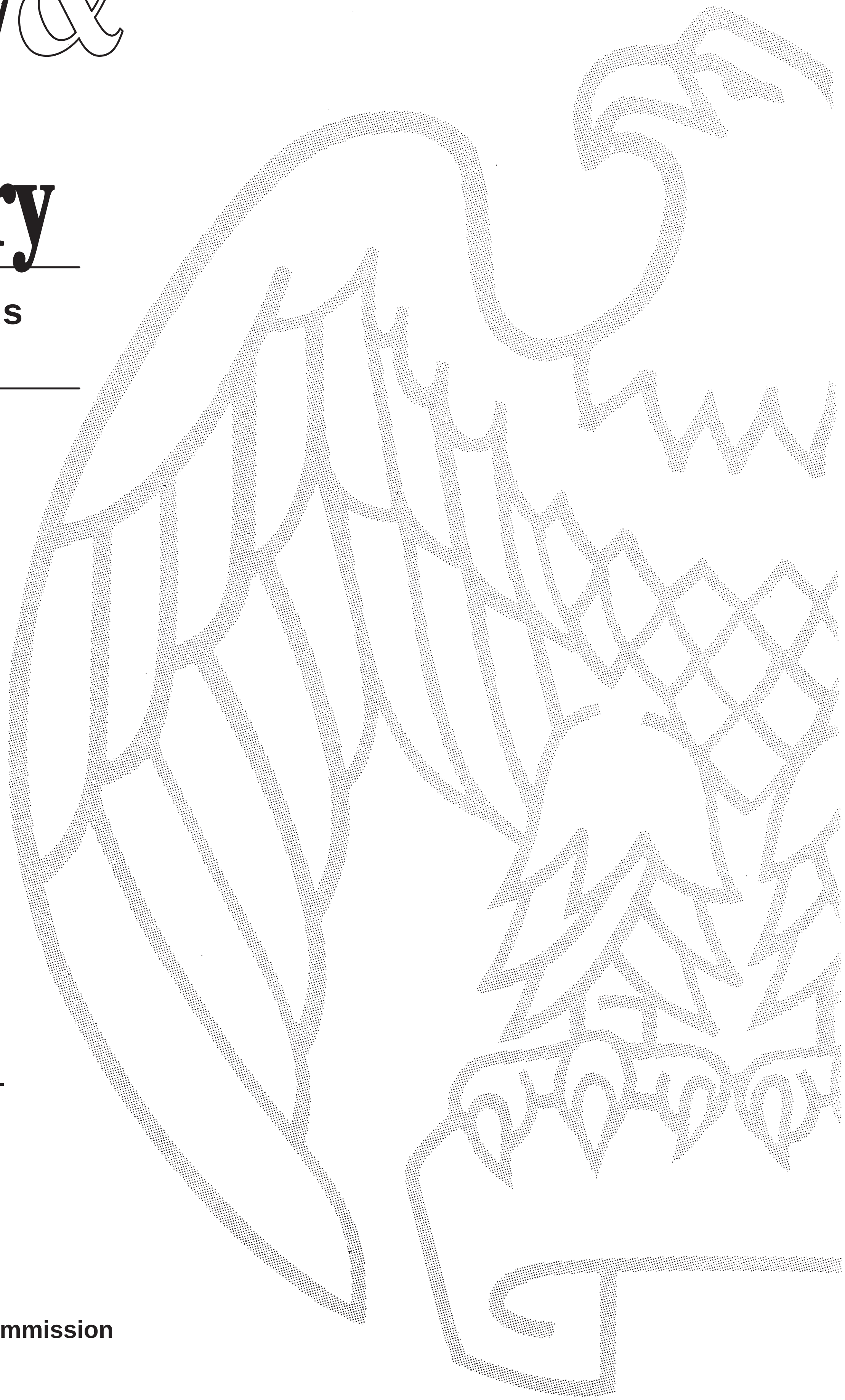
Industry & Trade Summary

Certain Nonferrous Metals



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PREFACE

In 1991 the United States International Trade Commission initiated its current *Industry and Trade Summary* series of informational reports on the thousands of products imported into and exported from the United States. Each summary addresses a different commodity/industry area and contains information on product uses, U.S. and foreign producers, and customs treatment. Also included is an analysis of the basic factors affecting trends in consumption, production, and trade of the commodity, as well as those bearing on the competitiveness of U.S. industries in domestic and foreign markets.[1]

This report on *Certain Nonferrous Metals* covers the period 1993 through 1997 and represents one of approximately 250 to 300 individual reports. Listed below are the individual summary reports published to date on the minerals, metals, machinery, and miscellaneous manufactures sector.

USITC publication number	***Publication date***	***Title***
2426	November 1991	Toys and models
2475	July 1992	Fluorspar and certain other mineral substances
2476	January 1992	Lamps and lighting fittings
2504	November 1992	Ceramic floor and wall tiles
2523	June 1992	Prefabricated buildings
2546	August 1992	Agricultural and horticultural machinery
2570	November 1992	Electric household appliances and certain heating equipment
2587	January 1993	Heavy structural steel shapes
2623	April 1993	Copper
2633	June 1993	Textile machinery and parts
2653	June 1993	Glass containers
2692	November 1993	Refractory ceramic products
2694	November 1993	Flat glass and certain flat glass products
2706	April 1994	Aluminum
2738	February 1994	Structural ceramic products
2742	March 1994	Fiberglass products
2748	March 1994	Brooms, brushes, and hair-grooming articles
2756	March 1994	Air-conditioning equipment and parts
2757	March 1994	Builders hardware
2758	March 1994	Semifinished steel

[1] The information and analysis provided in this report are for the purpose of this report only. Nothing in this report should be construed to indicate how the Commission would find in an investigation conducted under statutory authority covering the same or similar subject matter.

PREFACE—*Continued*

USITC publication number	***Publication date***	***Title***
2765	April 1994	Metalworking machine tools and accessories
2872	May 1995	Abrasives
2857	May 1995	Industrial food-processing machinery and related equipment
2858	May 1995	Precious metals
2880	June 1995	Stainless steel mill products
3018	March 1997	Gemstones
3161	March 1999	Certain Nonferrous Metals

ABSTRACT

Nonferrous minerals are critical building blocks for industrial economies. Countries with natural endowments of important minerals often enjoy competitive advantages in terms of lower raw material costs for their domestic industries. However, many countries without natural resources have efficient refining or alloying firms that further process minerals and also contribute to industrial competitiveness of specialized end products.

This industry summary analyzes four nonferrous mineral industries - nickel, lead, zinc, and magnesium - during the 1993-97 time period and the first six months of 1998. Although none of these domestic industries produces primary metal in large quantities, all four metals are vital to particular U.S. industries and each has unique characteristics. The summary is organized into four chapters highlighting key products and developments.

Nickel—Nickel is a critical ingredient in stainless and specialty steels. Steel products account for over half of the nickel used in the United States. Nickel alloys are used in jet engines and other high-tech applications where strength, corrosion-resistance, and high-temperature performance are important. Although the United States accounts for 14 percent of global nickel consumption, it produces virtually no primary nickel. Nickel is imported and consumed by stainless steel producers, nickel alloyers, and nickel-plating companies. Canada is one of the world's largest producers of refined nickel and the largest U.S. trading partner for nickel. Japan and Norway are major producers of nickel products although, like the United States, they have no nickel mining. Cuba also has large, high-quality nickel deposits, but Cuban nickel is restricted from import under the U.S. trade embargo.

Lead—Widely used in batteries and soldering, lead is recognized as an important metal for the transportation, electronics, roofing, nuclear, and medical industries. Global producers in Latin America and Asia are seeking to increase foreign exploration and investment in production facilities. Conversely, the introduction of environmental regulations is curtailing production in the European Union, and limitations on the use of lead in paint and gasoline have had a significant effect on the structure of the U.S. industry. More than half of the domestic lead smelters closed between 1993 and 1997, and there remains only one domestically owned primary lead mine. However, secondary production of lead has increased dramatically and new battery recycling plants have been built. Demand is expected to grow as population expands and consumer welfare rises.

Zinc—Zinc is one of the most widely used metals in the world. Nearly half of 1997 global zinc consumption was for steel galvanizing applications, primarily in the automotive and construction industries. Domestic production from mining operations exceeds U.S. smelting capacity. Only three U.S. smelters remained open in 1997; the others had been closed because of environmental concerns. Reflecting domestic dependence on foreign smelting and refining operations, 84 to 88 percent of U.S. exports are zinc ores and concentrates while 95 percent of imports is refined metal. Canada is the world's leading producer of zinc and the major market for U.S. producers of ore and concentrate.

Magnesium—Auto parts made from magnesium weigh less than those made of traditional materials and can contribute to increased fuel efficiency. During the 1993-97 period, U.S. production capacity declined almost 20 percent in response to competition from lower-cost Canadian, Russian, and Chinese products. Foreign production in China, Israel, and Canada is expanding, and global supplies could increase by another 40 percent by the year 2004. U.S. automakers have recently formed joint ventures or concluded long-term contracts with these new foreign production facilities in order to guarantee supply for future production of die-cast parts.

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CHAPTER 1
Nickel

Introduction

Nickel is an important metal for industrial societies because it maintains its strength at elevated temperatures and is highly resistant to corrosion. It is typically used as a constituent of other metal alloys, particularly stainless and alloy steels. The United States is one of the largest consumers of nickel in the world (accounting for approximately 14 percent of consumption) but has virtually no primary production.[1] Nickel deposits of sufficient tonnage and quality to support a mining industry do not exist in the United States. Much of the imported nickel is consumed by nickel alloy producers, and the United States is a major producer of these alloys.

Although historically the price of nickel has been substantially higher than prices for more common metals such as steel, aluminum, copper, lead, and zinc, its price has declined by almost 50 percent since 1995 primarily because of increased exports from Russia and reduced consumption in Asia as a result of the Asian economic crisis. Moreover, new low-cost production in Australia and the discovery of a major nickel deposit in Canada may portend a continuation of relatively low prices in the future, thereby contributing to the competitiveness of downstream consumers such as stainless steel and nickel alloy producers.

This chapter discusses the unwrought nickel industry for the years 1993-97. The products included for the purposes of this report are unwrought nickel, unwrought nickel alloys, associated nickel-containing raw materials (such as ores, concentrates, ash/residues, and waste/scrap), and nickel metallurgical products (such as mattes and nickel oxide sinters).[2]

Production Process

The principal unwrought nickel product is refined nickel. A flow chart of the production process for unwrought nickel products is shown in figure 1-1. Nickel is recovered from either sulfide or laterite ores.[3] Nickel sulfide ores typically contain copper and iron sulfides, and may also contain precious metals sulfides. In *pyrometallurgical* [4] processing, the ore is crushed and ground into fine particles; nickel sulfides and other metal sulfides are physically separated from waste minerals by *flotation* to form a *concentrate*.

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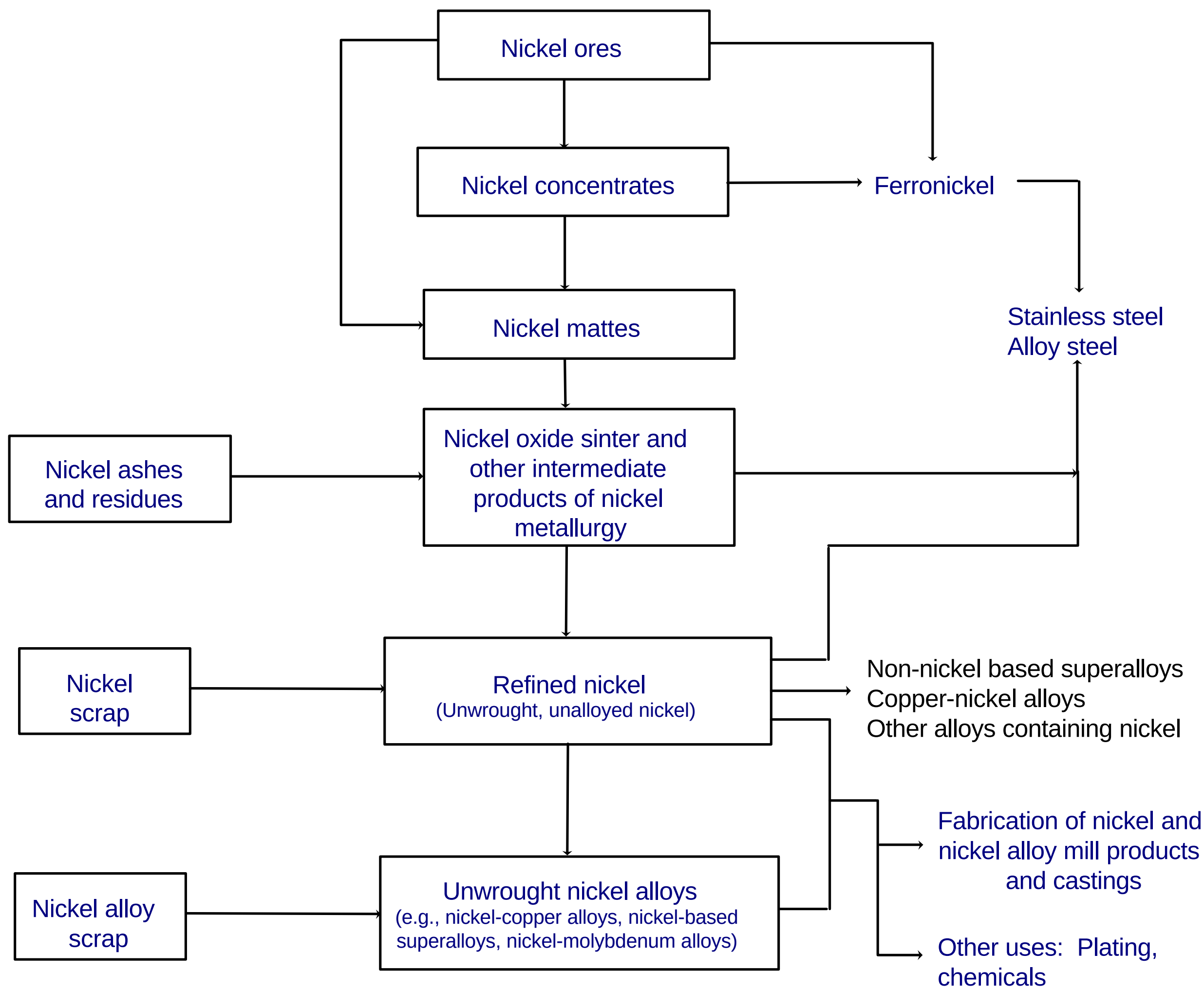
[1] Primary production refers to nickel recovery from new sources (i.e., from mined material). Secondary production is nickel recovered from recycled material.

[2] Unwrought refers to products that have not been mechanically formed into downstream shapes, such as sheets, bars, wire, etc. Nickel alloys are those in which nickel is the dominant metal by weight.

[3] Sulfide ores are of igneous or hydrothermal origin. Laterite ores are the product of mechanical and chemical weathering of nickel-containing rock. The chemical compositions of the two ore types differ, which determines the processing techniques used to recover the nickel.

[4] Italicized words are defined in the glossary, Appendix B.

Figure 1-1
Nickel: Product flow chart



Note.--Products included in the unwrought nickel industry for purposes of this report are boxed.

Source: Compiled by staff of U.S. International Trade Commission from publications of the U.S. Department of the Interior.

The sulfide concentrates are *roasted* and *smelted* (melted) to separate oxides and other impurities, which float to the surface as a *slag* to be skimmed away. The remaining material, called *matte*, is transferred to a converter where the remaining iron sulfide is oxidized and removed as slag. The final matte is comprised of nickel and copper sulfides, and a nickel-copper alloy that may contain precious metals. This matte is allowed to cool slowly and is crushed; grains of nickel sulfide are separated from those of copper-sulfide and nickel-copper alloy by flotation. The nickel-copper alloy typically is sent to a precious metals refinery and the copper sulfide to a copper smelter for processing into pure metals. The nickel sulfide may be melted and cast into *anodes* for electrorefining or *sintered* to a nickel oxide and further processed to produce refined nickel.[5]

Pyrometallurgical techniques are also suitable for laterite ores, most of which are processed directly because they are not amenable to concentration. The ore is first smelted with coke, sulfur, and limestone, and then processed into a nickel sulfide matte, which is further processed in the same manner as sulfide ores. Most laterite ores are processed directly into ferronickel.[6]

Nickel ores and concentrates may also be processed using *hydrometallurgical* methods in which they are leached (dissolved into a solution) and the component metals precipitated out. The acid leach method, applied to laterite ores, is especially important because it is potentially less costly than other hydrometallurgical and pyrometallurgical methods.[7]

Nickel ashes/residues and waste/scrap are important secondary sources. Ashes and residues result from many nickel-using operations, such as casting operations. Waste and scrap are typically generated by downstream users in the form of cuttings, raspings, and the like, from fabrication operations. Although the impure products must be recycled through a smelter, waste and scrap can be reused directly in nickel or nickel alloy products, if first segregated by alloy type.[8]

Nickel is added to stainless steel in one of three forms–refined nickel, nickel oxide sinter, or ferronickel. Ferronickel is the most commonly used primary nickel material for stainless steel and is produced directly from nickel ore or concentrates. Other applications, such as alloying or plating, use refined nickel in cathode or pellet form. To produce nickel alloys, refined nickel and alloying metals are melted in a furnace, in most cases in vacuum furnaces to prevent air contamination. Mill shapes (plates, sheets, tubes, and bars) of refined nickel and or nickel alloys are mechanically rolled from castings of suitable precursor shapes. Nickel and nickel alloy parts may also be formed by melting and casting the metal.

[5] In the electrorefining process, an electric current dissolves the nickel sulfide anodes which have been immersed in a tank with an electrolyte solution. As the nickel plates out onto a cathode, impurities collect at the bottom of the tank. After sintering, nickel oxide sinter is reduced with hydrogen or carbon to form crude nickel pellets. These pellets are further reacted with carbon monoxide, producing a nickel-containing gas that separates from the solid impurities. The gas is then heated to drive off the carbon monoxide, leaving pure nickel pellets.

[6] Ferronickel is produced by smelting and refining dried ores. In contrast to the production of refined nickel, the iron is not removed. Though ferronickel will be discussed as it pertains to nickel uses, the ferronickel industry is not included as part of the unwrought nickel industry for the purposes of this report.

[7] In acid leaching, wetted ore is mixed with high-temperature sulfuric acid to dissolve nickel and other metals (usually cobalt, copper, and magnesium). A precipitate containing the metals is separated out of this solution by reaction with hydrogen sulfide gas. The precipitate is subjected to a series of dissolution and precipitation steps to selectively separate the metals in their pure form.

[8] Nickel is also recovered when stainless steel scrap is recycled. This type of scrap provides approximately half of the raw materials for producing stainless steel.

Uses

The world consumes about 1 million metric tons (mt) of nickel annually, primarily as an alloying metal. Even when present in small quantities, nickel significantly improves the strength and corrosion resistance of an alloy. Stainless steel, which typically contains less than 15 percent nickel (by weight), and other alloy steels, together accounted for almost half of U.S. nickel consumption in 1997. In that same year, nonferrous and superalloy production accounted for 29 percent, plating for 15 percent, and other uses for 7 percent of U.S. consumption. Nickel and nickel alloys are typically used for specialized applications and are categorized as corrosion-resistant alloys, heat-resistant alloys, superalloys, and alloys with special physical properties. Corrosion-resistant alloys include pure nickel for exposure to extremely caustic chemicals and nickel-copper alloys for exposure to seawater. Heat-resistant alloys include nickel with chromium and iron for furnace components such as racks and baskets used to hold metal parts that are heat treated. Superalloys[9] are extremely strong and corrosion resistant and maintain these properties at high temperatures; they are among the highest performing of all metals used in industry. The nickel-based superalloys are metallurgically complex and typically contain other metals designed to enhance a specific physical characteristic. For example, adding trace amounts of aluminum and titanium doubles the hardness of the alloy when heat treated. Alloys with special physical properties include nickel-iron alloys for magnetic applications and nickel-chromium electrical-resistance alloys for furnace heating elements. Table 1-1 lists end uses for nickel.

U.S. Industry Profile

Industry Structure

Except for nickel alloys and nickel waste and scrap, the U.S. unwrought nickel industry is small in terms of production and number of producers (see table 1-2 for a list of companies and plant locations).[10] The only domestic nickel mine, which produced a small amount of ore during 1993-98, and its accompanying ferronickel smelter were closed in early 1998. Cominco Ltd., the Canadian owners of this complex, are abandoning the nickel business in the United States because of high operating costs.[11] One mine operation in Montana recovers a small amount of nickel concentrate as a by-product, and a few other mines may also recover small amounts of by-product nickel. No smelters or refineries produce unwrought nickel products in the United States.

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[9] Superalloys can be nickel, iron, or cobalt based.

[10] Unwrought nickel products are included in the following Standard Industrial Classification (SIC) categories: part of SIC 1061, Ferroalloy ores, except vanadium; part of SIC 3339, Primary smelting and refining of nonferrous metals, except copper and aluminum; and part of SIC 3341, Secondary smelting and refining of nonferrous metals.

[11] Cominco claims this operation has the highest operating costs in the world (the plant produced ferronickel using mostly imported ore). The company would sell the plant, but does not believe anyone will buy, given the current low price of nickel. USITC staff telephone interview with Cominco representative, Washington, DC, Sept. 30, 1998.

Table 1-1
Nickel: End uses, 1997

Sector or product(s)	Percent of U.S. consumption	Form	Examples
Transportation	26	Stainless steel Superalloy Plating	Vehicle body parts Jet engine parts Vehicle bumpers
Chemical industry	15	Nickel alloys	Processing equipment for caustic solutions
Construction	10	Stainless steel	Structural cladding and other architectural applications
Electrical equipment	9	Nickel alloys Magnetic alloys	Powerplant turbines, heat exchangers Magnets for motors
Fabricated metal products	9	Stainless steel	Cutlery, hospital equipment
Petroleum	8	Nickel alloys	Tubing for gas wells
Machinery (except electrical)	8	Alloy steels	Structural members such as frames
Household appliances	7	Nickel-copper alloys	Food-processing equipment
Other	8	Nickel powder Copper-nickel alloys	Rechargeable batteries Coins

Note.—Includes all uses, whether in applications where nickel is the predominate metal or a minor constituent of other metal alloys.

Source: U.S. Geological Survey.

