develop proprietary technology and construct a new plant because magnesium scrap receipts at all the firms had increased significantly, primarily from European automobile manufacturers. Although a decision on plant construction initially was expected by mid-1999, no decision had been made by yearend (Metal Bulletin, 1999d).

The Hydro Magnesium Div. of Norsk Hydro planned to increase the recycling capacity at its plant in Germany to 4,500 t/yr from 2,200 t/yr by September. The company also received local approval to expand further to 9,000 t/yr; this expansion will be made as market conditions permit. The expanded plant will allow Norsk Hydro to accommodate the increasing needs of the diecasting industry. The plant will recycle diecasting residues including painted and oily scrap and drosses in addition to class I scrap (Platt's Metals Week, 1999l).

Israel.—Debottlenecking work at Dead Sea Magnesium Ltd.'s magnesium plant in Sdom was completed; the process will allow production capacity to be increased to 33,000 t/yr. The company also ordered a direct-chill caster, which it plans to install and begin operating by the second quarter of 2000. The direct-chill caster will enable Dead Sea to supply the growing demand for T-bars (Metal Bulletin, 1999b).

Volkswagen AG of Germany and Israel Chemicals Ltd. will invest $100 million to expand Dead Sea Magnesium's plant. The investment will increase capacity from the current level of 33,000 t/yr, and the 65% ownership of the plant will be transferred from Israel Chemicals to Dead Sea Magnesium. Although the capacity increase was not stated, original plans for the plant called for an expansion to 50,000 t/yr (Platt's Metals Week, 1999g).

Japan.—A new magnesium recycling plant opened in Gifu Prefecture in April. The new facility, owned by Morimura Brothers Ltd. and Onoda Trading Ltd., has a capacity of 1,200 t/yr, and the recycled scrap will be used in magnesium alloy production. The company plans to increase capacity in response to increased demand for recycling magnesium (Platt's Metals Week, 1999p).

Nippon Kinzoku Co. Ltd. increased the melting capacity at its secondary magnesium plants in Japan from 2,200 to 4,800 t/yr. Expansion plans are concentrated at the company's Kimitsu, Chiba, and Futajima, Kitakyushu, plants. At Kimitsu, two melting furnaces are being added to increase the plant's annual capacity from 1,600 to 2,600 t of secondary magnesium and magnesium alloys. At Futajima, magnesium melting facilities are being added to the plant's existing aluminum melting operations, to give the plant a total capacity of 1,200 t/yr of magnesium alloys. In addition, Nippon Kinzoku is increasing production of secondary magnesium alloys at is Yawata, Kyushu, facility from 600 to 1,000 t/yr. The company completed an expansion at Silver River Corp., its joint-venture plant in China, increasing production of primary magnesium and alloys from 1,500 to 1,800 t/yr (Metal Bulletin, 1999g).

Netherlands.—A prefeasibility study was completed for the Antheus Magnesium Development Programme Delfzijl project in the Netherlands. Results of the study indicate that a demonstration plant with a capacity of 10,000 to 15,000 t/yr can be operating by 2005, and a full-scale plant of 40,000 t/yr can be in operation by 2008. Total investment needed for the project was estimated to be $10 million; the project includes a pipeline for transporting brine from an existing production facility at Veendam, a magnesium production plant, an ethylene pipeline, and a chlorine processing plant (Metal Bulletin, 1999h).

Russia.—Alcan Aluminium Ltd. signed a long-term agreement with Russia's Avisma Titanium and Magnesium Works in which Avisma would supply a fixed quantity of magnesium to Alcan's worldwide operations. This is believed to be the first multiyear contract between a Russian magnesium producer and an international aluminum firm. Under terms of the contract, which will begin in 2000, some of the metal will be supplied on a fixed-price basis, and the price of the remainder will be linked to Platt's Metals Week magnesium prices. Avisma is planning to increase its production capacity to accommodate the contract, but will determine the size of the increase on the basis of external commitments and expectations for increased domestic sales; the company's 1999 production is expected to be 18,000 t, 16,000 t of which is for export (Platt's Metals Week, 1999a).

Solikamsk Magnesium Works in Russia also is planning to increase production capacity by 15,000 t/yr by using new production technology. The new process was developed in cooperation with the Russian Institute of Titanium and Magnesium and builds on the existing process. The new process, however, will allow the production of synthetic carnallite from magnesium chloride solution. Magnesium oxide recovered from brucite will be the feed for the magnesium chloride solution. The company claims that the new process will be environmentally friendly by reducing excess chlorine gas generation and that it will be less costly—about $300 per metric ton less. Solikamsk is operating a pilot plant to test the new process, and construction of a full-scale plant can be done in 30 months at a cost of $80 million (Metal Bulletin, 1999i).

Ukraine.—In July, the Ukranian Government removed Shelton Canada Corp. from the management of the Government's 50% share of the Kalush magnesium plant, although the contract was not formally dissolved. The Kalush plant has been closed since the beginning of 1999, is $226 million in debt, and Shelton claims that the plant would need $50 million for refurbishment before it could be reopened. This investment would need to come from foreign investors, and Shelton was planning to privatize the plant. The Government claimed that because the plant had closed after it turned over management of the plant to Shelton and that Shelton's plans for refurbishment had not materialized, it was regaining control of the plant (Metal Bulletin, 1999j).

Instead of turning the Zaporozhye Titanium and Magnesium Works into a company eligible for privatization, the Ukraine

Government has converted it into a public enterprise, which therefore can not be subject to lease or bankruptcy proceedings. Because of the problems with the Kalush complex, Ukraine decided not to risk the privatization of the 30,000-t/yr Zaporozhye plant as well (Interfax Mining & Metals Report, 1999).

United Kingdom.—Magnesium Elektron, a unit of the Luxfer Group, announced that it was increasing capacity at its recycling operation in Manchester to 3,000 t/yr. The expansion was operational in September 1999, and can process residues, drosses, and end-of-life vehicle parts. Magnesium Elektron also plans to build a 10,000-t/yr recycling center in Germany, to be completed by September 2000. This center will provide recycled magnesium to the diecasting industry in Germany. If demand warrants, annual capacity at the recycling center could be expanded to 20,000 t (Luxfer Group, April 8, 1999, Magnesium Elektron announces plans to expand magnesium recycling capacity, accessed April 27, 1999, at URL http://www.luxfer.com/press/080499.html).

Current Research and Technology

Japanese steelmaking company, Nisshin Steel Co. Ltd., developed a new hot-dip steel galvanizing solution that reportedly increases corrosion resistance by three to five times that of traditional hot-dip solutions. The new galvanizing solution is composed of 3% magnesium, 5% aluminum, and 92% zinc compared with a normal hot-dip solution of 55% aluminum and 45% zinc. The magnesium-containing solution can galvanize steels that are 3 millimeters or thicker, which was impossible with the normal solution because of the corrosion that developed on cut surfaces. The new coated steel is expected to be used in housing and agricultural construction, and the company planned to market about 10,000 metric tons per month beginning in May (Furukawa, 1999).

Researchers at the U.S. Department of Energy's Ames Laboratory reportedly created the world's hardest substance, next to diamond. The researchers developed the new material by introducing a small amount of silicon and other additives to an alloy of aluminum, magnesium, and boron. The new material's hardness of 46 gigapascals is higher than that of cubic boron nitride (about 45 gigapascals) currently considered the second-hardest substance; diamond's hardness is between 70 and 100 gigapascals. The new material has another advantage over cubic boron nitride in that it costs significantly less; cubic boron nitride costs between $1,500 and $1,700 per pound, and the new alloy costs about $700 per pound. The principal potential application for the material is to replace ultrahard materials for coating, grinding, and machining applications (U.S. Department of Energy, [n.d.], Second-hardest bulk substance, accessed May 30, 2000, via URL http://www.external.ameslab.gov/news/boride.html).