There are 20 U.S. firms that produce nickel alloys. These companies buy refined nickel, nickel-bearing scrap, and other metals and have melting furnaces to combine these materials. The nickel alloyers typically produce other alloys as well, such as nonnickel-based superalloys and titanium alloys. Allegheny Teledyne, Al Tech Specialty Steel, Carpenter Technology Corp., and Slater Steels Corp. are primarily stainless and alloy steel producers, but these companies also produce nickel alloys and have downstream operations to produce mill shapes such as bars, sheets, and wire. Special Metals Corp. (SMC) is the largest U.S. producer, if the operations of Inco Alloys International are included (SMC recently announced an agreement to purchase Inco Alloys International but is awaiting regulatory agency approval).[12] There are no available data on production or employment of nickel alloyers.

The nickel alloy industry is a capital intensive industry. Sophisticated melting furnaces and process controls are required, especially for the production of superalloys. A high degree of technical knowledge is also required, much more so than for the production of alloys of steel, copper, or other base metals. To remain competitive, the U.S. industry modernized and improved operations during the 1990s. For example, Carpenter Technology invested over $120 million in upgrading superalloy production equipment.[13] At Howmet, production cycle times have been

[12] Inco Alloys International was the U.S. subsidiary of Inco, Ltd., the Canadian company that is among the world's largest nickel mining and processing companies.
[13] USITC staff telephone interview with a U.S. nickel alloy producer, Washington, DC, Oct. 22, 1998.

Table 1-2
Unwrought nickel: U.S. producers and plant locations, by product, 1998

Product	Producer	Plant location(s)	Comment
Ore	Glenbrook Nickel Co.	Oregon	Mine closed in early 1998
Concentrates	Stillwater Mining Co.	Montana	Recovers a nickel-cobalt sulfide as a byproduct from mining platinum-group metals
Waste/scrap[1]	Jones Alloys Inc.	West Virginia	Purchases scrap, segregates, and sells to scrap consumers
Nickel alloys (from scrap only)	Greenville Metals	Pennsylvania	Processes off-grade scrap into small nickel ingots
Nickel alloys	Allegheny Teledyne	New York Pennsylvania North Carolina	
	Al Tech Specialty Steel	New York	
	Cannon-Muskegon Corp.	Michigan	
	Carpenter Technology Corp.	Pennsylvania	
	Certified Alloy Products	California	
	Crucible Materials Corp.	New York	
	Cytemp Specialty Steel	Pennsylvania	
	Electralloy	Pennsylvania (2)	
	FirstMiss Steel	Pennsylvania	
	Hayes International	Indiana	
	Howmet Corp.	New Jersey	
	Inco Alloys International	West Virginia	Sold to Special Metals Corp. in July 1998 (pending approval)
	PCC Airfoils, Inc.	Ohio	
	Precision Castparts Corp.	Oregon	
	Slater Steels Corp.	Indiana	
	Special Metals Corp.	New York	
	Timken Co.	Ohio	
	Titanium Hearth Tech.	California	
	Universal Stainless and Alloy Products	Pennsylvania	
	VDM Technologies Corp.	New Jersey	Subsidiary of VDM-Krupp, a German metals company

[1] Representative company listed. According to industry sources, some six other companies segregate scrap.

Note.— In addition to these companies, numerous others process nickel-containing waste products, such as stainless steel waste and scrap, electroplating sludges, or nickel-cadmium batteries, into alloys containing some nickel and nickel chemicals.

Source: Compiled by staff of the U.S. International Trade Commission from U.S. Geological Survey information, trade journals, and conversations with industry representatives.

reduced from 16 weeks to 72 hours by improving process coordination, and furnace changeover times have been reduced from 37 hours to 8 hours.[14] SMC reduced production cycle times by 35 percent and improved inventory turnover by 40 percent by adding new furnaces and computer controls.[15]

The United States is one of the world's largest consumers of unwrought nickel and nickel alloys and generates a considerable amount of waste and scrap. Nickel alloy producers not only recycle waste and scrap generated from their fabricating operations but also often have agreements to buy back waste and scrap generated at their customers' operations. Several U.S. firms specialize in the collection of nickel waste and scrap; these companies do not have melting capability but segregate waste and scrap according to alloy type and sell this material to nickel alloyers.

Globalization of the U.S. industry does not appear to be extensive and, in fact, contracted during 1998. Closure of the mine by Cominco and Inco Alloys International's sale of its nickel alloy production facility reduced foreign presence in the U.S. industry. Reportedly, Inco sold its U.S. nickel alloy operations because it wants to focus on its core businesses and will use the proceeds from the sale to reduce its corporate debt. Krupp-VDM, a large German-based metals company, owns a U.S. subsidiary based in New Jersey that produces nickel alloys and mill products. Howmet, Inco Alloys International, and Allegheny Teledyne have nickel alloy production facilities in the United Kingdom, which gives these companies market access to the European jet engine industry.

U.S. Government Programs

Nickel is considered a critical material and is part of the Defense National Stockpile. With the lessening of Cold War tensions, Congress authorized a reduction of the stockpile in 1992, and the U.S. Government began selling its nickel holdings of almost 34,000 mt (virtually all in the form of refined nickel) in 1993. By midyear 1998, less than 4,000 mt remained in the stockpile, all of which is slated to be sold by the end of FY 1999.

U.S. Market

Consumer Characteristics and Factors Affecting Demand

Refined nickel is consumed primarily by stainless steel producers. The major U.S. consuming companies are Allegheny Ludlum Corp., Armco Inc., Carpenter Technology Corp., J&L Specialty Steel, Inc., Bethlehem-Lukens, Inc., and Republic Engineered Steels, which have plants in California, Connecticut, Illinois, Indiana, Maryland, Michigan, New York, Ohio, Oklahoma, Pennsylvania, and South Carolina. Nickel alloy producers are also significant consumers (listed in table 1-2). Other consumers include nickel plating companies, such as Lacks Industries, Inc. in Michigan and Siegel-Roberts Co. in Missouri, and wrought-copper companies that produce copper-nickel alloys, such as Olin Corporation, which has a plant in Illinois.

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[14] Jack Bonder and John Corrigan, "Many Factors Impact Energy Sector Consumption," *American Metal Market*, special superalloys issue, Feb. 18, 1998.

[15] Special Metals Corp. web site, found at http:/www.smcxinvest.com/page1.html.

Unwrought nickel alloys are primarily consumed by the nickel alloy companies for producing mill shapes. These unwrought alloys are also sold to companies that cast parts, such as Wyman Gordon (with plants in California, Connecticut, Nevada, New Hampshire, and Oregon), Carlton Forge Co. (California), Schlosser Forge Co. (California), and Metal Dynamics Corp. (Oklahoma).

Nickel is rarely the first metal of choice when designing a part because its price has historically been higher than prices of other metal and metal alloy alternatives, such as steel, aluminum, copper, and zinc. Nickel-containing metal parts are not usually considered unless severe operating conditions are expected. Even then, designers can minimize nickel consumption by coating or plating a less expensive metal or using small amounts, such as in the form of stainless steel, which typically contains no more than 15 percent nickel (by weight). Only under the most severe operating conditions, such as the high operating temperatures in a turbine engine or in applications with extremely corrosive chemicals, do designers consider parts made entirely of nickel or nickel alloys.

Future demand for nickel will likely continue to be tied to stainless steel production. The growth in consumption for stainless steel has been estimated at 3 to 9 percent per year through 2005.[16] Nickel alloy consumption declined in large part due to reduced defense spending during the 1990s; however, aerospace sales are expected to increase in response to growing commercial airline traffic, which will spur demand for jet engines and replacement parts.[17] Growth in the production of electric vehicles may also be a source of increased nickel demand in the future.[18] Many countries have extensive research and development efforts on nickel-based batteries for these types of vehicles.

Another major trend with potential to boost nickel consumption is environmental concerns about fossil fuels. Demand for nickel-containing superalloys for use in engine parts is likely to increase as engines are redesigned to increase efficiency and reduce emissions. For example, gas turbine manufacturers have greatly improved the efficiency of their engines during the past several years.[19] Improving the efficiency usually involves operating at higher temperatures, which creates a need for more temperature-resistant materials such as superalloys. Also driving the development of more-efficient gas turbines is the deregulation of the electric power industry in the United States and other parts of the world. Deregulation and increased competition act as an incentive for electricity providers to lower operating costs by employing more efficient power generating equipment.

Consumption

U.S. consumption of nickel ore is nil as a result of the closure of the Oregon ferronickel plant in early 1998. This plant was supplied mostly with imported ore, but also with a small amount of domestically produced ore.

U.S. consumption of refined nickel increased substantially during 1993-98 (table 1-3). Because there is virtually no domestic production, the United States relies on imports to meet its needs, although sales from the U.S. Strategic Stockpile also provided some refined nickel to the market. In quantity terms, consumption increased 23 percent between 1994 and 1995; in terms of value,

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[16] Peter Kuck, *Nickel Annual Review*, 1996, U.S. Geological Survey.
[17] Based on conversations with U.S. nickel alloy industry representatives, Oct. 1998.
[18] Kuck, *Nickel Annual Review*, 1996.
[19] Tom Gill, "Electricity Powers Superalloy Demand," *Metal Bulletin Monthly*, Oct. 1995, pp. 56-59.

the increase was much greater because the price of nickel increased in 1995. Changes in refined nickel consumption correspond closely to changes in U.S. production of raw stainless steel. The following tabulation (from the American Iron and Steel Institute) shows U.S. production of raw stainless steel:

Year	Amount (*1,000 metric tons*)
1993	1,774
1994	1,835
1995	2,055
1996	1,870
1997	2,161

Table 1-3
Refined nickel: U.S. stockpile sales, exports of domestic merchandise, imports for consumption, and apparent U.S. consumption, 1993-97, January - June 1997, and January - June 1998

Year	Stockpile sales[1]	U.S. exports	U.S. imports	Apparent U.S. consumption	Ratio of imports to consumption
	))))))))))))))))))))))) *1,000 kilograms*)))))))))))))))))))))))				*Percent*
1993	2,200	754	95,918	97,364	98.5
1994	4,800	564	95,695	99,932	95.8
1995	7,000	1,308	117,950	123,642	95.4
1996	3,900	586	112,849	116,163	97.2
1997	7,788	578	118,266	125,476	94.3
January - June—					
1997	3,738	199	58,504	62,043	94.3
1998	4,300	603	71,377	75,074	95.1

[1] Amount actually removed from stockpile and delivered to purchaser.

Note.—U.S. production of refined nickel is virtually zero, although a small amount may be produced from secondary sources. U.S. exports may be U.S. Strategic Stockpile sales and/or exports of imported material.

Source: Stockpile sales computed from information from U.S. Geological Survey. Trade statistics compiled from official statistics of the U.S. Department of Commerce.

Detailed data on consumption of nickel alloys are not readily available; however, industry sources indicate that consumption was stable during 1993-95 but increased significantly in 1996 and 1997, mostly because of increased U.S. production of jet engines.[20] Imports of nickel alloys do compete in the U.S. market, but imports probably account for a much smaller share of consumption than is the case for metals and metal alloys such as steel, stainless steel, aluminum, and copper. This is especially true for the U.S. market for superalloys, which is probably dominated by U.S. producers. Superalloy production originated in the United States, and domestic producers developed strong business ties to U.S. jet engine manufacturers. In many applications, superalloys must be qualified by the customer or end user, which requires extensive documentation of the production process and tight specifications as to alloy composition. Foreign competition in the U.S. market is more likely concentrated in nickel alloys other than superalloys.

[20] Information in this paragraph based on conversations with U.S. nickel alloy producers, Oct. 1998.

Pricing and Transactions

The benchmark free-market price for refined nickel is set on the London Metals Exchange (LME), one of the leading metal exchanges in the world. On the LME, standardized contracts (grade and weight) are traded on a competitive basis and prices change continuously. However, most physical metal changes hands through direct contracts between nickel producers and nickel consumers. Refined nickel producers sell their products based on the LME price, with adjustments as necessary for delivery and taxes. Nickel alloyers sell their products based on the LME price for nickel, with premiums to cover costs such as alloying of metals, fabrication, delivery, and taxes.

The LME nickel price fluctuated considerably during 1993-98, peaking in 1995 at over $8.00 per kilogram, before declining to almost $4.00 per kilogram as of August 1998 (figure 1-2). In real terms, the current price is among the lowest ever recorded for nickel.

Nickel prices are particularly impacted by developments in stainless steel production and consumption, the main end-use sector. World production of stainless steel increased from 11.6 million mt in 1993 to 16.6 million mt in 1997. Much of this growth was fueled by increased investments for pollution-control equipment (stainless steel parts are commonly used because of the corrosive nature of many pollutants) and high demand when Asian economies were growing rapidly during that period. However, upward pressure on nickel prices from increasing demand was eased as Russia began exporting large amounts of nickel during this time. Russian exports of less than 100,000 mt of refined nickel in 1994 doubled by 1997 as domestic demand for nickel and most other metals declined precipitously in the wake of economic restructuring.[21] Russian exports of stainless steel scrap also more than doubled, from 124,000 mt in 1994 to 285,000 mt in 1997.[22]

Prices declined further in 1998 due to prospects of reduced nickel consumption because of the economic slowdown in Asia. Stainless steel mills in Japan, Korea, and the United States cut back production and total 1998 production is expected to decline by over 2 percent as compared with 1997.[23] In addition, global nickel supplies are expected to increase because several new mines began production in late 1998, adding further downward pressure on prices.

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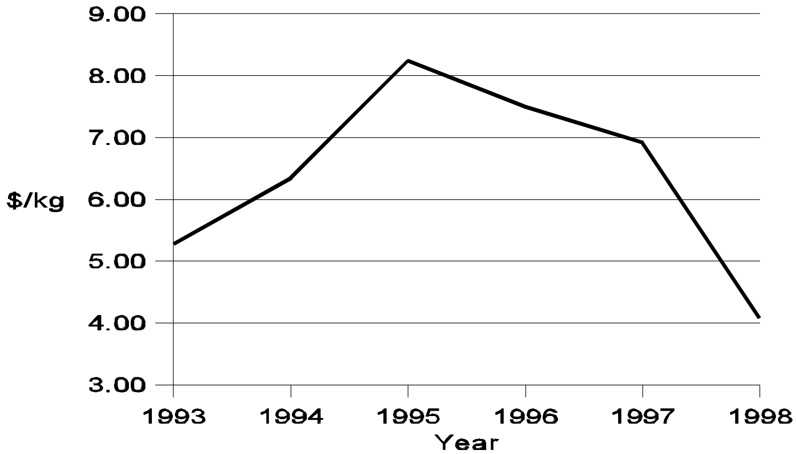
[21] Russian export figures from World Bureau of Metal Statistics.
[22] E.J. Hays, "Nickel," *Mining Journal*, July 31, 1998, p. 12.
[23] *Nickel Newsletter,* Falconbridge Ltd.'s quarterly commentary on the nickel market, issue 3, 1998.

Figure 1-2
Nickel: London metal exchange price, 1993-98



Note.—Prices are annual averages for 1993-97, and August average for 1998.
Source: World Bureau of Metal Statistics.

Production

During 1993-1998, a small amount of nickel ore was produced by one mine in Oregon. This mine was shut down in early 1998, and the company that owned it is leaving the business. The company does not believe it will be able to sell the operation, which includes a ferronickel plant, because it is a high-cost facility with obsolete process technology.[24]

The major items produced in the United States are nickel alloys and nickel waste and scrap. Production statistics on nickel alloys are not readily available, but industry sources state that domestic production has increased significantly since 1996 because of strong sales to the jet engine industry, both in the United States and Europe.[25]

U.S. Trade

Overview

The U.S. trade deficit in unwrought nickel products is detailed in table 1-4. The trade deficit reflects the large volume of refined nickel that must be imported because of the lack of domestic production. The deficit increased dramatically during 1995 because of a large increase in demand

[24] USITC staff telephone interview with a Cominco representative, Washington, DC, Sept. 30, 1998.
[25] USITC staff telephone interview with a U.S. nickel alloy producer, Washington, DC, Oct. 22, 1998.

Table 1-4
Unwrought nickel: U.S. exports of domestic merchandise, imports for consumption, and merchandise trade balance, by selected countries and country groups, 1993-1997[1]

(*Million dollars*)

Item	1993	1994	1995	1996	1997
U.S. exports of domestic merchandise:					
Canada	33	40	54	58	46
Russia	([2])	([2])	([2])	([2])	([2])
Norway	0	([2])	0	0	0
Australia	([2])	1	1	1	([2])
United Kingdom	5	5	13	11	17
France	8	9	22	21	28
New Caledonia	0	0	0	0	([2])
Finland	2	2	1	1	1
Japan	11	12	17	16	15
Germany	2	3	4	4	8
All Other	13	17	23	24	34
Total	74	89	135	136	151
EU-15	24	28	57	54	74
OPEC	([2])	([2])	([2])	([2])	([2])
Latin America	2	3	2	3	6
CBERA	([2])	([2])	([2])	([2])	([2])
Asian Pacific Rim	13	16	20	18	18
ASEAN	([2])	([2])	([2])	([2])	([2])
Central and Eastern Europe	([2])	([2])	([2])	([2])	([2])
U.S. imports for consumption:					
Canada	302	239	368	384	358
Russia	31	29	260	134	178
Norway	96	123	162	196	165
Australia	68	98	107	118	105
United Kingdom	10	14	31	23	30
France	11	10	17	17	17
New Caledonia	2	0	15	27	31
Finland	11	12	18	30	29
Japan	([2])	1	2	5	2
Germany	2	3	4	9	9
All Other	49	85	72	42	41
Total	582	614	1,056	986	965
EU-15	37	42	76	83	92
OPEC	([2])	0	([2])	([2])	([2])
Latin America	6	28	21	3	6
CBERA	([2])	([2])	2	([2])	1
Asian Pacific Rim	69	105	112	128	109
ASEAN	([2])	([2])	([2])	([2])	([2])
Central and Eastern Europe	0	0	0	0	0
U.S. merchandise trade balance:					
Canada	-269	-199	-314	-327	-312
Russia	-31	-28	-260	-134	-178
Norway	-96	-123	-162	-196	-165
Australia	-68	-98	-106	-117	-105
United Kingdom	-4	-9	-18	-11	-12
France	-3	-2	4	5	11
New Caledonia	-2	0	-15	-27	-31
Finland	-9	-10	-17	-30	-28
Japan	11	11	15	11	13
Germany	([2])	-1	([2])	-5	-1
All Other	-37	-68	-49	-17	-6
Total	-508	-525	-921	-849	-815
EU-15	-14	-14	-19	-28	-18
OPEC	([2])	([2])	([2])	([2])	([2])
Latin America	-4	-26	-18	([2])	-1
CBERA	([2])	([2])	-1	([2])	-1
Asian Pacific Rim	-55	-89	-91	-109	-92
ASEAN	([2])	([2])	([2])	([2])	([2])
Central and Eastern Europe	([2])	([2])	([2])	([2])	([2])

[1] Import values are based on Customs value; export values are based on f.a.s. value, U.S. port of export.
[2] Less than $500,000.

Note.—Because of rounding, figures may not add to totals shown. The countries shown are those with the largest total U.S. trade (U.S. imports plus exports) in these products in 1997.

Source: Compiled from official statistics of the U.S. Department of Commerce.

for refined nickel, which resulted primarily from rising demand for stainless steel raw materials. The deficit improved during 1996-97, but this was caused by a drop in the price of nickel.

U.S. Imports

Principal Suppliers and Import Levels

Refined nickel is the most significant import, accounting for 85 percent of total imports of unwrought nickel products in 1997. The principal U.S. sources and import values are shown in table 1-5. Canada is the leading U.S. supplier; it is one of the largest producers in the world and has extensive nickel mining and processing facilities. Russia was the second largest supplier in 1995, 1997, and 1998, supplanting Norway. Major importers include stainless steel producers, nickel alloy producers, and plating companies. The United States also imported nickel ores, mostly from New Caledonia, during 1994-98. These ores were raw material inputs to the ferronickel producer in Oregon. Since this facility closed in early 1998, any further ore imports are unlikely.

U.S. Trade Measures

All unwrought nickel products enter the United States duty free (table 1-6). Imports from Cuba, a significant producer of nickel, are subject to a U.S. embargo against trade with that country and are prohibited by law.[26] Furthermore, any nickel of Cuban origin that is processed in another country cannot be imported into the United States. Presently, nickel-cobalt sulfide is exported from Cuba to Canada for processing. U.S. investment in Cuba is also prohibited. Except for the prohibitions regarding Cuba, the Commission is unaware of any nontariff measures that affect U.S. trade or investment regarding unwrought nickel products.

U.S. Exports

Principal Markets and Export Levels

Nickel alloys and nickel waste/scrap are the only significant U.S. export items, accounting for 85 percent of the unwrought nickel products exported in 1997. Nickel alloy exports have grown substantially since 1994, reflecting strong demand by jet engine manufacturers for nickel alloy parts (table 1-7). One major U.S. nickel alloy producer reports that it exports one-third of its superalloy production.[27] Many of the jet-engine parts producers are located in the European Union, especially France and the United Kingdom, and supply European jet engine producers such as Rolls Royce, Snecma, Volvo, and MTU. Some of the jet engines manufactured in Europe are exported and used on aircraft built in the United States. The prices of nickel alloys apparently have not declined uniformly in response to declining refined nickel prices, and have actually

[26] Cuban Assets Control Regulations, 31 C.F.R. 515.
[27] USITC staff telephone interview with a U.S. nickel alloy producer, Washington, DC, Oct. 9, 1998.