Outlook

The automotive industry continues to be the segment of magnesium use for which the most significant growth is projected. One automotive industry specialist predicts that the potential exists for magnesium to reach consumption levels of about 100 kg per vehicle in about 20 years, but only if significant technological and economic hurdles are overcome. Although magnesium has advantages of light weight, ease of casting, and enhanced surface properties, there are many problems inhibited the large-scale penetration into the automotive market. These include cost issues, raw material supply issues, limited diecasting supplier-base issues, engineering and design issues, and recycling issues (Cole, 1999).

Although the aluminum alloying segment for magnesium consumption appears to be relatively mature, there are still opportunities for increased use of magnesium in the aluminum beverage can market, the largest portion of this segment. According to officials at Alcan Aluminium Ltd., even with allowances for downgauging and used beverage can recycling, global can stock demand will increase to 4.82 Mt by 2005 from its level of 4.22 Mt in 2000. Much of this increase will occur in South America and Asia where growth has outpaced world gross domestic product and is expected to continue to do so. This increase in can stock demand will translate into a 15.4% increase in the quantity of magnesium required. Material improvements by canmakers are projected to allow weight reductions of 6% by 2005, and, in order to maintain the strength of the can, the average magnesium content of the can will need to be increased to a total of 4.5% to 4.8%. Currently aluminum body stock contains 1% to 1.2% magnesium, and end stock contains about 4%; the average magnesium content of an aluminum can is about 2.5% (Platt's Metals Week, 2000).

If all the planned primary magnesium plants are built, 500,000 t/yr of capacity could be added to the world total by 2005. This figure does not include any capacity expansions by existing producers. Although construction of all the plants is unlikely, without the closure of some of the high-cost plants or some other method of capacity reduction, magnesium will most likely be in an oversupply situation within the next 5 years. Demand for magnesium for diecasting will continue to grow, but the startup of new plants will probably outpace demand.

References Cited

Cole, G.S., 1999, How magnesium can achieve high volume usage in ground transportation, *in* Magnesium in the Next Millennium, 56th, Rome, June 6-8, Proceedings: McLean, VA, International Magnesium Association, p. 21-30.

Furukawa, Tsukasa, 1999, Nisshin Steel hot-dips into magnesium: American Metal Market, v. 107, no. 44, March 8, p. 6.

Gomez, Brian, 1999, Magnesium project partners feud: American Metal Market, v. 107, no. 176, September 13, p. 7.

Interfax Mining & Metals Report, 1999, Ukraine turns Zaporozhye titanium plant into public enterprise: Interfax Mining & Metals Report, v. 8, no. 52, December 17-23, p. 11.

International Magnesium Association, 2000, Magnesium: International Magnesium Association, March, 6 p.

Light Metal Age, 2000, [Untitled]: Light Metal Age, v. 58, no. 3-4, April, p. 144.

Metal Bulletin, 1999a, Cassiar in talks with Koralu for magnesium project: Metal Bulletin, no. 8393, July 15, p. 7.

———1999b, Dead Sea Magnesium may expand production: Metal Bulletin, no. 8376, May 17, p. 7.

———1999c, EU launches Chinese Mg anti-dumping review: Metal Bulletin, no. 8408, September 13, p. 14.

———1999d, German firms plan secondary magnesium plant: Metal Bulletin, no. 8349, February 8, p. 10.

———1999e, Golden Triangle Resources selects Victoria for magnesium smelter:

Metal Bulletin, no. 8378, May 24, p. 13.
———1999f, Latest study improves viability of Australian Mg project: Metal Bulletin, no. 8413, September 30, p. 7.
———1999g, Nippon Kinzoku increases output of magnesium diecast products: Metal Bulletin, no. 8373, May 6, p. 10.
———1999h, Prefeasibility study is concluded on Antheus Mg project: Metal Bulletin, no. 8374, May 10, p. 9.
———1999i, Solikamsk plans 15,000 tpy expansion using new process: Metal Bulletin, no. 8386, June 21, p. 11.
———1999j, Ukraine regains control of Kalush Mg plant: Metal Bulletin, no. 8399, August 9, p. 5.
Platt's Metals Week, 1999a, Alcan Aluminium, Avisma ink long-term magnesium contract: Platt's Metals Week, v. 70, no. 24, June 14, p. 12.
———1999b, Australian Magnesium Corp[.] produces first test metal: Platt's Metals Week, v. 70, no. 36, September 6, p. 4-5.
———1999c, Australia's Anaconda Nickel studies magnesium project: Platt's Metals Week, v. 70, no. 31, August 2, p. 13.
———1999d, China seeks to control magnesium expansion projects: Platt's Metals Week, v. 70, no. 19, May 10, p. 12.
———1999e, China seeks to strengthen magnesium export price control: Platt's Metals Week, v. 70, no. 18, May 3, p. 2-3.
———1999f, Chinese producer shuts 4,000mt of Mg: Platt's Metals Week, v. 70, no. 17, April 26, p. 5.
———1999g, Dead Sea Magnesium gets $100-mil for expansion goal: Platt's Metals Week, v. 70, no. 43, October 25, p. 12.
———1999h, Dow licensing technology: Platt's Metals Week, v. 70, no. 4, January 25, p. 10.
———1999i, Harvard to shut Ripley plant: Platt's Metals Week, v. 70, no. 18, May 3, p. 3.
———1999j, Hydro magnesium expansion awaits better financial: Platt's Metals Week, v. 70, no. 13, March 29, p. 9.
———1999k, Hydro Magnesium won't rebuild DC caster, has new sow: Platt's Metals Week, v. 70, no. 34, August 23, p. 12.
———1999l, Hydro Magnesium's German unit to add recycling capacity: Platt's Metals Week, v. 70, no. 27, July 5, p. 8.
———1999m, Magcorp magnesium cell upgrade slightly delayed so far: Platt's Metals Week, v. 70, no. 16, April 19, p. 5.
———1999n, Mt[.] Grace plans to start Australian magnesium plant next year: Platt's Metals Week, v. 70, no. 37, September 13, p. 10.
———1999o, Multiplex bows out of Crest Mg: Platt's Metals Week, v. 70, no. 41, October 11, p. 10.
———1999p, New Japan Mg recycler to start: Platt's Metals Week, v. 70, no. 13, March 29, p. 10.
———1999q, Ningxia magnesium restart delayed: Platt's Metals Week, v. 70, no. 22, May 31, p. 10.
———1999r, Study confirms Congo magnesium project economics—MAC: Platt's Metals Week, v. 70, no. 23, June 7, p. 10-11.
———1999s, Wenxi Xindi plans Mg increase: Platt's Metals Week, v. 70, no. 21, May 24, p. 6.
———1999t, Xindi boosting magnesium alloy output: Platt's Metals Week, v. 70, no. 25, June 21, p. 11.
———2000, Can stock, magnesium demand to jump 14%—Alcan: Platt's Metals Week, v. 71, no. 22, May 29, p. 6.
U.S. Department of Commerce, 1999a, Initiation of antidumping and countervailing duty administrative reviews and requests for revocation in part: Federal Register, v. 64, no. 190, October 1, p. 53318-53320.
———1999b, Initiation of antidumping and countervailing duty administrative reviews, requests for revocation in part and deferral of administration review: Federal Register, v. 64, no. 125, June 30, p. 35124-35126.
———1999c, Pure magnesium and alloy magnesium from Canada—Final results of countervailing duty administrative reviews: Federal Register, v. 64, no. 173, September 8, p. 48805-48807.
———1999d, Pure magnesium from Canada; final results of antidumping duty administrative review and determination not to revoke order in part: Federal Register, v. 64, no. 50, March 16, p. 12977-12982.
———1999e, Pure magnesium from Canada; final results of antidumping duty administrative review and determination not to revoke order in part: Federal Register, v. 64, no. 180, September 17, p. 50489-50493.
U.S. International Trade Commission, 1999, Magnesium from Canada: Federal Register, v. 64, no. 147, August 2, p. 41961-41963.
Wrigley, Al, 1999a, Diemakers get GM brackets contract: American Metal Market, v. 107, no. 1, January 4, p. 16.
———1999b, Ford plans return to magnesium: American Metal Market, v. 107, no. 117, June 18, p. 5.
———1999c, Ford's magnesium affection rekindled: American Metal Market, v. 107, no. 112, June 11, p. 1, 16.
———1999d, GM shifting to magnesium beams: American Metal Market, v. 107, no. 42, March 4, p. 5.
———1999e, GM to use more magnesium: American Metal Market, v. 107, no. 115, June 16, p. 1.
———1999f, GM ups magnesium use in SUVs: American Metal Market, v. 107, no. 84, May 3, p. 8.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Magnesian refractories. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Magnesium. Ch. in Mineral Commodity Summaries, annual.[1]
Magnesium. Mineral Industry Surveys, quarterly.[1]
Magnesium. Ch. in Metal Prices in the United States Through 1998, 1999.