Table 1-5
Refined nickel: U.S. imports for consumption, by principal sources, 1994-97, January - June 1997, and January - June 1998

Source	1994	1995	1996	1997	January - June— 1997	January - June— 1998
	Quantity (*metric tons*)					
Canada	37,994	42,613	47,762	46,858	24,436	29,777
Russia	4,659	32,024	17,221	25,322	12,927	17,442
Norway	22,263	19,134	24,265	24,026	11,940	12,431
Australia	13,399	12,101	13,345	12,257	4,904	6,449
Finland	2,018	2,324	3,829	3,683	1,998	1,288
Zimbabwe	2,635	1,904	1,734	1,548	594	748
France	1,097	1,268	1,464	1,347	815	1,025
United Kingdom	880	1,747	865	931	149	220
South Africa	4,828	2,499	1,173	1,105	189	470
Brazil	4,764	2,081	118	548	300	1,280
All other	1,159	256	1,072	641	253	248
Total	95,695	117,950	112,849	118,266	58,504	71,377
	Value (*1,000 dollars*)					
Canada	222,219	338,927	372,974	328,040	176,613	174,211
Russia	28,384	259,586	132,317	176,594	93,523	95,931
Norway	122,734	161,151	195,945	164,786	87,965	65,188
Australia	77,505	99,888	104,432	84,850	35,181	35,920
Finland	11,936	18,312	30,445	27,064	15,102	8,051
Zimbabwe	14,164	15,975	13,824	10,792	4,441	4,225
France	6,452	10,514	11,200	9,242	5,758	5,388
United Kingdom	5,447	14,617	7,406	7,365	1,594	1,280
South Africa	28,865	20,290	9,008	7,230	1,347	2,703
Brazil	27,538	16,968	889	3,727	2,196	6,936
All other	6,873	2,814	11,223	5,731	3,212	1,440
Total	552,118	959,043	889,663	825,420	426,933	401,273
	Unit value (*dollars per kilogram*)					
Canada	5.85	7.95	7.81	7.00	7.23	5.85
Russia	6.09	8.11	7.68	6.97	7.23	5.50
Norway	5.51	8.42	8.08	6.86	7.37	5.24
Australia	5.78	8.25	7.83	6.92	7.17	5.57
Finland	5.92	7.88	7.95	7.35	7.56	6.25
Zimbabwe	5.37	8.39	7.97	6.97	7.48	5.65
France	5.88	8.29	7.65	6.86	7.07	5.26
United Kingdom	6.19	8.37	8.56	7.91	10.72	5.83
South Africa	5.98	8.12	7.68	6.54	7.14	5.75
Brazil	5.78	8.15	7.53	6.80	7.32	5.42
All other	5.93	11.01	10.47	8.94	12.69	5.81
Average	5.77	8.13	7.88	6.98	7.30	5.62

Note.—Because of rounding, figures may not add to the totals shown.

Source: Compiled from official statistics of the U.S. Department of Commerce

Table 1-6
Unwrought nickel: Harmonized Tariff Schedule (HTS) subheading; description; U.S. column-1 rate of duty as of January 1, 1998; U.S. exports, 1997; and U.S. imports, 1997

HTS subheading	Description	Col.-1 rate of duty as of January 1, 1998 General	Special[1]	U.S. exports, 1997	U.S. imports, 1997
		Percent		*Million dollars*	
2604.00.00	Nickel ores and concentrates	Free		6	31
2620.90.30	Nickel ash and residues	Free		8	([2])
7501.10.00	Nickel mattes	Free		1	([2])
7501.20.00	Nickel oxide sinters and other intermediate products of nickel metallurgy	Free		5	16
7502.10.00	Unwrought, unalloyed nickel	Free		4	825
7502.20.00	Unwrought, alloyed nickel	Free		68	39
7503.00.00	Nickel waste and scrap	Free		60	54
	Total and weighted average	Free		151	965

[1] Because all col.-1 general rates of duty are free, there are no col.-1 special rates of duty.
[2] Less than $500,000.

Note.—Because of rounding, figures may not add to the totals shown.

Source: U.S. exports and imports compiled from official statistics of the U.S. Department of Commerce.

Table 1-7
Nickel alloys: U.S. exports of domestic merchandise, by principal markets, 1994-97, January - June 1997, and January - June 1998

					January - June—	
Source	**1994**	**1995**	**1996**	**1997**	**1997**	**1998**
	Quantity (*metric tons*)					
France	690	1,568	1,410	1,919	823	1,338
United Kingdom	194	446	368	645	308	377
Germany	39	107	53	196	44	63
Israel	32	38	73	212	84	188
Canada	322	766	1,904	957	843	36
Japan	732	718	1,362	394	293	47
Netherlands	533	109	143	127	46	482
Chile	1	([1])	0	142	0	0
Mexico	45	69	111	62	42	11
Taiwan	110	35	4	35	17	5
All other	130	312	283	224	68	240
Total	2,827	4,169	5,711	4,912	2,569	2,788
	Value (*1,000 dollars*)					
France	7,395	19,194	21,061	27,767	12,423	17,236
United Kingdom	3,043	8,386	9,257	15,772	6,654	9,239
Germany	611	1,257	1,047	5,167	1,397	1,858
Israel	196	539	1,135	4,227	1,604	3,423
Canada	1,412	3,525	9,638	3,868	3,114	249
Japan	3,176	3,432	6,411	3,721	2,594	1,162
Netherlands	1,758	988	2,738	1,871	898	5,153
Chile	28	5	0	1,051	0	0
Mexico	427	445	949	977	790	100
Taiwan	1,021	163	117	699	324	69
All other	1,954	3,116	4,244	2,732	1,164	2,816
Total	21,020	41,049	56,599	67,851	30,962	41,304
	Unit value (*dollars per kilogram*)					
France	10.71	12.24	14.94	14.47	15.10	12.88
United Kingdom	15.69	18.81	25.14	24.46	21.58	24.53
Germany	15.70	11.70	19.58	26.41	31.97	29.48
Israel	6.17	14.32	15.63	19.94	19.01	18.23
Canada	4.39	4.60	5.06	4.04	3.69	6.84
Japan	4.34	4.78	4.71	9.45	8.85	24.76
Netherlands	3.30	9.09	19.20	14.77	19.55	10.70
Chile	33.43	46.78	([2])	7.38	([2])	([2])
Mexico	9.41	6.45	8.57	15.64	18.62	8.92
Taiwan	9.31	4.61	28.27	20.02	18.75	13.01
All other	14.99	9.99	15.00	12.22	17.05	11.71
Average	7.43	9.85	9.91	13.81	12.05	14.82

[1]Less than 500.
[2]Not applicable.

Note.–Because of rounding, figures may not add to the totals shown.

Source: Compiled from official statistics of the U.S. Department of Commerce

increased in some cases, as indicated by the unit value of exports shown in table 1-7.[28] One source attributes this to strong superalloy demand,[29] although one U.S. producer claims that superalloy prices are in many cases locked in under long-term contracts and prices will decline as these contracts expire and new contracts are negotiated.[30]

Foreign Trade Measures

Few major markets have tariffs on nickel alloy or nickel waste and scrap imports, as shown in table 1-8. There do not appear to be any nontariff measures that affect U.S. exports or investment in foreign markets.

Table 1-8
Tariff rates for nickel alloys and nickel waste/scrap in foreign markets and comparative U.S. tariffs, 1998

Country/country group	Nickel alloys	Nickel waste/scrap
European Union	Free	Free
Canada	Free	Free
Mexico	Free	Free
Japan	Free	Free
Israel	Free	Free
Chile	11.0 percent	11.0 percent
United States	Free	Free

Source: Country tariff schedules.

Foreign Industry

Nickel Mining and Processing

Five countries accounted for over 70 percent of the nickel mined in the world in 1997 (figure 1-3). About 80 percent of current global production is from sulfide ores, although in terms of reserves, laterite ores predominate. These ore types differ in their mining and processing characteristics. Sulfide ores are usually extracted by underground mining, which requires selective mining techniques and results in less material to be processed when compared with a laterite operation. Total production costs are most sensitive to labor rates. Sulfide ores typically have more by-products than laterite ores. Laterite ores are usually extracted by surface mining which involves moving and processing a relatively large amount of material. Total production costs are most sensitive to energy costs. Canadian and Russian ores are sulfide, Indonesian and New Caledonian ores are laterite, and Australia has both types.

[28] Price changes could be caused by product mix changes that could mask actual price trends in the export statistics.

[29] Bruce Kelly, "Nickel Prices Fall as Superalloys Spike," *American Metal Market*, special issue on superalloys, Feb. 18, 1998.

[30] USITC staff telephone interview with a U.S. nickel alloy producer, Washington, DC, Oct. 22, 1998.

Nickel smelting and refining is more widespread geographically. The top five countries account for approximately 60 percent of production (figure 1-4). Japan and Norway are major producers of nickel products even though these countries have no nickel mining industry. Japan imports material from Australia and Indonesia. Norway imports matte from Canada and Botswana. Australia also provides concentrates for a nickel smelter in Finland. New Caledonia exports matte to a smelter in France and also ships ore to Japan and Australia; it was also the source of ore for the now-closed Oregon ferronickel plant.

Australian nickel production is expected to increase substantially beginning in 1998 because three new mines and associated processing plants are scheduled to begin production.[31] These mines will recover nickel using a hydrometallurgical technique. This process uses acid in pressure chambers to leach the sulfides from the ore and then employs solvent extraction to separate the metals. The complete process is untested (although each step in the process has been successfully used at other plants), but the companies involved expect the cost of production to be under $2.20 per kilogram (compared with $3.75 to $5.70 per kilogram for sulfide ores).[32] Combined production is expected to be 66,000 mt per year, and a 75,000 mt expansion is already planned if initial production goals are achieved without problems.[33]

The prospects for future low-cost production in Canada initially appear favorable, especially with the Voisey Bay deposit in Newfoundland, one of the most significant mineral discoveries of the 1990s. [34] This deposit was purchased by Inco in 1996 for over $3 billion. Voisey Bay is a rich deposit, amenable to surface mining with plentiful byproducts; the estimated cost of production is less than $1.10 per kilogram. However, projected development costs are over $1 billion, and development has been delayed because of problems with the local government, protests by native peoples' groups, and the low price of nickel. Production is not likely to start for at least several years. Other rich nickel deposits have also been discovered in the area.

Nickel Alloys

In contrast to refined nickel production, there is little production of nickel alloys in developing countries. Although statistics are not readily available, industry sources indicate that production is concentrated in the United States, the European Union, Japan, and Australia. The main foreign producers are VDM-Krupp and Deutsche Nickel in Germany, Firth Rixson in the United Kingdom, Metal Imphy in France, Mitsubishi and Sumitomo in Japan, and Western Australian Specialty Alloys, a joint venture of Pratt & Whitney, Wyman-Gordon, and an Australian company.

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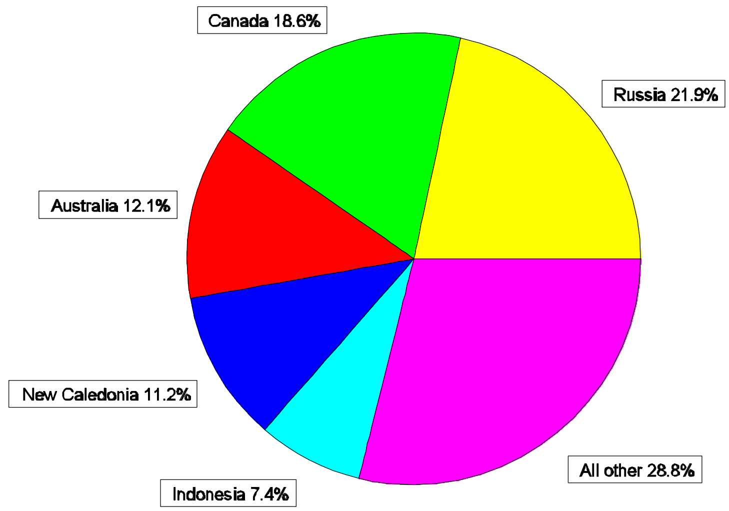
[31] Information in this paragraph from John Sacco, "Stainless Demand Seen Unlikely to Prop Prices," *American Metal Market*, Sept. 1, 1998.

[32] Ibid.

[33] Bruce Kelly, "Glut of New Mines Could Smother Nickel Prices," *American Metal Market*, Sept. 1, 1998.

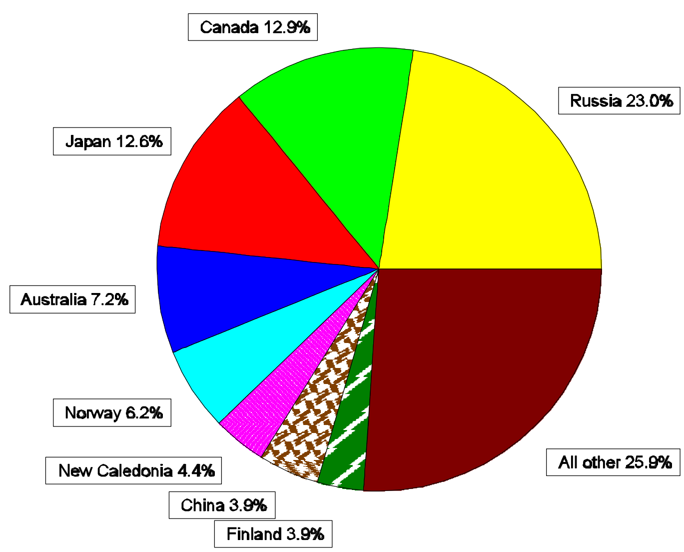
[34] Information in this paragraph from Kuck, *Nickel Annual Review*, 1996.

Figure 1-3
Nickel world mine production, 1997



Source: World Bureau of Metal Statistics

Figure 1-4
Nickel smelter/refinery production, 1997



Note.—Includes production of ferronickel and nickel-containing chemicals.

Source: World Bureau of Metal Statistics.

CHAPTER 2
Lead

Introduction

Lead is a soft, bluish-white, highly malleable, ductile metal and is one of the most widely used and versatile industrial materials. Lead's most important application is for lead-acid storage batteries that provide electrical power for vehicles and other machines, including those that provide emergency power in case of electric failure. Lead's softness, high resistance to corrosion, and high density also make it suitable for many other applications including weatherproofing for buildings, equipment for the manufacture of acids, as a shield against radiation in the nuclear and medical industries, and to reduce noise from machinery in factories and on ships.

Despite lead's utility, its production and use have been affected in recent years by environmental considerations limiting its use. In the United States, legislation prohibits the use of lead compounds in gasoline, paint, and consumer products for children.[1] Globally, there are increased suggestions for legislation curtailing the use of lead. Such activity has prompted a shift in production both in terms of production processes and geography. To maintain a competitive position and meet environmental standards, U.S. producers have increased secondary production, which uses lead scrap. Internationally, foreign investment has increased in Asian and Latin American lead operations. Despite environmental concerns, annual consumption of lead is growing in the United States and abroad as demand increases in the transportation, roofing, and nuclear industries.

This summary analyzes the competitive factors influencing the lead industry[2], the performance of the industry in foreign and domestic markets from 1993 through 1997, and the prospects for future demand and production.

[1] In February 1996, the Environmental Protection Agency (EPA), consistent with the regulations of the Clean Air Act that was effective January 1996, prohibited the use of lead additives or more than 0.05 gram of lead per gallon in gasoline for highway consumption. "*Lead, Annual Review 1997*," U.S. Geological Survey, p.2.

[2] Lead products included in this summary include: lead ores and concentrates, lead ash and residues, unwrought refined lead, unwrought lead bullion and alloys, and lead waste and scrap.

Production Process

The production process consists of both primary and secondary production. Most lead is mined using underground methods, and mineral coproducts often include copper, silver, and zinc. As with many other industrial metals, the primary production process consists of four steps: *sintering, smelting, drossing,* and *pyrometallurgical refining* [3](f igure 2-1). After lead-containing ore is crushed and concentrated, the feedstock is fed into a sintering machine, where it is subjected to blasts of hot air that burn off the sulfur, creating sulfur dioxide. The lead sinter is then smelted with coke, various recycled materials, limestone, and other fluxing agents in a blast furnace to reduce it to molten metal. The molten metal sinking to the bottom of the furnace separates into four layers: *speiss* (the lightest material, basically arsenic and antimony); *matte* (copper sulfide and other metal sulfides); blast furnace slag (primarily metal silicates); and lead bullion (98 percent lead by weight). All layers are then drained off. The speiss and matte are sold to copper smelters for recovery of copper and precious metals. The blast furnace slag, which contains zinc, iron, silica, and lime, is partially recycled.

Rough lead bullion from the blast furnace usually requires preliminary treatment in drossing kettles before undergoing refining operations. During drossing the impure lead is agitated and cooled to just above its solidification point (371.1 to 426.7°C). A *dross*, composed of lead oxide, copper, antimony, and other elements floats to the top, solidifies, and is removed for recovery.[4]

The remaining lead bullion is refined using pyrometallurgical methods to remove any other remaining saleable materials; gold, silver, bismuth, zinc, and oxides of antimony, arsenic, tin, and copper may be further refined by vacuum removal of zinc. Refining generally requires five stages to obtain the final required purity of 99.90 to 99.99 percent. Refined lead bullion may then be mixed with other metals to form alloys or it may be directly cast into shapes.

Secondary production of lead begins with the recovery of old and new scrap.[5] The chief source of old scrap in the United States is lead-acid batteries, although cable coverings, pipe, sheet, and *terne bearing* materials are also recovered for scrap. Lead-based solder alloys may also be retrieved from the processing of electronic circuit boards. Some secondary lead is recovered directly from primary production and is used for producing specialty products like *babbitt metal*, solder, re-melt, and copper-based alloys. However, about 97 percent of secondary lead is recovered from old batteries at secondary lead smelters and refineries as soft (unalloyed) or antimonial lead, and such lead is recycled directly back into the manufacture of new batteries.[6] Unlike copper and zinc, where scrap processing varies tremendously by scrap type and ultimate

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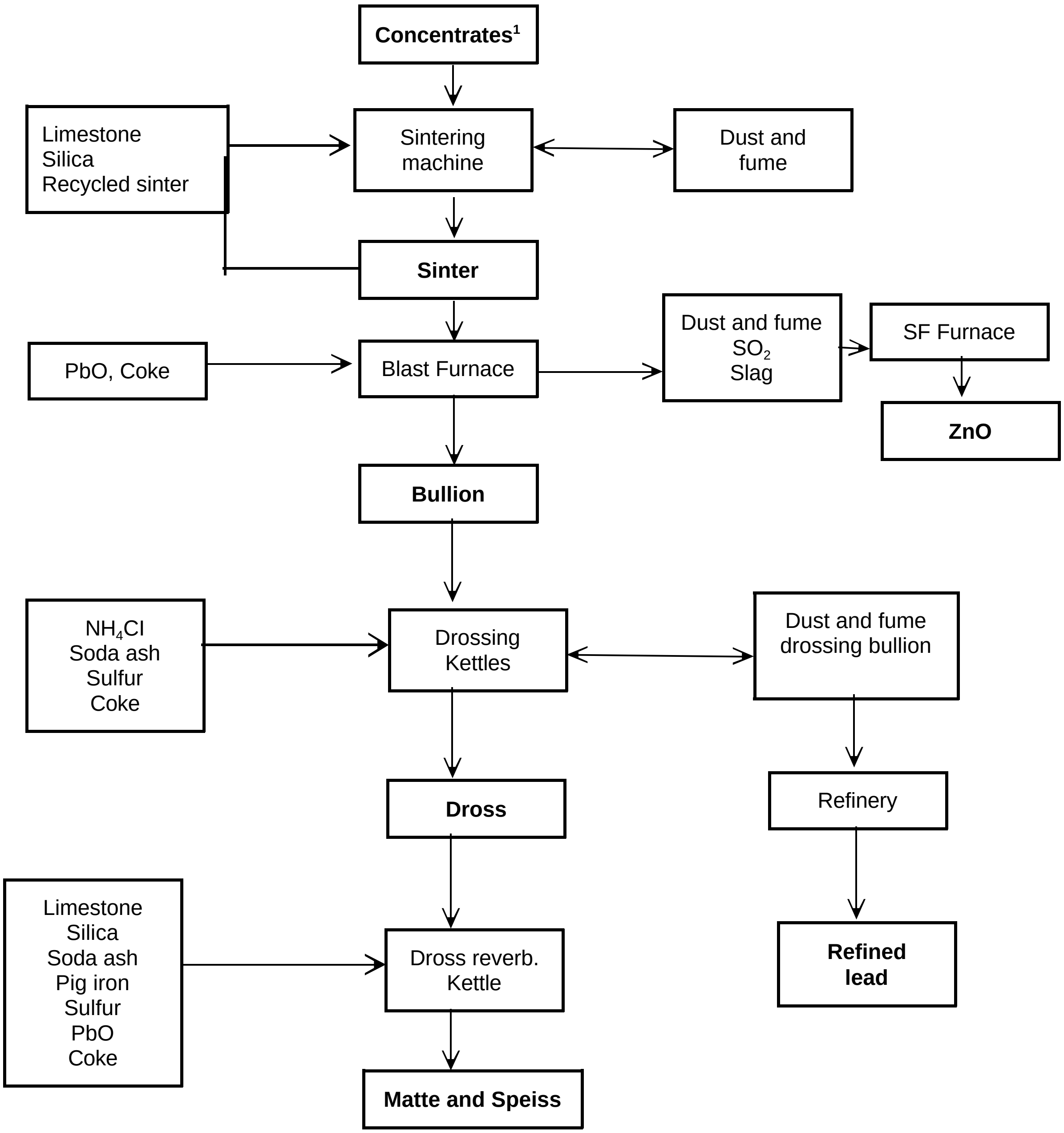
[3] Italicized words are defined in the glossary, Appendix B.

[4] To enhance copper recovery, drossed lead bullion is treated by adding sulfur-bearing materials, zinc, and/or aluminum. Such methods lower the copper content of the remaining bullion to approximately 0.01 percent.

[5] Old scrap is recovered from worn-out, damaged, or obsolete products and new scrap is product wastes and smelter-refinery drosses, residues, and slags.

[6] "Primary and Secondary Lead Processing Industry," Environmental Protection Agency, found at Internet address http//www.epa.gov, retrieved Sept.1998.

Figure 2-1
Primary lead production process



[1]Intermediate and final products in **bold**.

Source: Anthony J. Buonicore and Wayne T. Davis, ed., *Air Pollution Engineering Manual*, Air & Water Management Association, Van Norstrand Reinhold 1997.

end use, the dominance of lead battery scrap allows for a more standard secondary recovery process. Prior to smelting, batteries must be broken apart and classified into their constituent products.[7]

The majority of domestic battery scrap is processed in blast furnaces or rotary reverberatory furnaces. The average furnace can process about 45.36 metric tons (mt) per day. About 47 percent of the charge is recovered as lead product and is periodically tapped into mold or holding pots. Forty-six percent of the charge is removed as slag and later processed in blast furnaces to produce hard lead. The remaining 7 percent of the furnace charge escapes as dust or fume.[8]

U.S. Industry Profile

Industry Structure[9]

Domestic production has shifted from primary to secondary sources in the face of rising costs associated with environmental regulations, and lower production costs associated with using recovered secondary metal.[10] U.S. producers are also technologically competitive, particularly in secondary production.

Over 90 percent of domestic lead production occurs in two states—Missouri and Alaska--although Colorado, Idaho, and Montana also contribute to production (table 2-1). Largely in conjunction with the mining of other minerals, lead was produced at 16 mines employing about 1,200 people in 1997. Employment has remained relatively steady since 1995 after decreasing 20 percent from 1,500 to 1,200 employees during 1993-95.[11] The current employment level is expected to remain steady given continued strong domestic production to meet demand in the transportation industry.