Other

American Metal Market, daily.
International Magnesium Association. Magnesium, monthly, (also at URL http://www.intlmag.org).
Magnesium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Magnesium and magnesite in the CIS in 1996, 2d ed., Roskill Information Services Ltd.
Magnesium metal 1998, 7th ed., Roskill Information Services Ltd.
Metal Bulletin [London], biweekly.
Platt's Metals Week.

[1]Prior to January 1996, published by the U.S. Bureau of Mines.

TABLE 1
SALIENT MAGNESIUM STATISTICS 1/

(Metric tons unless otherwise specified)

	1995	1996	1997	1998	1999
United States:					
Production:					
Primary magnesium	142,000	133,000	125,000	106,000	W
Secondary magnesium	65,100	71,200	77,600	77,100 r/	87,300
Exports	38,300	40,500	40,500	35,400	29,100
Imports for consumption	34,800	46,600	65,100	82,500	90,700
Consumption, primary	109,000	102,000	100,000	107,000 r/	131,000
Yearend stocks, producer	12,100	17,400	13,100	13,500	W
Price per pound 2/	$1.93-$2.25	$1.70-$1.80	$1.60-$1.70	$1.52-$1.62	$1.40-$1.55
World, primary production	395,000	368,000	378,000	385,000 r/	277,000 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 1999

Company	Plant location	Raw material	Annual capacity (metric tons)
Magnesium Corp. of America	Rowley, UT	Lake brines	40,000
Northwest Alloys Inc.	Addy, WA	Dolomite	40,000
Total			80,000

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

(Metric tons)

	1998	1999
KIND OF SCRAP		
New scrap:		
Magnesium-base	7,730 r/	11,200
Aluminum-base	37,500	42,200
Total	45,200 r/	53,400
Old scrap:		
Magnesium-base	7,390	7,720
Aluminum-base	24,400	26,100
Total	31,800	33,900
Grand total	77,100 r/	87,300
FORM OF RECOVERY		
Magnesium alloy ingot 2/	W	W
Magnesium alloy castings	2,480 r/	5,130
Magnesium alloy shapes	381	670
Aluminum alloys	62,400	69,200
Zinc and other alloys	11	2
Other 3/	11,800 r/	12,300
Total	77,100 r/	87,300

r/ Revised. 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 secondary magnesium content of secondary and primary alloy ingot.
3/ Includes chemical and other dissipative uses and cathodic protection, as well as data indicated by symbol W.