The United States is also the world's largest recycler of lead. Over 80 percent of lead produced is now consumed in recyclable applications, mostly in batteries. Lead has the

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[7] The modern battery breaking process classifies the lead into metallics, oxides, and sulfate fragments, and organics into separate casing and plate separator fractions. Ibid.

[8] Newer secondary recovery plants use lead paste desulfurization to reduce sulfur dioxide emissions and waste sludge generation during smelting. Smelting emissions are also usually controlled with a settling and cooling chamber, followed by a baghouse. Ibid.

[9] Lead ores and concentrates are provided for in Chapter 26 and unwrought refined lead metals are provided for in Chapter 78 of the *Harmonized Tariff Schedule of the United States*. The Standard Industrial Classification (SIC) coverage of these products generally corresponds with SIC 1031, Lead and zinc ores; SIC 3339, Primary smelting and refining of nonferrous metals, except copper and aluminum; and SIC 3341, Secondary smelting and refining of nonferrous metals.

[10] For example, the Doe Run Co. spends about 17 percent of its annual production costs on environmental compliance. USITC staff interview with J. Zelms, CEO, Oct. 22, 1998.

[11] *Lead Annual Review*, 1997, p.1.

highest recycling rate of all the common nonferrous metals, and the use of secondary metal makes some important contributions to the environment:

- The recovery of lead from scrap requires far less energy than smelting from ore.
- Recycling keeps unwanted products out of the waste stream.
- Recycling conserves natural resources.

Table 2-1
Lead producing mines in the United States in 1997, in order of output

Mine	County and state	Operator	Source of lead
Red Dog	NW Arctic, AK	Cominco Alaska Inc.	Zinc ore
Buick	Iron. MO	The Doe Run Co.	Lead-zinc ore
Casteel[1]	Iron, MO	The Doe Run Co.	Lead-zinc ore
Fletcher	Reynolds, MO	The Doe Run Co.	Lead-zinc ore
Sweetwater	Reynolds, MO	ASARCO Inc.[2]	Lead-zinc ore
West Fork	Reynolds, MO	ASARCO Inc.[2]	Lead-zinc ore
Green Creek	Southeastern, AK	Kennecott Minerals Corp.	Zinc ore
Lucky Friday	Shoshone, ID	Hecla Mining Co.	Lead-zinc ore
Viburnum No. 29	Washington, MO	The Doe Run Co.	Lead-zinc ore
Viburnum No. 28	Iron, MO	The Doe Run Co.	Lead-zinc ore
Montana Tunnels	Jefferson, MT	Pegasus Gold Corp.	Zinc ore
Leadville Unit	Lake, CO	ASARCO Inc.	Zinc ore
Sunshine	Shoshone, ID	Sunshine Mining Co.	Silver ore
Balmat	St. Lawrence, NY	Zinc Corporation of America	Lead-zinc ore
Pierrepont	St. Lawrence, NY	Zinc Corporation of America	Lead-zinc ore
Coy	Jefferson, TN	ASARCO Inc.	Zinc ore

[1] Includes Brushy Creek Mill.
[2] In 1998, ASARCO Inc. sold its Sweetwater and West Fork mines to The Doe Run Co. Please refer to the text for more information on the sale.

Source: U.S. Geological Survey

Secondary lead, derived principally from scrapped lead-acid batteries, accounted for 76 percent of refined lead production in the United States. Lead recovered from scrap lead-acid batteries accounted for 97 percent of all lead produced from secondary sources. Ninety-eight percent of secondary lead production was generated by 10 companies that operated 17 smelters, each with annual capacity of 10,000 (mt) or more.

The leading U.S. producers are Asarco Inc., Doe Run Co., and Cominco Alaska Inc., which together accounted for 92 percent of domestic production in 1997. Asarco Inc., which operated four mines in Missouri, completed modernization of its Glover, MO, facility in 1997, bringing it into compliance with Federal ambient air standards.[12] As part of its strategy to

[12] *Lead Annual Review*, 1997, p.4.

concentrate on silver and copper operations, Asarco sold its Missouri lead business to Doe Run in September 1998.[13] The sale included two underground lead mines, Sweetwater and West Fork, and the Glover smelter and refinery, all in southeast Missouri. The purchase price was nearly $75 million.

Before this acquisition, the Doe Run Co., of St. Louis, MO, operated five lead mines and four mills centered in southeastern Missouri. The company also operates a state-of-the-art battery recycling facility for recovery of secondary lead. With the recent acquisition of Asarco's lead business in Missouri, Doe Run is the only domestically owned primary lead producer in the United States. The company expects to operate these mines and plants in conjunction with existing operations in a more efficient manner that will increase production and lower costs.[14] Doe Run also recently acquired 100-percent interest in the La Oroya smelting and refining complex owned by Peru's Empresa Minera del Centro del Peru (CETROMIN).[15] Doe Run is the only domestic lead company reported to have invested in overseas lead production.

Cominco Alaska Inc., a wholly owned subsidiary of Cominco Ltd. of Toronto, Canada, operates the Red Dog zinc-lead mine in northwestern Alaska. Cominco Ltd., also continued development of the Pend Oreille zinc-lead mine near Metaline Falls, WA, which it purchased from Resource Finance Corp. of Toronto in 1996. Surface and underground drilling were performed at the mine to locate new zones for potential mining.

Foreign presence in the U.S. lead industry may increase with conclusion of a 1997 agreement between Teck Corp. of Vancouver and Sumitomo Metal Mining of Tokyo, Japan. This joint venture agreement would permit exploration of the 16,000 square km Stone Boy survey area of Alaska for lead-zinc deposits until 2000.[16] Also, Venture Resource Corp., an international exploration company, reported the discovery of significant sulfide mineralization containing lead, zinc, and silver on its Lead Creek property in east-central Alaska.[17]

Research and Development

In response to curtailed demand by the gasoline and paint industries, lead producers are developing new uses for lead. Since 1992, $37 million has been spent by the Advanced Lead Acid Battery Consortium (ALABC), whose members include the world's major primary and secondary lead producers and lead-acid batteries manufacturers, on developing a battery suitable for use in electric and hybrid electric vehicles.[18] Furthermore, ALABC supports ongoing research for lead batteries in the transportation, telecommunication, and computer industries.

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[13] "ASARCO Sells Missouri Lead Business to Doe Run," *Platt's Metals Week*, April 27, 1998, p. 15.

[14] Ibid.

[15] *Lead Annual Review, 1997*, p.4.

[16] Ibid.

[17] Ibid.

[18] "Legislation: a lead weight for the industry?," *Metal Bulletin Monthly*, Apr. 1998, p. 14.

In other recent developments, the International Lead Zinc Research Organization and the Solar Energy Industries signed a memorandum of understanding with the Government of Peru to begin demonstrations of the Remote Area Power Systems (RAPS). RAPS uses renewable energy sources such as wind, solar, or hydro, with a lead-acid storage battery energy system. The goal of this project is to cut the use of diesel generators in Peruvian villages in the Amazon River Basin to two hours per day. The potential future market for lead in storage batteries for this application in Peru is estimated between 250,000 mt to 500, 000 mt.[19]

U.S. Government Programs

The National Defense Authorization Act in 1993 authorized the sale of all available lead inventory at reasonable prices. The starting inventory was 545,365 mt and the yearly quota to be sold is limited to 54,000 mt. Sales of lead from the Defense National Stockpile continued monthly through the 1993-97 period, and the 1997 yearend inventory was 363,000 mt. Annual sales from the stockpile have averaged about 32,000 mt.

U.S. Market

Consumer Characteristics and Factors Affecting Demand

The United States and Canada are the world's largest markets for lead. U.S. consumption of both primary and secondary lead steadily increased during 1993-97, rising 29 percent from 411,000 mt to 529,000 mt. This trend is expected to continue, relative to demand for automobiles and other vehicles.[20] Demand for lead in other industries is also growing, as lead is increasingly used in such diverse products as emergency power systems (e.g., for hospitals), computers, glass and plastic, and radiation shielding. As demand in lead-acid storage batteries increases, nonbattery uses of lead are expected to grow at a slower rate.[21] Import penetration of primary lead products peaked in 1996 at 60 percent but declined by 5 percent in 1997, largely due to increased primary and secondary lead production in the United States and increased foreign demand.[22]

Consumption

Long-term lead consumption is cyclical and follows market conditions in its primary consuming sector, transportation. In 1997, lead was consumed at about 160 U.S. manufacturing plants; the transportation industry, the principal user of lead, consumed 87

[19] *Lead, Annual Review, 1997,* p.1.

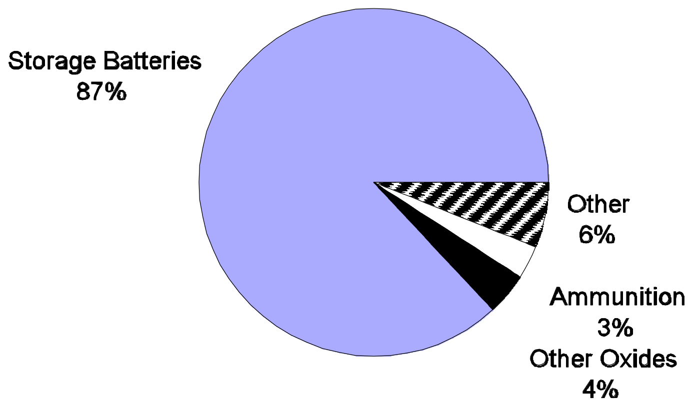
[20] USITC conversation with industry officials, Nov. 1998.

[21] *U.S. Industry & Trade Outlook '98*, prepared by the U.S. Department of Commerce, International Trade Administration.

[22] Ibid.

percent of it for batteries (figure 2-2).[23] Short-term consumption reflects weather conditions; in severe weather, demand for replacement car batteries rises, increasing demand for lead.

Figure 2-2
End uses of lead



Source: U.S. Geological Survey

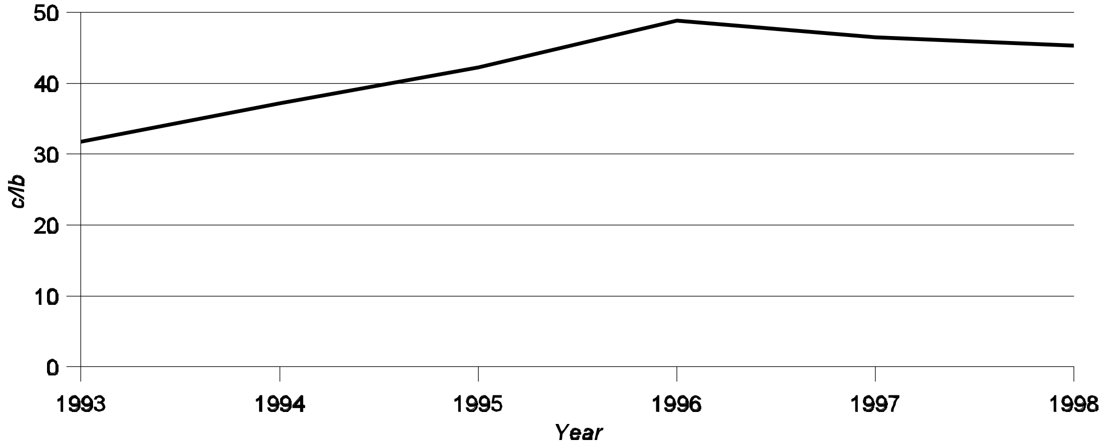
Largely in response to environmental legislation, the lead industry faces strong competition from other materials in a number of end uses. For example, substitution by plastics has reduced the use of lead in building construction, electrical cable covering, cans, and containers. Aluminum, tin, iron, and plastics compete with lead in other packaging and protective coatings, and lead-free tin alloys have replaced lead alloys in solder for new or replacement potable water systems in the United States.[24] In the automotive industry, Mitsubishi Motors Corp. is introducing lead-free coated steel sheet in fuel tanks, while Nissan Motor Co. has developed a steel wheel-balancing weight that will be used in new models starting in 1998.[25]

Prices

After increasing yearly since 1993, lead prices declined in 1997 (figure 2-3). The average 1997 London Metal Exchange (LME) and North American Producer prices fell by $0.029 per pound and $0.023 per pound, respectively, from the average 1996 prices of $0.312 and $0.488 per pound.[26] Lower prices may continue in the near term, as surplus stocks are expected to develop because of increased production and the opening of several mines (Cannington in Australia and Faro in Canada).

[23] *Lead Annual Review, 1997,* p.1.
[24] Ibid.
[25] "Mitsubishi and Nissan Reduce Lead Use," *American Minerals and Metals,* Sept. 1998, found at Internet address http//www.amm.com/subscrib/1998/inside/0908nf.htm, retrieved Sept. 11, 1998.
[26] *Lead, Annual Review, 1997,* p.1.

Figure 2-3
Lead: North American producer price



Note: Prices are annual averages for 1993-97, and June average for 1998.

Source: U.S. Geological Survey.

Production

The United States is the world's third largest producer of primary lead and the largest producer of secondary lead. Strong domestic demand by the transportation industry and rising environmental pressure[27] contributed to increased secondary lead production and scrap recovery during 1993-97. Secondary production increased 24 percent (from 893,000 mt to 1.1 million mt), more than twice the rate of the 11-percent increase in primary production (310,000 mt to 343,000 mt). See table 2-2. With the increase in domestic secondary production, more lead is produced domestically by recycling than by mining; secondary lead accounts for more than 75 percent of domestic lead refinery production. Industry experts expect this trend to continue.[28]

[27] In June 1997, the EPA issued a direct final rule amending national emission standards for hazardous air pollutants from secondary lead smelting. The rule establishes standards to limit hazardous air pollutant emissions from smelting furnaces, refining kettles, agglomerating furnaces, dryers, and fugitive dust sources at major and area source secondary lead smelters.

[28] "Current Trends for Lead and Zinc," *Mining Journal*, June 19, 1998.

Table 2-2
Unwrought Lead: U.S. primary production of ores, concentrates, and bullion, exports of domestic merchandise, imports for consumption, and apparent consumption, 1993-97 and January-June 1998

Year/period	U.S. production	U.S. exports	U.S. imports	Apparent U.S. consumption	Ratio of imports to consumption
	))))))))))))))))))))))) ***1,000 metric tons***			)))))))))))))))))))))))))	***Percent***
1993	310	87	183	406	45
1994	328	105	211	434	49
1995	374	119	236	491	48
1996	326	162	246	410	60
1997	343	130	256	469	55
January - June—					
1998	165	45	127	247	51

Note.— Secondary production was excluded from this table because of the lack of statistical information available for imports and exports of secondary products.

Source: U.S. Geological Survey

U.S. Trade

Overview

The U.S. trade deficit for unwrought lead and lead waste and scrap decreased from $28 million to $21 million (25 percent) during 1993-97 after peaking at $98 million in 1995 (table 2-3). Improvement in the trade deficit since 1995 is attributable to the closure of the Canadian Faro lead-zinc mining complex, increased reliance on domestic production, and declining import value due to falling prices.

The largest U.S. trading partners during the period were Canada and Mexico. The closure of lead refinery facilities in the United States contributed to increased exports of lead bullion to Canada and Mexico but also led to increased imports of unwrought refined lead reexported to the United States for further manufacture.

Table 2-3
Unwrought lead and lead waste and scrap: U.S. exports of domestic merchandise, imports for consumption, and merchandise trade balance, by selected countries and country groups, 1993-1997[1]

(*Million dollars*)

Item	1993	1994	1995	1996	1997
U.S. exports of domestic merchandise:					
Canada	17	25	30	67	104
Mexico	([2])	2	1	28	12
Belgium	4	11	12	11	26
Korea	12	20	21	23	8
Japan	3	3	5	5	8
Peru	0	([2])	0	([2])	0
United Kingdom	([2])	([2])	([2])	([2])	5
Malaysia	1	1	1	([2])	3
Taiwan	6	6	11	10	2
Australia	([2])	([2])	([2])	([2])	([2])
All Other	16	7	5	6	4
Total	59	73	86	150	171
EU-15	7	11	13	13	32
OPEC	2	1	([2])	2	1
Latin America	9	5	3	30	12
CBERA	([2])	([2])	([2])	([2])	([2])
Asian Pacific Rim	25	31	38	38	22
ASEAN	3	2	1	([2])	4
Central and Eastern Europe	0	0	0	0	0
U.S. imports for consumption:					
Canada	59	95	126	160	136
Mexico	17	17	36	47	44
Belgium	([2])	2	([2])	([2])	([2])
Korea	([2])	1	0	0	0
Japan	0	([2])	0	0	0
Peru	7	14	15	14	5
United Kingdom	([2])	([2])	([2])	([2])	([2])
Malaysia	0	0	0	0	0
Taiwan	0	0	0	0	0
Australia	2	([2])	0	0	2
All Other	1	8	7	4	4
Total	87	138	184	225	192
EU-15	1	6	3	1	1
OPEC	1	1	1	1	([2])
Latin America	24	32	52	63	50
CBERA	([2])	([2])	([2])	([2])	([2])
Asian Pacific Rim	2	1	([2])	([2])	2
ASEAN	0	0	0	0	0
Central and Eastern Europe	0	([2])	1	0	0
U.S. merchandise trade balance:					
Canada	-43	-70	-96	-93	-32
Mexico	-17	-15	-35	-19	-33
Belgium	3	9	12	11	26
Korea	12	19	21	23	8
Japan	3	3	5	5	8
Peru	-7	-14	-15	-14	-5
United Kingdom	([2])	([2])	([2])	([2])	5
Malaysia	1	1	1	([2])	3
Taiwan	6	6	11	10	2
Australia	-2	([2])	([2])	([2])	-2
All Other	15	-2	-2	2	([2])
Total	-28	-64	-98	-75	-21
EU-15	6	6	11	12	31
OPEC	1	([2])	-1	([2])	([2])
Latin America	-14	-27	-49	-33	-38
CBERA	([2])	([2])	([2])	([2])	([2])
Asian Pacific Rim	23	30	38	38	20
ASEAN	3	2	1	([2])	4
Central and Eastern Europe	0	([2])	-1	0	0

[1] Import values are based on Customs value; export values are based on f.a.s. value, U.S. port of export.
[2] Less than $500,000.

Note.—Because of rounding, figures may not add to totals shown. The countries shown are those with the largest total U.S. trade (U.S. imports plus exports) in these products in 1997.

Source: Compiled from official statistics of the U.S. Department of Commerce.

U.S. Imports

Principal Suppliers and Import Levels

Canada and Mexico, the two largest import sources of lead for the United States, accounted for over 71 and 23 percent, respectively, of all U.S. lead imports in 1997 (table 2-3). Both countries' imports are competitive because of their proximity and extensive ties to U.S. production.[29] During 1993-96, imports steadily increased at an average annual rate of 38 percent, rising from $87 million to $225 million. However, in 1997, there was a 15 percent decrease in the value of imports, largely attributable to increased U.S. production and the 1996 closure of the Canadian Faro lead-zinc mining complex. In terms of overall quantity, imports of unwrought refined lead remained relatively unchanged in the first six months of 1998. However, Mexican imports accounted for a larger share, largely because of declining prices for Mexican products.

Unwrought refined lead is the leading type of import (table 2-4), accounting for over 70 percent of all U.S. lead imports in 1997. This type of lead import will likely increase relative to imports of bullion and other unrefined products, reflecting increased reliance on *toll smelting* abroad of lead bullion exports due to the closure of domestic smelting facilities.

U.S. Trade Measures

U.S. column-1 rates of duty applicable to imports of primary lead and lead waste and scrap are provided in table 2-5. The average trade-weighted ad valorem column-1 general rate of duty for these products was 2.9 percent. Rates of duty for countries qualifying for special tariff programs are also shown.

[29] USITC conversation with an industry official, Oct. 1998.

Table 2-4
Unwrought, refined lead: U.S. imports for consumption, by principal sources, 1994-97, January - June 1997, and January - June 1998

Source	1994	1995	1996	1997	January - June— 1997	January - June— 1998
	Quantity (*metric tons*)					
Canada	119,079	124,654	140,612	136,068	68,208	63,119
Mexico	29,548	49,706	55,165	67,377	24,987	33,872
Peru	25,608	22,115	17,114	6,421	3,200	1,400
India	0	207	607	766	749	0
El Salvador	0	0	0	20	20	0
United Kingdom	0	0	19	([1])	([1])	0
Australia	500	0	0	0	0	0
Belgium	0	0	0	0	0	0
Kazakhstan	25	0	0	0	0	0
Namibia	3,197	0	0	0	0	0
All other	7,508	3,695	0	0	0	3
Total	185,463	200,378	213,517	210,653	97,165	98,393
	Value (*1,000 dollars*)					
Canada	65,742	80,978	111,122	94,333	49,081	45,992
Mexico	15,370	30,372	40,862	39,884	15,925	17,433
Peru	14,419	14,609	13,707	4,104	2,168	759
India	0	191	360	374	366	0
El Salvador	0	0	0	14	14	0
United Kingdom	0	0	31	3	3	0
Australia	191	0	0	0	0	0
Belgium	0	0	0	0	0	0
Kazakhstan	14	0	0	0	0	0
Namibia	2,001	0	0	0	0	0
All other	4,393	2,236	0	0	0	13
Total	102,130	128,387	166,082	138,712	67,556	64,196
	Unit value (*dollars per kilogram*)					
Canada	0.55	0.65	0.79	0.69	0.72	0.73
Mexico	0.52	0.61	0.74	0.59	0.64	0.51
Peru	0.56	0.66	0.80	0.64	0.68	0.54
India	([2])	0.92	0.59	0.49	0.49	([2])
El Salvador	([2])	([2])	([2])	0.69	0.69	([2])
United Kingdom	([2])	([2])	1.61	8.16	8.16	([2])
Australia	0.38	([2])	([2])	([2])	([2])	([2])
Belgium	([2])	([2])	([2])	([2])	([2])	([2])
Kazakhstan	0.59	([2])	([2])	([2])	([2])	([2])
Namibia	0.63	([2])	([2])	([2])	([2])	([2])
All other	0.59	0.61	([2])	([2])	([2])	4.54
Average	0.55	0.64	0.78	0.66	0.70	0.65

[1] Less than 500.
[2] Not applicable.

Note.—Because of rounding, figures may not add to the totals shown.

Source: Compiled from official statistics of the U.S. Department of Commerce

Table 2-5
Unwrought lead and lead waste and scrap: Harmonized Tariff Schedule (HTS) subheading; description; U.S. column 1 rate of duty as of January 1, 1998; U.S. exports, 1997; and U.S. imports, 1997

HTS subheading	Description	Col. 1 rate of duty as of January 1, 1998 General	Special[1]	U.S. exports, 1997	U.S. imports, 1997
		Percent		*— Million dollars —*	
2607.00.00	Lead ores and concentrates	1.2¢/kg on lead content	Free (A, CA, E, IL, J, MX)	28	([2])
2620.20.00	Lead ash and residues	0.1¢/kg on copper and lead content	Free (A, CA, E, IL, J, MX)	8	([2])
7801.10.00	Refined lead, unwrought	2.7% on value of lead content	Free (A, CA, E, IL, J, MX)	27	139
7801.91.00	Lead, unwrought containing by weight antimony as the primary other element	2.7% on value of lead content	Free (A, CA E, Il, J, MX)	4	([2])
7801.99.00	Lead bullion & alloys, unwrought . .	2.7% on value of lead content	Free (A, CA, E, IL, J, MX)	89	51
7802.00.00	Lead waste & scrap	0.5% on value of lead content	Free (A, CA, E, IL, J, MX)	16	([2])
	Total and weighted average	2.9%		171	192

[1] Products under which special tariff treatment may be provided, and the corresponding symbols for such programs as they are indicated in the "Special" subcolumn, are as follows: Generalized System of Preferences (A); Automotive Products Trade Act (B); North American Free Trade Agreement, Goods of Canada (CA) and Mexico (MX); Carribean Basin Economic Recovery Act (E); United States-Israel Free Trade Area (L); and Andean Trade Preference Act (J).
[2] Less than $500,000.

Note.—Because of rounding, figures may not add to the totals shown.

Source: U.S. exports and imports compiled from data of the U.S. Department of Commerce.

U.S. Exports

Principal Markets and Export Levels

U.S. exports increased during 1993-97, with the largest annual increase (74 percent) between 1995-1996 (table 2-3). Over 60 percent of U.S. exports of unwrought lead and lead waste and scrap were directed to the Canadian market during 1997, most of which consisted of unwrought lead bullion (table 2-6). The permanent closing of Asarco's lead refinery in Omaha, NE, resulted in exports of all lead bullion produced at its East Helena facility. Canada is regarded as an attractive market due to its close proximity to the United States and the lack of tariff barriers for U.S. producers. However, exports to Mexico increased by 68 percent in the first 6 months of 1998. The level of total U.S. lead exports is expected to continue to increase because of higher foreign demand for lead-acid batteries and rising U.S. production of lead bullion.

Table 2-6
Lead bullion: U.S. exports of domestic merchandise, by principal markets, 1994-97, January-June 1997, and January-June 1998

Source	1994	1995	1996	1997	January - June— 1997	1998
	Quantity (*metric tons*)					
Canada	115	43	16,608	24,344	13,137	7,517
Mexico	7	123	24,399	9,623	6,441	10,807
Belgium	16	1,179	228	113	113	0
Israel	132	253	0	0	0	0
Italy	0	0	9	0	0	0
All other	0	0	0	0	0	0
Total	270	1,597	41,245	34,081	19,691	18,324
	Value (*1,000 dollars*)					
Canada	129	44	36,225	76,405	42,868	19,837
Mexico	7	130	27,433	10,824	7,242	12,151
Belgium	212	1,770	667	702	702	0
Israel	97	180	0	0	0	0
Italy	0	0	10	0	0	0
All other	0	0	0	0	0	0
Total	446	2,125	64,335	87,931	50,811	31,988
	Unit value (*dollars per kilogram*)					
Canada	1.12	1.03	2.18	3.14	3.26	2.64
Mexico	1.12	1.06	1.12	1.12	1.12	1.12
Belgium	12.88	1.50	2.92	6.20	6.20	([1])
Israel	0.74	0.71	([1])	([1])	([1])	([1])
Italy	([1])	([1])	1.12	([1])	([1])	([1])
All other	([1])	([1])	([1])	([1])	([1])	([1])
Average	1.65	1.33	1.56	2.58	2.58	1.75

[1] Not applicable.

Note.—Because of rounding, figures may not add to the totals shown.

Source: Compiled from official statistics of the U.S. Department of Commerce

Foreign Trade Measures

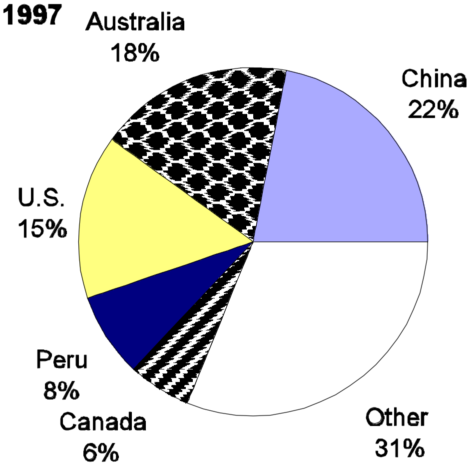
In 1998, imports of U.S. origin primary lead products, except lead ash and residue, entered Mexico free of duty under NAFTA. The Mexican tariff rate under NAFTA for imports of lead ash and residues was 5 percent effective January 1, 1998, and under a staged reduction of 1 percent each year, such imports will be eligible for duty-free treatment effective January 1, 2003. Imports of unwrought lead bullion and alloys of U.S. origin entered Canada free of duty under the CFTA. The Commission is unaware of any nontariff measures that affect U.S. exports of primary lead products.[30]

[30] The Basel Convention specified hazardous waste products and imposed tariff barriers to discourage imports and exports of these materials among the signing countries. The main lead (continued...)

Foreign Industry

Lead was mined in 44 countries, the top 5 of which accounted for 69 percent of total world production of just over 3 million mt in 1997 (figure 2-4). During 1993-97, global lead production was pushed in two opposing directions. As the European Union initiated legislation to restrict the production and use of lead because of environmental and health concerns, other regions such as Latin America and Asia sought to increase production by attracting foreign investment and modernizing existing facilities.

Figure 2-4
World production of lead, 1997



Source: U.S. Geological Survey

Scrutiny of the environmental and health effects of lead products has increased internationally. The European Commission is developing draft directives that would eliminate virtually all lead from motor vehicles, except batteries. Denmark has proposed a ban on the import, sales, and production of lead and products containing the metal. Sweden, Norway, Finland, and Iceland are also considering similar legislation. Sweden's proposed policy would completely eliminate the use of lead, including that used in automotive batteries, by 2007.[31]

In other recent legislative developments, Canada's Health Protection Board issued a discussion paper in August 1997 proposing a strategy for reducing lead in childrens' products and other consumer goods. The paper set forth guidelines that call for the lead content of relevant products not to exceed 15 ppm.[32]

Also, the Environment and Standing Committee of the International Lead and Zinc Study Group (ILZSG) met on April 23-24, 1998, to determine how to distinguish between hazardous

[30] (...continued)
product that could have been included was lead-acid battery scrap, but was not due to its high-rate of recyclability.

[31] "Linked metals head in different directions," *Metallurgical & Mineral Processing Developments*, August, 1998, no. 4, p. 19.

[32] "Legislation: a lead weight for the industry?" *Metal Bulletin Monthly*, Apr. 1998.

lead waste and secondary raw materials, and how to reclassify lead wastes. Delegates reviewed U.S. draft legislation detailing the distinction since the U.S. assessment of this issue reportedly is the most advanced in the world. The committee recommended that ILZSG member countries adopt legislation modeled after the U.S. draft,[33] despite anticipated cost increases for secondary lead production and waste disposal.

China

China is currently the world's largest producer of lead, but its output is projected to decline by as much as 40 percent by the year 2000. Factors contributing to China's diminished position in the global industry include the significant depletion of reserves at several large, relatively old, state-owned mines and decreasing domestic investment in these operations. China reportedly hopes to reverse the trend by encouraging foreign investment in the mining sector. Under the new Mineral Resource Act, which became effective at the beginning of 1998, foreign companies will be permitted to own equity interest in Chinese mining projects.[34] The potential impact of reduced Chinese exports on overall global supply may be partially offset by the increased production in Australia and Canada.

Australia

Australia is the second-largest lead producer in the world. Australian production is expected to increase as a result of a 1997 settlement of a legal dispute between mining companies and aboriginal Native Title claimants, clearing the way for the development of a large zinc-lead deposit in Queensland.[35] This deposit is expected to come into production by year-end 2000 and augment world mine production of lead by about 2 percent.[36] In addition, the opening of Cannington Mine in Queensland reportedly will increase world lead mine output by 4.4 percent to 3.1 million tons.[37]

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[33] U.S. Department of State telegram No. 004602, "ILZSG: April 23-24 Environment and Standing Committee Meetings," prepared by U.S. Embassy, London, May 1, 1998.

[34] Previously, the mining sector had been off-limits to foreign investment. *Lead Annual Review, 1997*, p.7.

[35] Australia's RTZ-CRA, recently renamed Rio-Tinto Ltd., signed an agreement with the aboriginal Native Title claimants and the local government of Queensland, allowing for the sale of its Century zinc-lead mine to Pasminco Mining Ltd. The Queensland state government agreed in May 1997, to reinstate it's A$30 million compensation package to the Native Title claimants. In September 1997, the Queensland state parliament passed the Century Zinc Project Bill, providing final clearance for completion of the sale and the start of construction by the last quarter of 1997. Ibid.

[36] Ibid.

[37] "Lead metal demand expected to fall 1%," *American Minerals and Metals*, April 1998, found at Internet address http://www.amm.com/cg-win/csearch, retrieved, July 7, 1998.

Canada[38]

Canada is the United States' largest trading partner and its share of U.S. trade has been steadily increasing as U.S. legislation effects a shift toward domestic secondary production. Canadian lead producers hold interests in lead mines in the United States, Mexico, Spain, and Tunisia, and are actively pursuing other overseas interest. Two of Canada's leading lead producers have recently expanded domestic operations in anticipation of increased global demand. Cominco opened a new 120,000 metric tons per year (mtpy) Kivcet lead smelter and slag fuming furnace at Trail, British Columbia, replacing an aging 100,000 mtpy lead smelter. In January 1997, Cominco also acquired a 28 percent interest in the Anvil Range company in a joint venture with Switzerland's Glencore Ltd.; the purchase price was C$9.4 million with an additional C$20 million provided in loans for upgrades to the mine. Also, Nova Pb, the largest secondary lead producer, added a secondary rotary kiln and auxiliary technology to increase lead smelting capacity at its Sainte Catherine, Quebec, facility from 60,000 mtpy to 90,000 mtpy by the year 2000.

Other Countries

Other countries are also actively seeking foreign investment to expand lead production in anticipation of increased demand. For example, Bolivia is promoting investment opportunities in the San Vincent and San Jose mines to help expand production.[39] In India, state-run Hindustan Zinc Ltd. (HZL), the main primary lead producer, plans to seek joint ventures to increase output of lead concentrate; HZL currently has the capacity to produce 65,000 mt of lead annually. Indian Lead Ltd., the country's main secondary lead producer, intends to expand annual capacity to 40,000 mt in 1999, almost double the 1998 level of 24,000 mt. Indian demand for lead is forecast to grow at 7 percent annually, and consumption is projected to reach 120,000 mt by 2002.[40] In Southeast Asia, the Japanese Metal Mining Agency and the Japan International Cooperation Agency are embarking on a 3-year exploration of lead and zinc mineral resources in the Mae Sariang region of Thailand. Investigations will involve analysis of existing data, geological surveys, geochemical probes, and physical exploration work, combined with boring operations to pinpoint promising lead-zinc deposits.[41]

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[38] Information in this section is from Annual Mining Review, *Mining Journal*, London, May 15, 1998, p. 5, unless otherwise noted.

[39] Ibid.

[40] Ibid.

[41] "Japan seeks Thai lead, zinc," *American Minerals and Metals*, Nov. 1997, found at Internet address http://www.amm.com/cg-win/csearch, retrieved July, 1998.

Outlook

The future outlook of production and consumption of lead looks promising despite some proposed legislative restrictions. Given rising population and living standards, an increased use of lead-acid batteries for automobiles and energy-storage applications is likely, as well as an increased demand for lead shingles in the roofing industry. Production is expanding and investment increasing in countries that have less-restrictive legislation affecting lead. Lead producers worldwide are investing in research and development to find new uses of lead to offset potential restrictions stemming from environmental legislation.

CHAPTER 3
Zinc

Introduction

Zinc is the third most commonly used nonferrous metal in the world, following copper and aluminum. It is a lustrous, bluish-white metal element, brittle at ordinary temperatures but ductile and malleable at 100-150° Celsius, nonreactive in water, and resistant to corrosion in dry air at ordinary temperatures. Though essential to modern living, zinc applications are generally intermediary processes for other end-use products and are therefore not generally recognized by the public. For example, nearly half of global zinc consumption in 1997 was for *galvanizing*[1] applications, primarily for steel products consumed by the automotive and building construction industries. Other uses include alloying with copper to make brass, die castings for home appliances as well as automotive, plumbing, and electrical apparatus, and chemical compounds in rubber and paints.

Zinc is one of the less commonly occurring elements in nature, comprising an estimated 0.0005 to 0.02 percent of the earth's crust.[2] But from this crustal resource endowment, the global zinc mining industry produced about 7.1 million metric tons (mt) of zinc ores and concentrates and 7.6 million mt of zinc slab[3] in 1997, drawing from the previous year's concentrate input supply. Most countries report zinc production.[4] Canada is the largest producer of ores and concentrates, accounting for 15 percent of world production in 1997 (1.1 million mt), followed by Australia (961,800 mt), China (900,000 mt), and Peru (857,100 mt).[5] The United States accounted for approximately 8 percent (588,800 mt). China is the largest producer of zinc slab (17 percent or 1.3 million mt), followed by Canada (702,200 mt), Japan (603,100 mt), and the United States (375,400 mt) in 1997.[6] This rank order among producers has been consistent since 1994; in 1993, Japan was the second largest producer of zinc slab followed by Canada and the United States.

Domestic demand for zinc metal grew during 1993-97, but U.S. refining capacity was insufficient to process U.S. concentrate output and meet demand. In 1997, the United States exported 80 percent of its concentrate production for refining and imported 68 percent of its refined zinc consumption. Industry products covered in this chapter include zinc ores and concentrates, waste and scrap, refined, and unwrought zinc metal. Analysis generally covers the 5-year period 1993-97.

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[1] Galvanizing is the process for coating iron or steel with zinc to retard rust and corrosion. Italicized words are defined in the glossary, appendix B.

[2] William E. Cooley, "Zinc," *McGraw-Hill Encyclopedia of Science and Technology*, 6th ed. (New York: McGraw-Hill Book Company, 1987), vol. 19, p. 620.

[3] Slab is the term used for zinc cast in various shapes and sizes; slabs typically weigh 25 kilograms. A registered brand name is cast into the metal identifying the producer and purity grade.

[4] Unwrought zinc refers to refined zinc that has not been formed in downstream products such as powders, wires, sheets, and tubes.

[5] *World Metal Statistics*, World Bureau of Metal Statistics, June 1998, p. 128.

[6] Ibid., p. 129.

Production Process

The primary zinc industry produces metal from mined zinc-containing ore through a series of metallurgical operations common to many nonferrous metals: concentration, smelting, refining, and casting. Depending on the intended end use, further shaping or finishing operations such as rolling may be undertaken. These operations are typically conducted at separate locations. The mineralogy of the ore determines the technology employed and the economics of the operations. Most zinc ores of commercial value are zinc sulfide minerals (sphalerite); a smaller, but still important source is oxidized zinc ores, which may include zinc silicate and zinc carbonate. Metals commonly occurring in zinc ores include lead, copper, silver, and gold, which can contribute to the economic viability of a deposit if they can be separated and recovered as coproducts or by-products.[7] See figure 3-1 for an overview of the primary zinc metallurgy process.

Concentration

Concentration of zinc sulfides usually occurs adjacent to the mine site, to minimize the transportation costs of moving waste material. Ore is ground to a fine particle size and separated; the specific type of separation process depends on the mineralogy of the zinc-bearing ores which is based on such important factors as the types of metallic and nonmetallic minerals, size and interlocking structure of the mineral grains, and degree of oxidation or coating with soluble salts on the mineral surfaces. Most zinc ores are separated by a process called *flotation*. *Gravity concentration* is another separation method suitable for coarse-grained zinc ores. The last step is a filtration process to remove liquid from the zinc concentrate and solidify it. The resulting grade of the concentrate and types of remaining mineral impurities affect subsequent reduction methods and costs, and thus, directly affect the terms of purchase offered by zinc smelters.

Oxidized zinc ores also require mineral separation and concentrating, but this process is generally performed in conjunction with the *smelting* operation rather than at the mine site. Oxidized zinc ores may be of sufficient grade to skip the concentrate operation and pass directly to the smelting operation. Alternatively, the oxidized ore may require the injection of sodium sulfide to coat the surfaces of the mineral grains for processing as a sulfide form,[8] and other processing variations.

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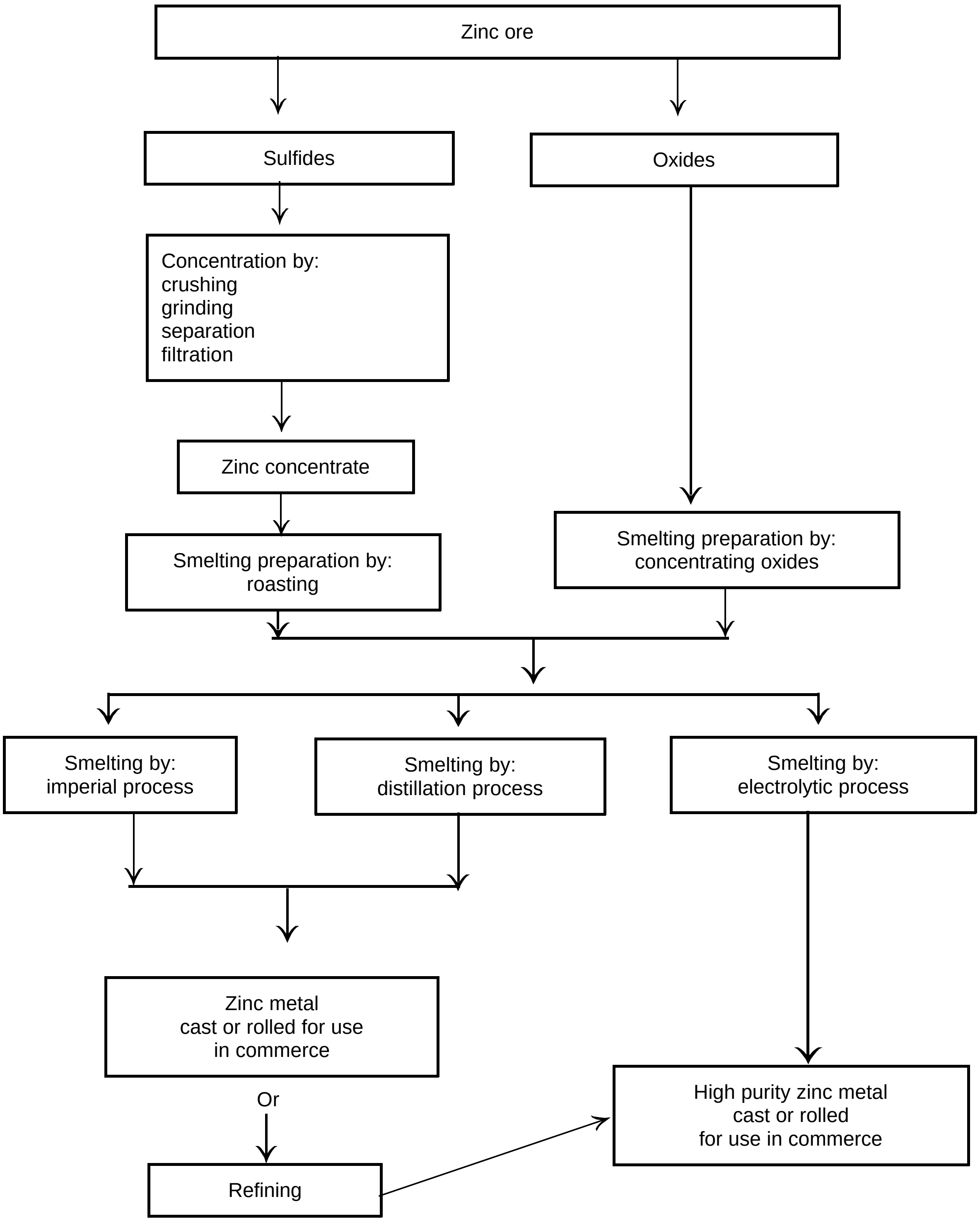
[7] Norman L. Weiss, ed., *SME Mineral Processing Handbook*, vol. 2 (New York: Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, 1985), pp. 15-2 to15-3.

[8] V. Anthony Cammarota, Jr., Herbert R. Babitzke, and John M. Hague, "Zinc," *Minerals Facts and Problems, 1975*, (Washington, DC: U.S. Bureau of Mines, 1975), p. 1230.

Figure 3-1
Primary zinc: Production



Source: Compiled by staff of the U.S. International Trade Commission from publications of the U.S. Department of Interior; Norman Weiss, *SME Mineral Processing Handbook*, vol. 2, pp. 15-4 to 15-12; and Carl H. Cotterill, "Zinc Metallurgy": *McGraw-Hill Encyclopedia of Science and Technology*, 6th ed., vol. 19 (New York: McGraw-Hill, 1987) pp. 624-626.

Smelting[9] and Refining

The further reduction of zinc from concentrate is usually accomplished by one of three basic methods: electrolytic deposition from a solution, Imperial smelting process (a blast furnace process), or distillation in retorts or furnaces. The electrolytic process is reportedly the most common method in the world and accounts for about 80 percent of U.S. smelting production. This process generally produces a purer, higher-grade zinc product than other methods and eliminates the need for refining. The preference for this process also reflects the industry's trend of requiring higher-quality zinc.