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

(Metric tons)

Use	1998	1999
For structural products:		
Castings:		
Die	20,800 r/	42,600
Permanent mold	5,660 r/	6,100
Sand	597 r/	481
Wrought products 2/	7,100	9,380
Total	34,200 r/	58,600
For distributive or sacrificial purposes:		
Aluminum alloys	52,000 r/	57,800
Cathodic protection (anodes)	3,360	70
Chemicals	W	W
Iron and steel desulfurization	11,200	9,440
Reducing agent for titanium, zirconium, hafnium, uranium, beryllium	2,640	1,730
Other 3/	3,710	3,650
Total	72,900 r/	72,700
Grand total	107,000 r/	131,000

r/ Revised. 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)
1998:								
Australia	--	--	594	$1,450	--	--	1	$11
Canada	13,100	$30,000	525	1,600	5,050	$16,800	220	2,140
Japan	--	--	2,480	6,070	674	1,950	308	2,630
Korea, Republic of	--	--	3	25	85	323	47	399
Mexico	7	26	260	726	54	311	441	1,740
Netherlands	--	--	6,330	16,400	2,430	6,200	25	89
United Kingdom	8	16	147	469	140	420	10	185
Other r/	23	57	1,210	4,310	787	3,870	417	2,370
Total	13,200	30,100	11,500	31,100	9,220 r/	29,800	1,470	9,560
1999:								
Australia	--	--	20	47	--	--	2	19
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	598	2,650	594	3,500	301	2,780
Total	16,500	46,500	4,790	14,600	2,760	11,300	4,990	20,200

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		Metal		Alloys (magnesium content)		Powder, sheets, tubing, ribbons, wire, other forms (magnesium content)	
	Quantity (metric tons)	Value (thou-sands)	Quantity (metric tons)	Value (thou-sands)	Quantity (metric tons)	Value (thou-sands)	Quantity (metric tons)	Value (thou-sands)
1998:								
Brazil	--	--	359	$1,100	--	--	--	--
Canada	2,690	$4,700	2,300	8,170	32,100	$115,000	55	$356
China	473	526	2,190	5,310	13,300	34,800	--	--
Israel	38	43	7,990	25,000	100	258	545	1,170
Kazakhstan	--	--	421	1,160	--	--	--	--
Mexico	--	--	169	557	543	1,850	154	608
Russia	32	31	12,700	33,300	2,160	8,050	--	--
United Kingdom	517	548	48	142	482	3,870	1	134
Other	1,970	2,060	260 r/	892 r/	877	3,180	2	24
Total	5,720	7,910	26,500	75,700	49,600	167,000	757	2,290
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

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 7
WORLD ANNUAL PRIMARY MAGNESIUM
PRODUCTION CAPACITY, DECEMBER 31, 1999 1/ 2/

(Metric tons)

Country	Capacity
Brazil	12,000
Canada	64,000
China 3/	120,000
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	80,000
Total	426,000

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	1995	1996	1997	1998	1999 e/
Primary production:					
Brazil e/	9,700	9,000	9,000	9,000	9,000
Canada e/ 3/	48,100	54,000	57,700	77,100 r/	71,000
China e/	93,600	73,100	75,990	70,500 r/	83,000
France	14,450	14,000 e/	13,740	14,000 e/	14,000
Israel	--	--	7,400 r/	24,500 r/	25,000
Kazakhstan e/	9,000	9,000	8,972 4/	9,000	9,500
Norway e/	28,000	28,000	28,000	28,000	28,000
Russia e/ 3/	37,500	35,000	39,500	41,500	35,000
Serbia and Montenegro	2,560	2,500 e/	2,500 e/	3,965 r/	1,203 4/
Ukraine e/	10,000	10,000	10,000	1,000	1,000
United States	142,000	133,000	125,000	106,000	W
Total	395,000	368,000	378,000	385,000 r/	277,000
Secondary production:					
Brazil e/	1,600	1,600	1,600	1,600	1,600
Japan	11,767	8,175 r/	10,934 r/	7,807 r/	7,500
U.S.S.R. e/ 5/	6,000	6,000	NA	NA	NA
United Kingdom e/ 6/	1,000	1,000	1,000	1,000	1,000
United States	65,100	71,200 r/	77,600 r/	77,100 r/	87,300 4/
Total	85,500	88,000 r/	91,100 r/	87,500 r/	97,400

e/ Estimated. r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data. -- Zero.
1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
2/ Table includes data available through July 21, 2000.
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.