Before smelting, the zinc concentrate is roasted to eliminate most of the sulfur and produce an impure zinc oxide called roasted concentrate or *calcine*. The roasted concentrate is leached with dilute sulfuric acid to form a zinc sulfate solution, which is then purified and piped to electrolytic cells where the zinc is electrodeposited onto aluminum cathodes. These cathodes are regularly lifted from the tanks and stripped of the zinc, which is then melted in a furnace and cast into slab form, the standard product for zinc commerce. The resulting product is the standards of either special high-grade zinc (99.99 percent pure) or high-grade zinc (99.9 percent pure). To the extent that zinc concentrate shipped to electrolytic plants contains lead, silver, and sometimes gold, these metals are collected from the processing tank as residues and further processed for sale as by-products. Both the Imperial vertical smelter process and the distillation process produce lower grades of zinc.[10]

Further reduction of zinc metal is typically accomplished in vertical fractionating columns. Lead, iron, and other high-boiling impurities are concentrated in the lower end of a column, pushing zinc, cadmium, and other lower-boiling metals over the top and into another column. Lower-boiling metals (impurities) are condensed on top while purified zinc is withdrawn from the bottom and cast into slabs. This process can produce zinc of 99.995-percent purity.

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[9] Smelting is a metallurgy process to further reduce zinc from concentrate and usually involves fusion, a process that turns remaining impurities in the concentrate into lighter fusible slags that can be readily separated and removed from the zinc metal.

[10] The Imperial vertical smelter process has the advantage of treating a mixed zinc-lead concentrate to recover both metals simultaneously, as well as any gold and silver present. This simultaneous recovery reduces coke consumption costs and requires little extra labor as it is a favorable design for lower-quality ores. Basically, carbonaceous matter is burned with the zinc concentrate, the reduced zinc is released as a vapor, condensed to a liquid metal, and cast into slab form. Zinc produced by this method conforms to prime western grade (98.3 percent zinc), containing about 1.2 percent lead and 0.02 percent iron. The distillation process uses one of three kinds of retort plants: batch horizontal, continuous vertical externally heated by fuel, and continuous vertical heated electrothermally. Distillation releases zinc vapor and carbon monoxide from the retorts into condensers where the zinc is collected as a liquid metal and cast into slab form. Distillation normally produces the lower commercial grades of zinc, which can be further reduced of impurities and upgraded through a refining operation.

Secondary smelting

Reclaiming zinc from chemical and metallurgical residues and from scrapped appliances, automobiles, and aircraft dies is an increasingly important source of zinc metal. Nonmetallic forms of zinc, such as residues, are processed in primary and secondary smelters, requiring carbon reduction. The metallic forms are treated in secondary smelters where they are usually melted in special furnaces or retorts. The zinc is selectively vaporized, condensed into a liquid, and cast into slab form for reuse. Although metals reclaimed by the secondary smelting process usually cannot meet higher-grade zinc specifications, even with the benefit of a refining process, careful preselection of the scrap material can result in a purity level of up to high grade (99.9 percent). See figure 3-2 for a diagram of secondary zinc production.

U.S. INDUSTRY PROFILE

During 1968 to 1975, U.S. capacity to refine zinc concentrate declined by almost 50 percent as many U.S. plants became obsolete and failed to meet environmental standards. Subsequently, unable to process all domestic concentrate, the U.S. zinc industry increasingly turned to foreign smelting and refining facilities; by 1997, it exported 80 percent of its concentrate production and imported 68 percent of its zinc metal requirements. Among the world's leading producers of zinc, Canada and Australia are well represented in the U.S. industry. Canada's Cominco Ltd. operates the largest U.S. zinc mining facility, which is located in Alaska, and Australia's Savage Resources Ltd. operates three mines and a smelter facility in Tennessee, one of only three domestic smelter facilities.

Industry Structure[11]

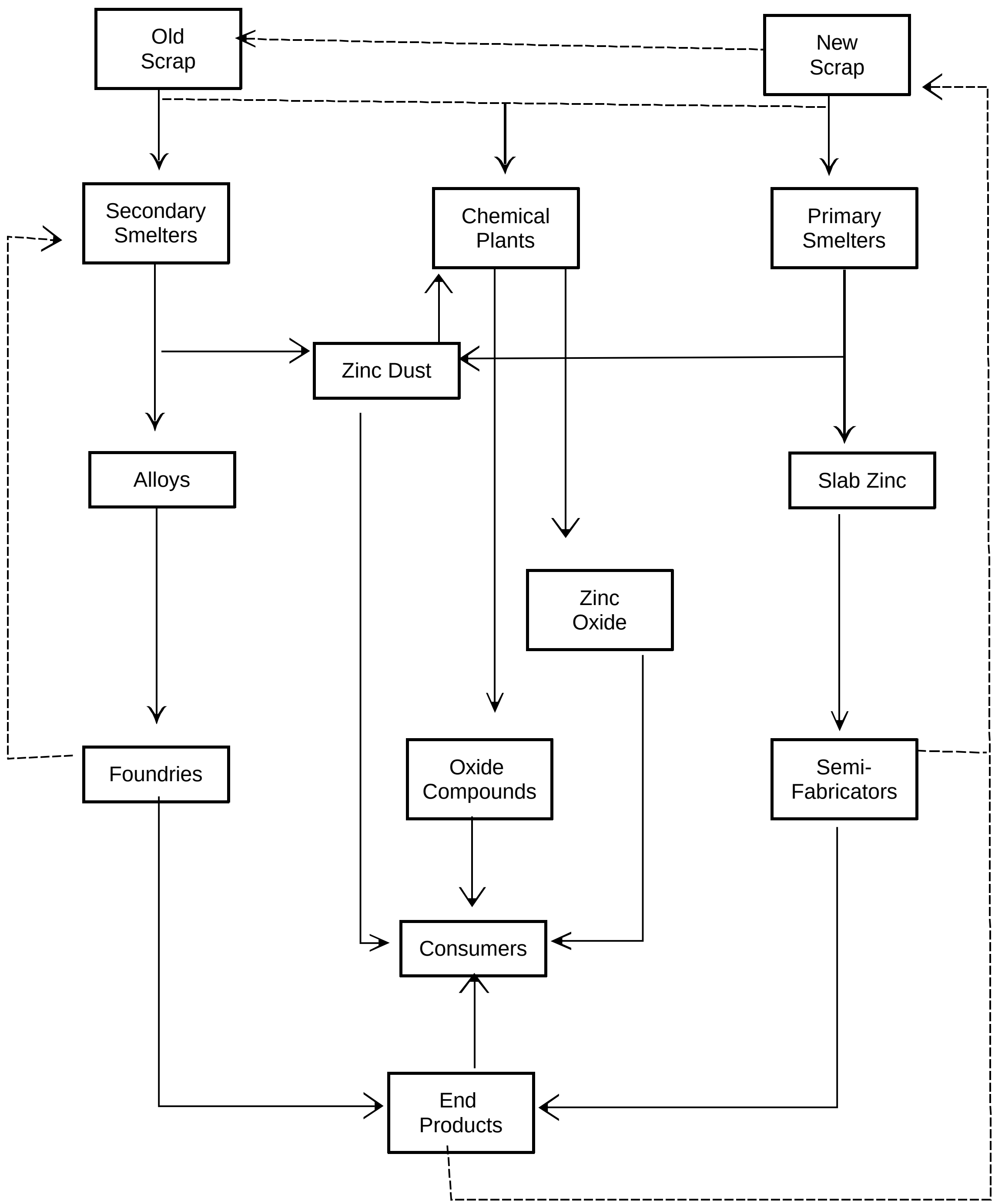
In 1997, the U.S. zinc industry comprised 20 mines located in 7 states (table 3-1) and operated by 8 mining companies, compared with 24 mines operated by 12 mining companies in 1993.[12]

However, the number of employees in the mining sector increased from 2,500 to 2,700 during the same time period. Operations in Alaska, Tennessee, New York, and Missouri together accounted

[11] Information in this section is from Jozef Plachy, "Zinc, 1997 Annual Review," *Mineral Industry Survey*, U.S. Geological Survey, Sept. 1998, unless otherwise indicated.

[12] Zinc ores and concentrates are provided for in Chapter 26 and unwrought refined zinc metals are provided for in Chapter 79 of the *Harmonized Tariff Schedule of the United States*. The Standard Industrial Classification (SIC) coverage of these products generally corresponds with SIC 1031, Lead and zinc ores; SIC 3339, Primary smelting and refining of nonferrous metals, except copper and aluminum; and SIC 3341, Secondary smelting and refining of nonferrous metals.

Figure 3-2
Zinc scrap flow diagram



Source: V. Anthony Cammarota, Jr., Herbert R. Babitzke, and John M. Hague, “Zinc,” *In Mineral Facts and Problems, 1975*, (Washington, DC: U.S. Bureau of Mines, 1975), p. 1234.

for 94 percent of U.S.-mined zinc production in 1997; Alaska was the leading mining state for the seventh consecutive year and accounted for more than one-half of U.S. production, most of which came from Red Dog, the largest U.S. mine.

Table 3-1
Zinc ores and concentrates: Top producing U.S. zinc mines in 1997, in order of output

Rank	Mine	County and state	Operator	Source of zinc
1	Red Dog	Northwest Arctic, AK	Cominco Alaska Inc.	Zinc ore
2	Greens Creek	Southeastern, AK	Kennecott Mining Co.	Zinc ore
3	Balmat	St. Lawrence, NY	Zinc Corporation of America	Zinc ore
4	Elmwood-Gordonsville	Smith, TN	Savage Zinc Inc.	Zinc ore
5	Young	Jefferson, TN	Asarco Inc.	Zinc ore
6	Montana Tunnels	Jefferson, MT	Montana Tunnels Mining Inc.	Zinc ore
7	Pierrepont	St. Lawrence, NY	Zinc Corporation of America	Zinc ore
8	Cumberland	Smith, TN	Savage Zinc Inc.	Zinc ore
9	Casteel[1]	Iron, MO	The Doe Run Co.	Lead ore
10	Buick	Iron, MO	The Doe Run Co.	Lead ore
11	Immel	Knox, TN	Asarco Inc.	Zinc ore
12	Clinch Valley	Grainger, TN	Savage Zinc Inc.	Zinc ore
13	Leadville Unit	Lake, CO	Asarco Inc.	Zinc ore
14	Coy	Jefferson, TN	Asarco Inc.	Zinc ore
15	Fletcher	Reynolds, MO	The Doe Run Co.	Lead-zinc ore
16	West Fork	Reynolds, MO	Asarco Inc.	Lead-zinc ore
17	Viburnum No. 29	Washington, MO	The Doe Run Co.	Lead-zinc ore
18	Sweetwater	Reynolds, MO	Asarco Inc.	Lead-zinc ore
19	Lucky Friday	Shoshone, ID	Hecla Mining Co.	Lead-zinc ore
20	Viburnum No. 28	Iron, MO	The Doe Run Co.	Lead-zinc ore

[1] Includes Brushy Creek Mill.
Source: U.S. Geological Survey

Primary zinc was produced at four smelters in 1993, one of which closed in that year. Between 1994-97, primary zinc was produced at three smelters. Big River Zinc in Illinois and Savage Zinc in Tennessee[13] use the electrolytic processing, and Zinc Corporation of America (ZCA) in Pennsylvania uses the electrothermic process. The number of primary smelter employees fell from 1,300 in 1993 to 1,000 in 1994, a level that remained constant through 1997. The largest producer is currently ZCA, despite closure of some smelting capacity in 1993.

Secondary zinc production increased by 5 percent between 1993-97 to 228,000 mt.[14] Although there are no known reports of new or added capacity to existing secondary smelter facilities, increased production may be attributed to a combination of ZCA's technological ability to adjust the percentage of secondary zinc in its feed stocks and the increased availability of secondary zinc due to improved methods for recovering zinc from waste materials produced during steel production.

[13] Savage Zinc Company is reportedly planning to more than double the size of its facility in Clarksville, TN, by adding another 170,000 tons of smelting capacity. ITC staff conversation with industry sources.

[14] Secondary zinc production increased by 9 percent between 1993-96 to 237,000 mt before dropping to 228,000 mt in 1997.

Research and Development

New, more-efficient technologies to recover zinc from the steelmaking process contribute to the relative competitiveness of the secondary sector. One such technology is the *Waelz* process, which some industry sources credit with helping to increase production of secondary zinc. The Waelz process recovers zinc from electric arc furnace (EAF) dust and galvanizing scrap.[15] The waste zinc is heated in a special kiln (Waelz kiln) with a mixture of coke breeze, anthracite coal, or both, to produce zinc vapor, which is then cooled, leached, and dehydrated. The resulting zinc oxide, containing up to 70 percent zinc, can then be shaped into briquets or calcined for smelting.[16]

Another innovation involves the recovery of zinc from galvanized scrap before the steelmaking process. This method was developed by Metal Recovery Technologies (MRT) in conjunction with the Argonne National Laboratory.[17] Researchers anticipate that this dezincing process could reduce energy consumption, reduce raw materials cost for the U.S. iron and steel industry, and eliminate zinc from waste streams. MRT conducted a pilot operation in March 1997, but fell short of its planned production of 250 mt of zinc and 9,750 mt of high-grade steel from 10,000 mt of galvanized steel scrap. Efforts continue to bring this project into commercial production.[18]

U.S. Government Programs

In 1992, Federal legislation authorized the Defense National Stockpile Center to dispose of all zinc in the Defense National Stockpile over several years as long as the sales do not cause undue disruption in the market.[19] In October 1997, the Defense Logistics Agency (DLA), which maintains the stockpile, and zinc industry representatives agreed to split the sales between sealed-bid and negotiated bid formats; the DLA began offering zinc on a long-term basis in a negotiated bid format, setting aside about 1,000 mt per month for spot sales.

About 90 percent of the stockpile is comprised of high grade (99.90 percent pure) and prime western grade (98.0 percent pure) zinc.[20] In 1991, prior to the legislation, the zinc stockpile level was 343,613 mt; as of June 1998, the stockpile level was about 216,000 mt.[21]

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[15] In the global market, zinc production from EAF dust and oxide reportedly increased three times faster than primary zinc production during 1984-96.

[16] The Waelz zinc recovery process provides a significant environment benefit as well because the level of airborne particles around steelworks is reduced and secondary zinc oxide feed eliminates the need for electrolytic smelting plants and their waste products. See Plachy,"Zinc, 1997 Annual Review," p. 3.

[17] This research project was conducted under the Department of Energy's program on Metals Initiative.

[18] Plachy, "Zinc, 1997 Annual Review," p. 3; and ITC staff conversation with industry sources.

[19] Public Law 102-484. The General Accounting Office has defined the market as the total U.S. zinc market.

[20] Both high- and prime-western grades are used primarily for galvanizing. Depending on the mineral composition, stockpiled zinc sold into the market may be further refined for higher purity levels as required by endusers.

[21] Figures compiled from Stephen M. Jasinski, "Zinc, 1993," *Annual Report*, U.S. Department of the Interior, Bureau of Mines, Mar. 1995, p. 5; Plachy, "Zinc, 1997 Annual Review," p. 10; and "Zinc in June 1998," *Mineral Industry Survey*, USGS, Aug. 1998, p. 3.

Consumer Characteristics and Factors Affecting Demand

The chemical and physical properties of zinc metal make it a preferred material for coating and casting applications, with steel-coating applications (galvanizing) reportedly the largest and fastest growing enduse. About 54 percent of U.S. zinc metal consumption in 1996 was used for galvanizing;[22] in that same year, about 30 percent of U.S. flat-rolled steel was galvanized.[23] The U.S. Department of Commerce estimates that galvanizing consumption will increase from 652,000 mt in 1996 to 685,000 mt in 1998, and rise 2 percent annually to 740,000 mt by 2002.[24] The motor vehicle sector, the largest market for galvanized steel, increased consumption substantially during the past 5 years as virtually all domestic producers adopted the use of two-sided galvanized steel.

The building sector, led by residential housing, highways, bridges, and wastewater treatment systems, has become the fastest growing new market for zinc-coated products due to the durability of galvanized steel. These applications primarily use premium galvanized products, such as *galvalume*, a blend of 45 percent zinc and 55 percent aluminum. Two major programs in the zinc market have helped to bring about these developments. First, the International Lead and Zinc Association (ILZA) has campaigned for increased use of galvanized rebar. It is estimated that less than 1 percent of rebar worldwide is galvanized, representing only about 30,000 mt of zinc a year. If efforts by the ILZA prove successful, annual consumption could increase to 150,000 mt worldwide, saving billions of dollars in the future replacement of reinforced concrete infrastructures. Second, the North American steel and zinc industries jointly sponsor the use of galvanized steel framing for residential homes, as such products provide corrosion protection and less price volatility than wood framing. In 1996, an estimated 75,000 homes were steel framed (about 7,000 mt of zinc consumed). The American Iron and Steel Institute hopes to capture one-quarter of the residential framing market by year 2002 (about 60,000 mt of zinc per year).[25] A number of new domestic galvanizing lines are projected, including:

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[22] U.S. Department of Commerce (USDOC), International Trade Administration, "Metals, Zinc," *U.S. Industry and Trade Outlook 1998* (New York: McGraw-Hill, 1998), p. 14-16.

[23] Plachy, "Zinc, 1997 Annual Review," p. 3.

[24] USDOC, "Metals, Zinc," *U.S. Industry and Trade Outlook 1998*, p. 14-17. There are some discrepancies in production figures among the different data collection organizations. World Bureau of Metal Statistics reports U.S. consumption for galvanizing at 584,000 mt in 1996.

[25] USDOC, "Metals, Zinc," p. 14-17.

Company and Location	Capacity (mtpy)	Market
Pro-Tec Coating, Ohio[1]	400,000[2]	Automotive
Galvastar L.P., Indiana[3]	300,000	Construction
National Steel, Indiana	270,000	Construction
National Steel[4]	450,000	Automotive
AK Steel, Indiana	800,000	Automotive, appliance
Nucor Steel, Arkansas	500,000	Construction, agriculture

[1] A joint venture between U.S. Steel and Kobe Steel (Japan).
[2] With this addition, the facility will be the world's largest galvanizing plant with total capacity of over l million mtpy.
[3] A joint venture between Weirton Steel and Hoogovens (Netherlands).
[4] Location to be determined.

Consumption

The United States is the world's largest market for refined (slab) zinc, accounting for about 17 percent of global consumption, a trend that remained constant during the report period. U.S. apparent consumption of refined (slab) zinc is estimated to have increased in terms of quantity by about 15 percent during 1993-97 and then declined during January-June 1998 (table 3-2), possibly reflecting slowing global and U.S. economic growth associated with the 1997-98 Asian financial crisis. The value of refined consumption directly tracked quantity consumption during the whole period. The share of imports in the consumption of refined zinc, in terms of quantity, ranged between 65 and 70 percent.

Apparent consumption of zinc ores and concentrates decreased by about 10 percent in terms of quantity from 1993-97, reflecting U.S. reliance on offshore refining operations (table 3-3). In terms of value, however, consumption of ores and concentrates increased by 45 percent, primarily because of rising prices. The share of imports in the consumption of ores and concentrates, in terms of quantity, fluctuated between 5 to 26 percent.

Prices

Zinc is traded in the international market at values based on the commodity price set daily by the London Metal Exchange (LME),[26] although local prices vary in each country depending on market conditions.[27] The global zinc industry experienced significant growth of exports from China and the Commonwealth of Independent States (CIS) between 1992-94, driving LME stocks to record level highs and pushing down LME prices. Net exports from China and the CIS rose from 115,000 mt in 1991 to 304,000 mt in 1992 and continued to climb to 551,000 mt in 1994. At the same time, Europe and Japan experienced recessionary conditions. These factors contributed to a 1 million mt increase in Western commercial stocks, which reached about

[26] North American zinc producers reportedly adopted the LME pricing in 1990, and in February 1991 the first USA LME-approved warehousing facility was established in Baltimore. (see David King, "Quo Vadis LME?" *The Ringsider*, Oct. 1997, p. 10.)

[27] The other important factor in zinc prices is the smelting charge for producing zinc metal from zinc concentrate, which is periodically negotiated between mining and smelting companies.

Table 3-2
Refined (slab) zinc: U.S. production, exports of domestic product, imports for consumption, and apparent consumption, 1993-97, January-June 1997, and January-June 1998

Year/period	U.S. production	U.S. exports	U.S. imports	Shipments from U.S. Govt. Stockpile	Apparent U.S. consumption	Ratio of imports to consumption
	1,000 metric tons					*Percent*
1993	381	1	724	18	1,122	64.5
1994	356	6	794	39	1,183	67.1
1995	363	3	856	14	1,230	69.6
1996	366	2	827	15	1,206	68.6
1997	377	4	876	40	1,289	68.0
January - June—						
1997 . . .	190	1	448	35	672	66.7
1998 . . .	195	2	385	9	587	65.6

Note.— Ores and concentrates are not part of the U.S. Government Stockpile.

Source: Compiled from official statistics of the U.S. Department of Commerce and the U.S. Geological Survey.

Table 3-3
Mined zinc, recoverable from ores: U.S. production, exports of domestic product, imports for consumption, and apparent consumption, 1993-97, January-June 1997, and January-June 1998

Year/period	U.S. production	U.S. exports	U.S. imports	Apparent U.S. consumption	Ratio of imports to consumption
	1,000 metric tons				*Percent*
1993	488	311	33	210	15.7
1994	570	389	27	208	13.0
1995	614	424	10	200	5.0
1996	600	425	15	190	7.9
1997	601	461	50	190	26.3
January - June—					
1997 . . .	285	81	18	222	8.1
1998 . . .	325	55	11	281	3.9

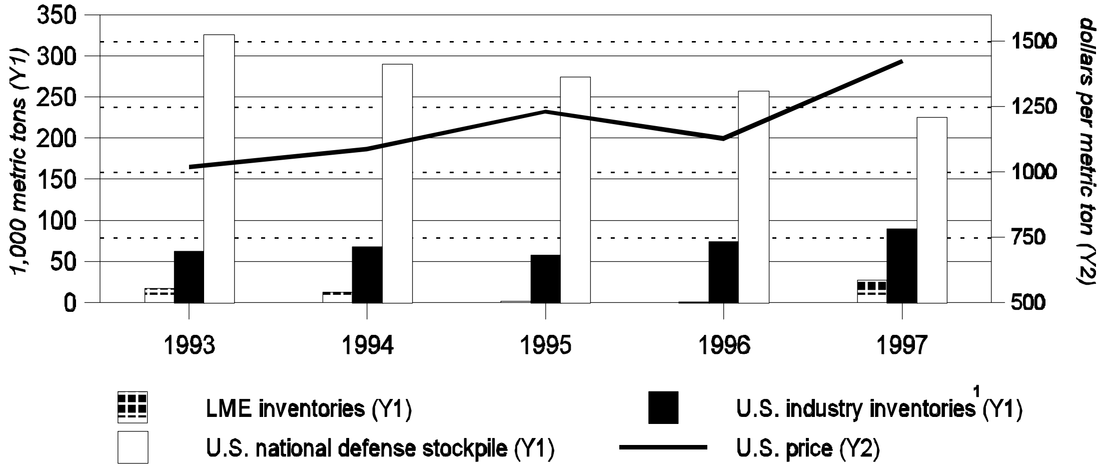
Note.—Ores and concentrates are not part of the U.S. Government Stockpile.

Source: Compiled from official statistics of the U.S. Department of Commerce and the U.S. Geological Survey.

1.7 million mt in 1994.[28] Starting in 1995, the surplus in world supply has been offset by a continued drawing down of stocks, reducing the inventory level to 491,000 mt by year-end 1997. Tracking global inventory levels, the average annual LME zinc price slid from about $1,240 per mt in 1992 to $961 in 1993 before rebounding to $1,318 in 1997. It subsequently slid back to $1,030 by August 1998. U.S. zinc market prices tended to run parallel with global price trends but at slightly higher levels compared to those of the LME.[29] See figure 3-3 for a comparison of inventory and price levels.

[28] Excludes government stocks. *World Metal Statistics*, June 1998, p. 133.
[29] U.S. zinc prices per pound fluctuated from 58.38 cents per pound in 1992 down to a low of 46.15 cents in 1993, rebounding to 64.6 cents in 1997.

Figure 3-3
Zinc slab: Inventories and U.S. price, 1993-1997



[1] U.S. industry inventories include unwrought zinc held at U.S. smelters, consumer industries, and merchants.
Source: Compiled from data of the U.S. Geological Survey.

Production

The United States is the worlds' fourth-largest producer of refined zinc and the fifth-largest producer of ores and concentrates. The quantity of U.S. refined production fluctuated between 1993-97, decreasing about 1 percent, despite price increases. Comparing the first 6 months of 1997 with the same period of 1998, production increased about 3 percent. About 37 percent of refined output came from domestic secondary production.[30] In contrast, the quantity of ore and concentrate production increased by 23 percent to 601,000 mt in 1997, and by 14 percent between January-June 1997 and the first 6 months of 1998, largely in response to rising prices and the revamping of existing mining facilities.

U.S. Trade

Overview

Increased imports widened the U.S. trade deficit for zinc ore and concentrate; and for unwrought metal, the deficit grew by $255 million between 1993-97 (from $565 million to $820 million), largely due to increased imports of refined zinc from Canada, Spain, and Mexico (table 3-4) . Domestic exports of zinc ore and concentrate to Canada, which more than doubled during the same period, limited the deficit expansion.

[30] Plachy, "Zinc, 1997 Annual Review," p. 10.

Table 3-4
Unwrought zinc: U.S. exports of domestic merchandise, imports for consumption, and merchandise trade balance, by selected countries and country groups, 1993-1997[1]

(*Million dollars*)

Item	1993	1994	1995	1996	1997
U.S. exports of domestic merchandise:					
Canada	57	99	120	99	158
Spain	2	2	3	6	([2])
Mexico	4	3	3	2	2
Belgium	24	44	32	45	88
Japan	28	27	33	22	64
Netherlands	([2])	([2])	14	29	22
Russia	2	2	2	0	0
Korea	4	7	14	23	18
Peru	([2])	([2])	0	0	0
Brazil	([2])	0	0	0	0
All Other	46	44	60	36	74
Total	167	228	282	262	426
EU-15	55	61	66	86	160
OPEC	([2])	([2])	([2])	1	([2])
Latin America	4	3	4	2	3
CBERA	([2])	([2])	([2])	([2])	([2])
Asian Pacific Rim	46	51	76	66	100
ASEAN	([2])	([2])	5	([2])	([2])
Central and Eastern Europe	0	0	0	0	0
U.S. imports for consumption:					
Canada	442	518	532	561	650
Spain	70	39	100	99	132
Mexico	103	99	110	103	121
Belgium	([2])	([2])	6	([2])	3
Japan	1	([2])	([2])	([2])	([2])
Netherlands	0	4	2	5	28
Russia	11	18	13	24	48
Korea	2	12	4	0	26
Peru	44	48	21	30	41
Brazil	17	20	69	34	29
All Other	43	51	79	57	168
Total	732	808	936	913	1,246
EU-15	83	55	134	126	212
OPEC	([2])	([2])	([2])	([2])	7
Latin America	164	171	206	172	194
CBERA	([2])	1	1	1	1
Asian Pacific Rim	26	38	23	8	56
ASEAN	0	0	([2])	0	2
Central and Eastern Europe	([2])	1	9	7	31
U.S. merchandise trade balance:					
Canada	-385	-419	-411	-462	-492
Spain	-68	-36	-96	-93	-132
Mexico	-99	-96	-107	-101	-119
Belgium	24	44	25	45	85
Japan	27	27	32	22	64
Netherlands	([2])	-4	12	24	-7
Russia	-9	-16	-11	-24	-48
Korea	3	-6	10	23	-8
Peru	-44	-48	-21	-30	-41
Brazil	-16	-20	-69	-34	-29
All Other	3	-6	-19	-21	-93
Total	-565	-580	-654	-650	-820
EU-15	-28	5	-68	-39	-52
OPEC	([2])	([2])	([2])	1	-6
Latin America	-160	-168	-202	-170	-191
CBERA	([2])	([2])	-1	([2])	-1
Asian Pacific Rim	20	13	53	58	44
ASEAN	([2])	([2])	5	([2])	-1
Central and Eastern Europe	([2])	-1	-9	-7	-31

[1] Import values are based on Customs value; export values are based on f.a.s. value, U.S. port of export.
[2] Less than $500,000.

Note—Because of rounding, figures may not add to totals shown. The countries shown are those with the largest total U.S. trade (U.S. imports plus exports) in these products in 1997.

Source: Compiled from official statistics of the U.S. Department of Commerce.

U.S. Imports

Principal Suppliers and Import Levels

Influenced by a relatively strong economy and rising prices for refined zinc, the value of U.S. imports grew by 70 percent during 1993-97 to $1.2 billion. Canada, Spain, and Mexico supplied about 75 percent of all zinc imports in terms of value during 1993-97, with Canada alone providing just over half (mostly refined and waste and scrap[31]). Canada's dominant role is due primarily to its proximity to the United States and close corporate ties with the Red Dog Mine in Alaska.[32] Mexico and Spain together supplied another 20 percent of total imports in 1997, which remained fairly consistent through the period covered by this report. Mexico is the United States' leading source for zinc alloy and a significant source for waste and scrap. Mexico and Spain together are significant sources for refined zinc. Peru, Australia, and Mexico supplied nearly all (93 percent) imported ores and concentrates in 1997.

In terms of value, unwrought, unalloyed refined zinc comprised 95 percent of all zinc imports during 1994-97 and increased by 54 percent to almost $1.2 billion during this period, primarily due to rising prices; however, the quantity increased by only 10 percent to 876,000 mt during 1994-97 (table 3-5). Comparing the first half of 1997 to that of 1998, the value and quantity of unwrought, unalloyed refined zinc imports decreased by 19 percent (to $438 million) and 14 percent (to 385,000 mt), respectively. Zinc ores and concentrates accounted for about 3 percent of imports. Their total value fluctuated during the report period, resulting in a $22 million increase to $31 million (a 22,000 mt increase to 50,000 mt) during 1994-97. Waste and scrap comprised about 2 percent of zinc imports during 1994-97 and increased in terms of value by 3 percent to about $29 million; however, the quantity of imports decreased by 26 percent to nearly 50,000 mt. Comparing the first half of 1997 to 1998, value and quantity increased by 23 percent (to $15 million) and 9 percent (to 27,000 mt), respectively. Zinc alloys accounted for less than 0.05 percent of imports and decreased in both value and quantity from $496,000 (553 mt) in 1994 to $351,000 (256 mt) in 1997, but increased from $207,000 (136 mt) to $1 million (861 mt) between the first six months of 1997 and 1998. This partial year growth in alloys is believed to be due primarily to the expanding market for galvanized products.

U.S. Trade Measures

Throughout the report period about 99 percent ($1.2 billion) of imported products entered the United States free of duty. Table 3-6 shows the column-1 general and special rates of duty as of January 1, 1998.[33] The aggregate average trade-weighted tariff rate of duty for zinc imports in 1997 was 0.40 percent ad valorem equivalent. This average dropped each year during the report period from 0.68 percent in 1993 primarily due to increased duty-free imports from Canada and Mexico under the CFTA and NAFTA.

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[31] In this context, waste and scrap includes ash and residues. Waste and scrap is generally used as input material for refined zinc.

[32] The Red Dog Mine ships zinc concentrate to Canada to be smelted and refined, much of which is then re-exported to the U.S. market.

[33] See appendix A for an explanation of tariff and trade agreement terms.

Table 3-5
Unwrought, unalloyed zinc: U.S. imports for consumption, by principal sources, 1994-97, January - June 1997, and January - June 1998

Source	1994	1995	1996	1997	January - June-- 1997	January - June-- 1998
			Quantity (*metric tons*)			
Canada	496,001	469,094	502,880	472,476	233,402	247,751
Spain	41,048	98,036	91,408	105,842	71,942	7,704
Mexico	98,845	99,205	93,932	83,089	31,923	36,451
Russia	20,106	12,774	24,088	27,662	12,633	5,466
Brazil	18,475	67,780	32,041	22,980	14,939	4,605
Netherlands	3,511	2,527	5,078	9,076	7,865	0
Korea	12,705	3,671	0	21,126	7,650	20,181
Kazakhstan	0	7,577	4,890	17,551	6,818	11,401
Peru	51,846	21,520	23,787	18,385	7,867	21,264
Finland	12,004	13,483	18,265	15,110	11,004	0
All other	38,962	60,384	30,942	82,896	41,911	30,474
Total	793,502	856,052	827,311	876,193	447,954	385,298
			Value (*1,000 dollars*)			
Canada	492,584	507,844	542,397	630,191	282,200	285,158
Spain	38,575	99,524	98,818	131,538	84,679	8,608
Mexico	91,611	103,070	97,079	113,312	39,455	39,889
Russia	18,144	13,190	24,301	48,114	15,389	5,569
Brazil	19,522	68,712	33,555	29,169	17,683	4,993
Netherlands	4,052	2,475	5,107	27,756	10,609	0
Korea	12,359	3,928	0	25,929	8,665	23,044
Kazakhstan	0	7,632	5,063	25,673	8,383	20,151
Peru	45,260	19,296	25,603	24,341	9,090	23,289
Finland	11,704	16,054	18,475	18,450	12,518	0
All other	36,218	61,259	31,296	111,360	50,666	27,085
Total	770,029	902,984	881,695	1,185,833	539,337	437,787
			Unit value (*dollars per kilogram*)			
Canada	0.99	1.08	1.08	1.33	1.21	1.15
Spain	0.94	1.02	1.08	1.24	1.18	1.12
Mexico	0.93	1.04	1.03	1.36	1.24	1.09
Russia	0.90	1.03	1.01	1.74	1.22	1.02
Brazil	1.06	1.01	1.05	1.27	1.18	1.08
Netherlands	1.15	0.98	1.01	3.06	1.35	([1])
Korea	0.97	1.07	([1])	1.23	1.13	1.14
Kazakhstan	([1])	1.01	1.04	1.46	1.23	1.77
Peru	0.87	0.90	1.08	1.32	1.16	1.10
Finland	0.98	1.19	1.01	1.22	1.14	([1])
All other	0.93	1.01	1.01	1.34	1.21	0.89
Average	0.97	1.05	1.07	1.35	1.20	1.14

[1]Not applicable.

Note.–Because of rounding, figures may not add to the totals shown.

Source: Compiled from official statistics of the U.S. Department of Commerce

Table 3-6
Unwrought zinc: Harmonized Tariff Schedule (HTS) subheading; description; U.S. Column-1 rate of duty as of Jan. 1, 1998; U.S. exports, 1997; and U.S. imports, 1997

HTS subheading	Description	Col.-1 rate of duty as of Jan. 1, 1998: General	Col.-1 rate of duty as of Jan. 1, 1998: Special[1]	U.S. exports, 1997	U.S. imports, 1997
				))) *1,000 dollars*)))	
2608.00.00	Zinc ores and concentrates	0.3 cents / kg on lead content	Free (A*[2], CA, E, IL, J, MX)	326,445	31,357
2620.11.00	Hard zinc spelter	0.3 %	Free (A+, CA, E, IL, J) 0.7% (MX) (s)[3]	275	196
2620.19.30	Zinc dross and skimmings	Free		([4])	13,284
2620.19.60	Other ash and residues containing mainly zinc	0.7 cents / kg on copper content + 0.7 cents / kg on lead content	Free (A, CA, E, IL, J, MX)	7,771	487
7901.11.00	Unwrought zinc, not alloyed, containing by weight 99.99 percent or more of zinc	1.5%	Free (A*[5], CA, E, IL, J, MX)	3,194	934,919
7901.12.10	Casting grade zinc	6.2%	Free (A+, CA, E, IL, J, MX)	1,618	81
7901.12.50	Other unwrought zinc, not alloyed	1.5%	Free (A*[5] CA, E, IL, J, MX)	([6])	250,832
7901.20.00	Zinc alloys	6.2%	Free (A, CA, E, IL, J, MX)	17,518	351
7902.00.00	Zinc waste and scrap	Free		24,124	14,485

[1] Products under which special tariff treatment may be provided, and the corresponding symbols for such programs as they are indicated in the "Special" subcolumn, are as follows: Generalized System of Preferences (A), (A*), (A+) indicates that all least-developed beneficiary countries are also eligible for preferential treatment under the Generalized System of Preferences; North American Free-Trade Agreement, Goods of Canada (CA) and Mexico (MX); Caribbean Basin Economic Recovery Act (E) United States-Israel Free Trade Area (IL); and Andean Trade Preference Act (J).
[2] Peru is not eligible for duty-free treatment for this product under the Generalized System of Preferences.
[3] The General Column rate is lower than the 0.7 percent special column rate for imports from Mexico because the special rate is an intermediate stage in a series of rate reductions under the North American Free-Trade Agreement.
[4] Export data are not collected specifically for dross and skimmings of zinc, but is included in HTS subheading 2620.19.0000: other ash and residues.
[5] Argentina is not eligible for duty-free treatment for this product under the Generalized System of Preferences.
[6] Export data is not collected specifically for this product but are included in HTS subheading 7901.12.10: casting grade zinc.

Source: U.S. exports and imports compiled from official statistics of the U.S. Department of Commerce.

U.S. Exports

Principal Markets and Export Levels

The value of U.S. exports more than doubled to $426 million during 1993-97 because of increased production and rising zinc prices. In terms of quantity, 64 to 77 percent of domestic zinc concentrate production was exported during 1993-97 (table 3-3). Most exports (84 to 88 percent in terms of quantity) were zinc ores and concentrates, reflecting U.S. reliance on foreign smeltering and refining operations (table 3-7). Remaining U.S. exports were waste and scrap (9 to13 percent in terms of quantity), alloys (2 percent), and refined zinc (1 percent or less). Foreign markets are important for the U.S. zinc industry. Canada is the primary U.S. export market for all zinc products except waste and scrap. Taiwan is the major U.S. market for zinc waste, accounting for about 47 percent of U.S. exports in terms of quantity.

Foreign Trade Measures

Zinc imports of U.S. origin enter Canada free of duty. Although Mexico is not currently a major market for the U.S. zinc industry, zinc ores and concentrate of U.S. origin were eligible for immediate duty-free treatment when NAFTA went into effect on January 1, 1994.[34] Since that time, Mexico has phased out duties on the remaining zinc products of U.S. origin. Tariff rates for zinc products entering other major U.S. export markets (such as Belgium and Japan) are free. The Commission is unaware of any nontariff measures that affect exports of zinc products covered in this summary.

Foreign Industry[35]

The competitive strengths of foreign producers include the quantity and quality of indigenous zinc-bearing deposits, favorable production costs (including energy and labor), and adequacy of infrastructure for transporting ore and concentrate to refining operations.[36] World production of mined zinc ores and concentrate increased by about 4 percent during 1993-97 to 7.1 million mt. Canada is the world's largest producer of zinc ore and concentrate, accounting for between 15 to 17 percent of global production during 1993-97, followed by Australia (14 percent), China (13 percent), and Peru (12 percent). Accordingly, the four largest zinc-producing companies in the world are Canadian-based Cominco Ltd. and Noranda Inc., followed by Australian-based Pasminco Mining Ltd. and MIM Holdings Ltd; all four companies have invested holdings in domestic as well as foreign mining and refining operations. World production of refined zinc increased by about 6 percent during the reporting period to 7.6 million mt in 1997. China was

[34] Mexico received about $1.6 million (1,300 mt) in U.S. ores and concentrates in 1997, representing almost 0.05 percent of commodity exports.

[35] Information on the foreign industry was developed principally from Plachy, "Zinc, 1997 Annual Review," pp. 4-8, except as noted.

[36] Compared with the refined product, zinc ore and concentrate have relatively low value-to-weight ratio and transportation costs are high.

Table 3-7
Zinc ores and concentrates: U.S. exports of domestic merchandise, by principal markets, 1994-97, January - June 1997, and January - June 1998

Source	1994	1995	1996	1997	January - June— 1997	January - June— 1998
	Quantity (*metric tons zinc content*)					
Canada	146,797	176,182	177,765	178,548	12,782	9,157
Belgium	86,744	54,962	61,105	94,149	2,382	3,124
Japan	68,421	68,046	47,296	79,007	38,943	20,266
Germany	30,214	30,162	0	32,796	237	18
Netherlands	9	25,449	60,213	25,288	0	0
United Kingdom	1	5,450	2,231	24,060	20,145	11,456
Korea	11,667	22,301	46,072	20,245	0	0
Italy	5,019	0	0	5,502	5,502	0
Mexico	649	861	891	1,294	609	795
Colombia	0	0	46	59	26	15
All other	39,970	40,710	29,264	26	19	10,006
Total	389,488	424,123	424,883	460,974	80,645	54,838
	Value (*1,000 dollars*)[2]					
Canada	83,691	106,619	84,457	135,660	9,251	7,097
Belgium	37,503	31,022	44,796	86,537	6,781	12,714
Japan	26,422	31,840	20,228	61,137	19,946	11,567
Germany	12,571	14,434	0	25,180	156	13
Netherlands	8	14,053	28,869	21,622	0	0
United Kingdom	3	1,561	4,500	20,062	10,425	11,508
Korea	4,854	13,130	22,049	15,592	0	0
Italy	1,104	0	0	2,929	2,929	1,666
Mexico	941	1,369	1,186	1,621	715	669
Colombia	0	0	96	154	78	37
All other	8,947	14,597	10,282	253	47	4,044
Total	176,044	228,625	216,463	370,745	50,327	49,315
	Unit value (*dollars per kilogram zinc content*)[2]					
Canada	0.57	0.61	0.48	0.76	0.72	0.77
Belgium	0.43	0.56	0.73	0.92	2.85	4.07
Japan	0.39	0.47	0.43	0.77	0.51	0.57
Germany	0.42	0.48	([1])	0.77	0.66	0.75
Netherlands	0.88	0.55	0.48	0.86	([1])	([1])
United Kingdom	4.30	0.29	2.02	0.83	0.52	1.00
Korea	0.42	0.59	0.48	0.77	([1])	([1])
Italy	0.22	([1])	([1])	0.53	0.53	([1])
Mexico	1.45	1.59	1.33	1.25	1.17	0.84
Colombia	([1])	([1])	2.09	2.61	3.04	2.50
All other	0.22	0.36	0.35	9.90	2.49	0.40
Average	0.45	0.54	0.51	0.80	0.62	0.90

[1] Not applicable.
[2] Value and unit value for zinc ores and concentrates includes the value of precious and other metal content.

Note.–Because of rounding, figures may not add to the totals shown.
Source: Compiled from official statistics of the U.S. Department of Commerce

the leading producer of refined zinc during this time, accounting for 17 percent of world output in 1997, up from 12 percent in 1993.

Canada and Australia

During 1993-96, Canadian mine production of zinc ore and concentrate increased by 23 percent to a peak of 1.2 million mt before falling to about 1.1 million mt in 1997. This decline was due primarily to several closures and the cancellation of scheduled reopenings of operations throughout the Yukon Territory, Quebec, and New Brunswick. A significant global shortfall in zinc concentrate was averted, however, by the addition of 212,000 mt of zinc mining capacity in Canada and Australia during 1997. In contrast, Australia experienced a continuous loss of production from 1993-95, but then reached a production peak of 1.1 million mt of ore and concentrate in 1996 before dropping to just below 1.0 million mt in 1997. Over the next 5 years, a number of Australian mines are scheduled to close; however, the opening of new mines and expansion of existing facilities are expected to replace lost production and actually increase Australia's share of world production to 29 percent by the year 2000.[37]

China

Zinc mining and refining operations in China are primarily government owned, and many operate under the China National Nonferrous Metals Industry Corp. (CNNMIC). However, on January 1, 1997, new amendments to the Mineral Resources Law were enacted to provide some decentralization of the regulatory body. Specifically, the amendments shifted more responsibility for exploration and mining to local governments so that some provincial capitals and coastal cities are now authorized to approve projects valued up to $30 million; higher-valued projects must still be approved by the regulatory bodies of the central government. Subsequently, local companies operating outside the CNNMIC increased their share of zinc concentrate production from 55 percent of national output in 1992 to 70 percent in 1997. In addition, the amendments allow private enterprises and Sino-foreign joint ventures to participate in exploration projects, but only under central government supervision. Canadian exploration company Marshall Minerals Corp. has since signed a letter of intent with CNNMIC-affiliated Xien Corp. to develop the Qian Dong Shan mine located west of Xian in Shaanxi Province. Also, China's State Tariff Commission reduced the export duty rate on zinc concentrate to 10 percent and abolished export duties on refined zinc and zinc scrap, contributing to a 327,000 mt increase (to 534,000 mt) in refined zinc exports during 1996-97. Most of China's refined zinc exports are traded with Asian markets. Reportedly, China plans to increase its current zinc smelting capacity from 1.45 million mt in 1997 to 1.58 million mt by the year 2000, which may require increased imports of zinc concentrate.

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[37] Plachy, "Zinc, 1997 Annual Review," p. 4.

Peru

Peru's zinc mining industry showed the largest growth of all major worldwide producers during 1993-97, as ore production increased by 29 percent to 857,000 mt. Contributing factors included a return to a more stable political and economic environment and improved world zinc prices. The Government of Peru continued to privatize Empresa Minera del Centro del Peru S.A. (Centromin) with the sale of three zinc-mining facilities to Peru-based mining companies and hopes to complete this privatization program by the end of 1998. Foreign companies from Canada, Japan, the United Kingdom, and the United States are well represented in Peru's zinc mining industry (table 3-8).

Table 3-8
Zinc: Foreign companies represented in Peru's zinc industry

Operation	Owner(s)/country represented	Comment
Bongara zinc deposit	Cominco Peru (subsidiary of Cominco Ltd., Canada) Solitaro Resources (a 57.6-percent owned subsidiary of Crown Resources Corp., Canada)	A joint venture to explore and develop the deposit over the next 4 years at an estimated cost of $27.5 million
Antamina copper-zinc mine	Inmet Mining Corp., Canada Rio Algom Ltd., Canada	Approximate purchase price, $2.2 billion Anticipated annual production of 385,000 mt by year 2001
Metal Oroya zinc smelter-refinery	Doe Run Co. (subsidiary of Renco Group, United States) obtained controlling interest	Approximate purchase price, $246 million Anticipated additional production improvement costs, over $311 million
Cajamarquilla Peru's largest refinery	Cominco Ltd., Canada, owns 81.6 percent Marubeni Corp., Japan, 16.7 percent Refinery employees, 1.7 percent	An expansion to double annual output to 240,000 mt by year 2000 was reportedly approved at an estimated cost of $300 million
San Valentin zinc mine	Zinc Corp. del Peru S.A. (subsidiary of Zinc Corp. PLC, United Kingdom)	Signed an agreement with Compania Minera San Valentin S.A. to install the first commercial-scale Warner plant (concentrate and smeltering operations combined) at the mine site

Source: Compiled by staff of the U.S. International Trade Commission from U.S. Geological Survey information.

Outlook[38]

The International Lead and Zinc Study Group estimates that world zinc ore and concentrate production will increase by 8.7 percent to 7.9 million mt in 1998, while refined zinc production will increase by 4.9 percent to about 8 mmt. World consumption of refined zinc is projected to grow by 2.4 percent to 7.9 million mt in 1998. Depending on the global economy and the realization of planned new and improved production facilities, forecasts for the world zinc market

[38] Information in this section from Plachy, "Zinc, 1997 Annual Review," p. 8, unless otherwise noted.

in the next 2 years range from a balanced level of inventory to a surplus by year 2000.[39] A surplus is anticipated if the financial crisis in some of the Southeast Asian countries spreads to other countries. Reportedly, Asia accounted for 30 percent of global zinc demand in 1997, while markets in Southeast Asia accounted for only 7 percent of demand.

During the next 3 years, global ore and concentrate production is expected to increase principally due to the reopening of the Bougrine Mine in Tunisia, the opening of new mines in Ireland and Australia, and increased production at the Red Dog Mine in Alaska. Future global increases in refined zinc are expected as a result of a new facility in Australia as well as expanded operations in Canada, Peru, Korea, and Finland. In the United States, galvanizing is expected to remain the major market for zinc, with most of the refined zinc supplied by the Savage smelter in Clarksville, TN, and through imports from Canada and Mexico.

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[39] George Jones, a senior vice president with Noranda Inc. in Canada, "Current Trends for Lead and Zinc, Zinc Poised for Growth," *Mining Journal*, London, Jun. 19, 1998, p. 478; and Edward Worden, "Zinc Output Seen Outpacing Demand," AMM Online, Top Stories for Sept. 14, 1998.

CHAPTER 4
Magnesium

Introduction

Primary magnesium metal,[1] both pure and alloy, is widely used in commercial and industrial applications because it is easily machined, light weight, and has a high strength-to-weight ratio. Pure magnesium is primarily an alloying metal used for beverage cans and in some automotive parts.[2] It is also used for desulfurization of iron and steel, as a reducing agent for various nonferrous metals (titanium, zirconium, hafnium, uranium, beryllium), and in magnesium anodes for the protection of iron and steel in underground pipe and water tanks and various marine applications. Magnesium alloys, which typically contain aluminum, are utilized in structural applications, primarily in castings and extrusions for the automotive industry.

During the 1993-97 period, domestic demand for magnesium for use in structural applications, particularly automotive castings, grew faster than demand for use in traditional end uses such as an alloy in aluminum beverage cans. This shift is due to major efforts by both the magnesium and automotive industries to increase vehicle fuel economy by substituting light-weight, high-strength magnesium alloy automotive components for heavier steel and cast iron components.

At the same time, the domestic primary magnesium industry, which accounted for nearly 50 percent of global production in 1993, saw its competitive position erode. Almost 20 percent of U.S. production capacity closed during 1993-97, partly as a result of the entry into world markets of competitively priced magnesium from Russia and China and the significant expansion of low-cost production in Canada by Norsk Hydro (Norway).[3] The trade surpluses that existed in 1994 and 1995 were replaced with deficits in 1996 and 1997 as imports rose to meet strong consumer demand.

[1] Primary magnesium metal includes unwrought magnesium that contains at least 99.8 percent magnesium by weight (so-called pure and commodity-grade magnesium) and alloy magnesium, which consists of pure magnesium and other metals, typically aluminum and zinc, containing less than 99.8 percent magnesium by weight, with magnesium being the largest metallic element, by weight, in the alloy. Because most magnesium ore and concentrate are captively produced and consumed with virtually no trade in these items, separate shipments and trade data for these items are not presented. Secondary magnesium (magnesium waste and scrap), which accounts for almost 40 percent of total magnesium production, is not included in data tables because of its general exclusion from structural applications.

[2] When pure magnesium is alloyed with aluminum in these applications, magnesium forms a minor part, between 2 and 4 percent of the alloy.

[3] USITC staff telephone interview with an official of International Magnesium Association, Aug. 19, 1998.

Production Process

Most primary magnesium is derived from magnesium-bearing ores (dolomite, magnesite, brucite, and olivine) or seawater and well and lake brines.[4] Large deposits of dolomite are widely distributed throughout the world, and dolomite is the principal magnesium-bearing ore found in the United States. Magnesium-bearing ores are mined by open-pit methods, and primary crushing is usually performed near the mine site due to the high cost of transporting ore. Magnesium is also produced from well and lake brines containing dissolved magnesium salts. In the United States, magnesium salts are obtained as brines from underground *evaporite deposits*,[5] principally from the Great Salt Lake in Utah. Nearly 45 percent of U.S. primary magnesium is produced from seawater.[6]

Primary magnesium metal is produced by either the *electrolytic process* or the *silicothermic process*, with the electrolytic process dominating in terms of the volume of U.S. and world production. In the electrolytic process, seawater or brine is evaporated and treated to produce a concentrated solution of magnesium chloride (figure 4-1),[7] which is further concentrated and dried to yield magnesium chloride powder. The powder is then melted, further purified, and fed into electrolytic cells operating at 700^{0} Celsius. Direct electrical current is sent through the cells to break down the magnesium chloride into chlorine gas and molten magnesium metal. The metal rises to the surface where it is guided into storage wells and cast into ingots. Both Magnesium Corporation of America (Magcorp) and Dow Chemical--two of the three U.S. producers--rely on the electrolytic method to produce primary magnesium.

In the silicothermic process, magnesium-bearing ores, typically dolomite, are the primary feed material (figure 4-2). *Calcined* dolomite, ferrosilicon, and alumina are ground, heated, and *briquetted*. The briquets are subsequently reduced in a heated vacuum, producing magnesium vapor. The vapor is crystallized in a condensing chamber, melted, and ladled into casting forms. Northwest Alloys is the sole U.S. producer using the silicothermic process to produce primary magnesium.

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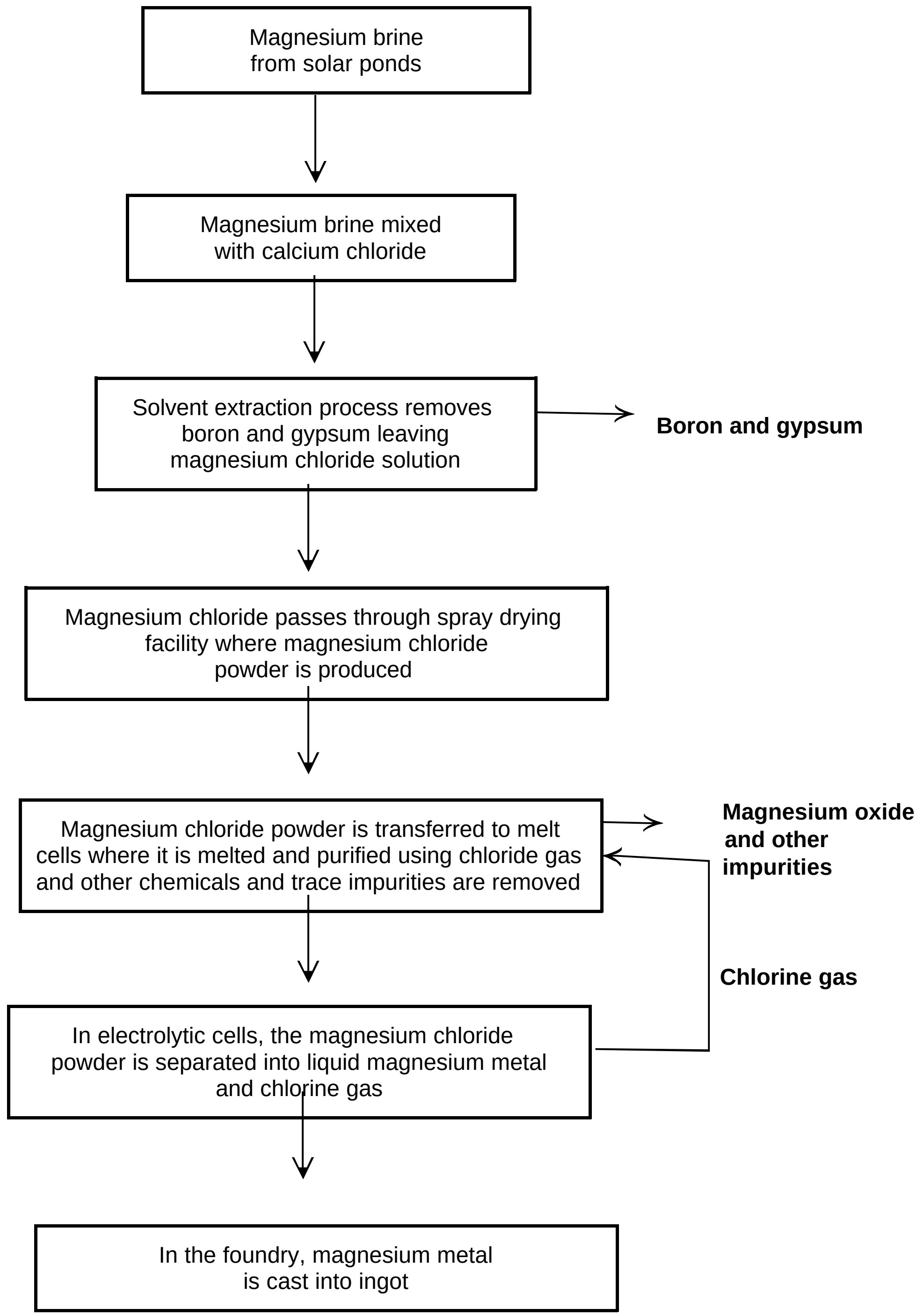
[4] The magnesium content of magnesium-bearing ores typically ranges from nearly 22 percent for dolomite to 60 percent for brucite. The magnesium content of seawater is 0.13 percent, which is much lower than that of the lowest grade of magnesium ore deposits; however, seawater has the advantage of being abundant, accessible, and extremely uniform in its magnesium content, allowing for easier standardization of the refining process.

[5] Italicized words are defined in the glossary, appendix B.

[6] Deborah A. Kramer, *Magnesium Mineral Industry Survey, Annual Review-1997*, U.S. Geological Survey (USGS), p. 6.

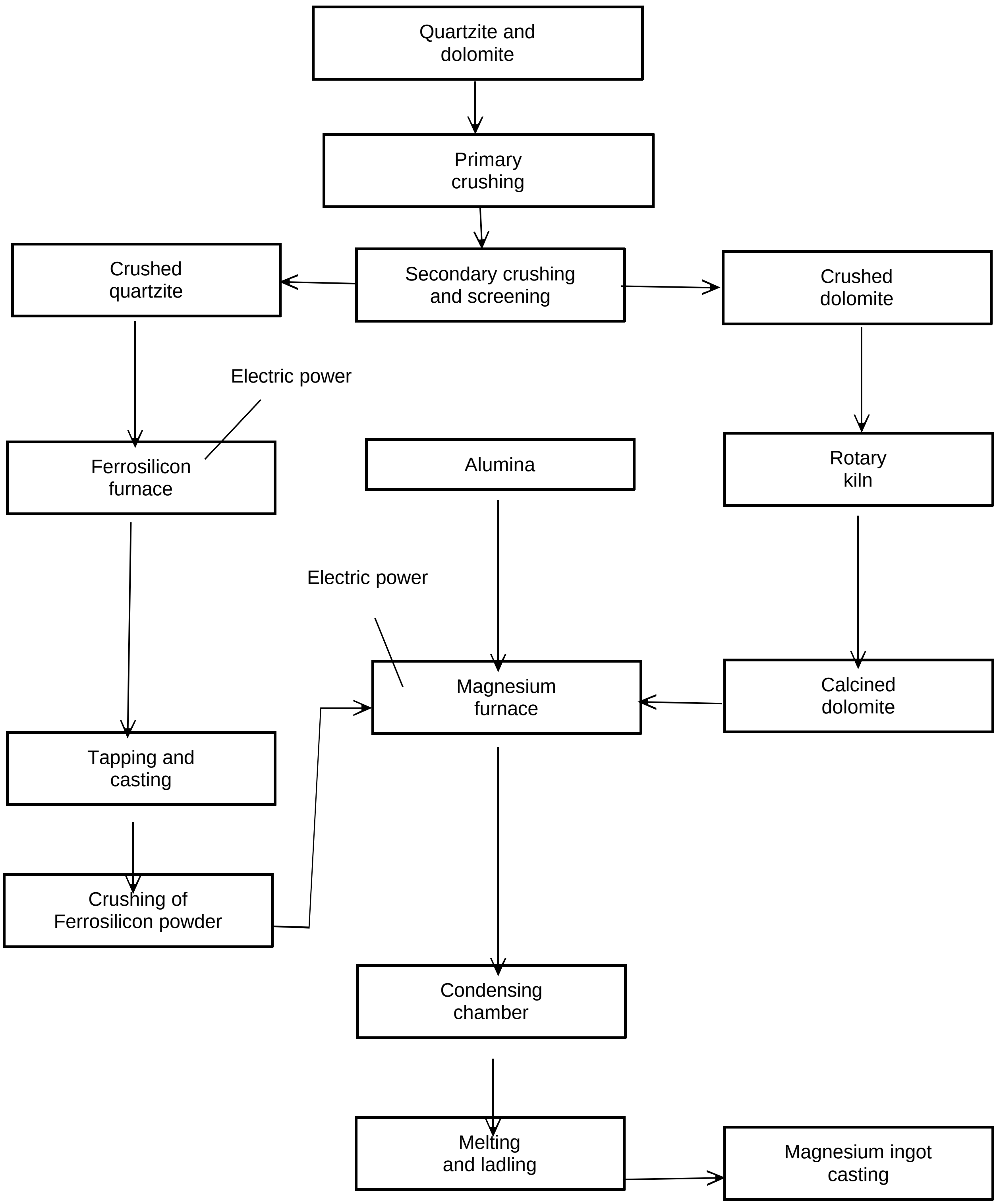
[7] Magnesium chloride may be either hydrous or anhydrous. Subsequent purification processes vary according to whether the solution is hydrous or anhydrous.

Figure 4-1
Magnesium: Electrolytic production process



Source: Compiled by staff from information provided by Magnesium Corporation of America.

Figure 4-2
Primary magnesium: Silicothermic production process



Source: Compiled by staff from information provided by Northwest Alloys.

Primary magnesium is typically cast into ingots or slabs. Ingots, weighing between 7 and 225 kilograms, are rolled or extruded into bar, wire, and seamless pipe. Slabs can be rolled into sheets and plate. Magnesium castings are produced by melting magnesium ingot and pouring the molten metal into a mold.

Secondary magnesium is usually recovered from scrap generated as a result of aluminum recycling. Approximately 85 percent of magnesium recovered from scrap is from aluminum-based alloyed products, especially recycled two-piece beverage cans. Secondary magnesium producers purchase aluminum-base and magnesium-base scrap and melt and cast it into ingots and slabs. Secondary magnesium is almost entirely consumed in aluminum alloys; structural applications are largely excluded due to elevated levels of oxide impurities that have thus far proven too costly to remove.

U.S. Industry Profile

Despite increasing production in other countries, the U.S. magnesium industry remained the world's leading producer of magnesium during 1993-97.[8] Canadian, Russian, and Chinese producers rapidly expanded their magnesium capacity and output and increased competition for export markets traditionally dominated by U.S. producers.[9] During this period, as much as 20 percent of U.S. primary magnesium capacity was idled, according to figures published by the U.S. Geological Survey.[10] Currently, U.S. production of primary magnesium metal is divided among three firms:

Company	**Plant location**	**Raw material**	**Annual capacity** *(metric tons)*
The Dow Chemical Co.	Freeport, TX	Seawater	65,000
Magnesium Corporation of America	Rowley, UT	Lake brines	40,000
Northwest Alloys Inc.	Addy, WA	Dolomite	40,000
Total			145,000

[8] Establishments producing primary magnesium metal are classified under Standard Industrial Classification (SIC) code 3339, the miscellaneous category for the primary smelting and refining of nonferrous metals.

[9] Byron Clow, "Magnesium: Record Shipments in 1997," *Engineering and Mining Journal*, Mar. 1998, p. 50.

[10] Kramer, *Magnesium Mineral Industry Survey 1997.*

In 1998, Dow Magnesium[11] and Timminco Ltd. (Canada) announced the sale of Dow's magnesium extrusion operations in Aurora, CO. This move was viewed by industry analysts as a first step that could lead to Dow's exit from the magnesium industry and reflects the strong competitive conditions that currently exist in the industry.[12] Dow is also currently "exploring alternatives" for its primary production facility in Freeport, reportedly in an effort to increase shareholder value by concentrating on Dow's core chemicals business.[13] Dow has been de-emphasizing its magnesium operations since 1995 when it closed 30,000 to 36,000 metric tons (mt) of primary magnesium-producing capacity.[14]

During the time that Dow Magnesium was eliminating magnesium metal capacity in the United States, Norsk Hydro (Norway) installed a 43,000 metric ton per year (mtpy) plant in Quebec, Canada, from which it supplies significant quantities of magnesium to the United States. Norsk Hydro's operations in Canada have benefited from low-cost electrical energy, enabling the firm to produce magnesium at highly competitive prices. Both Magnesium Corporation of America and Northwest Alloys maintained stable magnesium production capacity during 1993-97, and neither company has announced changes in their production plans covered by this report.

Secondary magnesium is recovered in the United States by nearly 30 independent firms, almost entirely located in the midwestern United States. These firms produce magnesium for aluminum alloying applications. Estimated annual employment in the entire magnesium metal industry fluctuated between 1,000 and 1,400 employees during the period covered by this report.[15]

U.S. Market

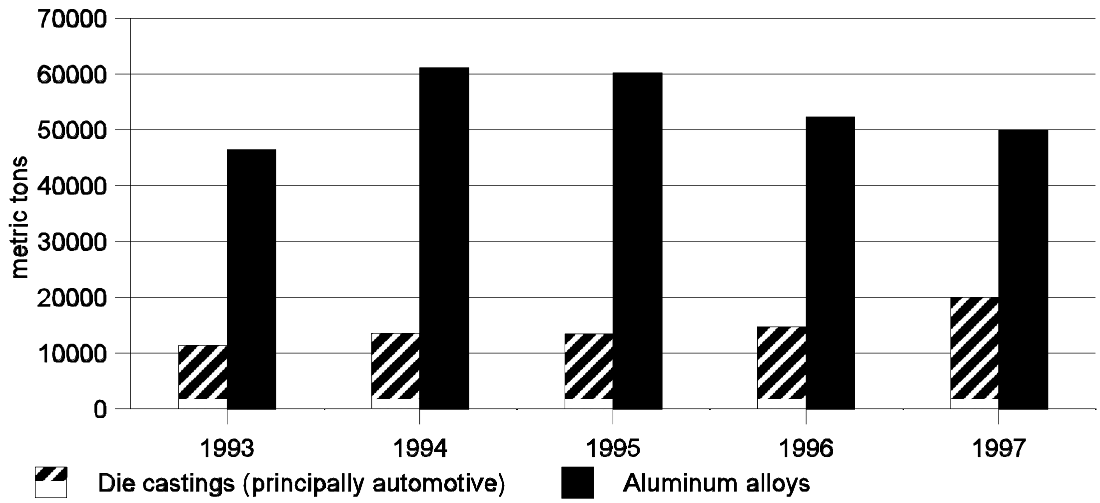
Consumer Characteristics and Factors Affecting Demand

The period 1993-97 witnessed a gradual change in the structure of U.S. demand for magnesium metal. Magnesium in die-casting applications, particularly for the automotive industry, emerged as a major market, while traditional aluminum alloying applications grew at a much slower pace. Demand for die-cast magnesium for structural applications reached 25 percent of total U.S. magnesium consumption in 1997, compared with 22 percent of consumption in 1993 (figure 4-3). Although, aluminum alloying is still the largest end-use application, representing nearly 50 percent of total magnesium consumption, growth in demand has slowed due to increased recycling of aluminum cans, increased use of plastic bottles, and a preference for glass containers in

[11] Dow Magnesium is a wholly owned subsidiary of Dow Chemical Co.
[12] Bob Regan, "Dow Still Pushing Magnesium Exit," *American Metal Market*, May 7, 1998, p. 1.
[13] Dexter Johnson, "Magnesium Metal Market Turns Up but Dow Evaluates Plan to Depart," *Chemical Market Reporter*, Jan. 19, 1998, at Internet http://proquest.umi.com/pqdweb.
[14] Ibid.
[15] "Magnesium Metal," *Mineral Commodity Summaries, 1998,* U.S. Geological Survey (USGS).

Third World markets.[16] Industry experts estimate that demand for pure magnesium by the aluminum canstock industry will continue to grow at an annual rate of 3.0 to 3.5 percent over the next 5 years.[17]

Figure 4-3
U.S. consumption of primary magnesium metal, by principal end users, 1993-97



Source: U.S. Geological Survey.

Strong growth in magnesium die castings has been encouraged by two factors. First, automobile manufacturers continue to substitute magnesium alloy for steel and aluminum alloy components in valve covers, steering and instrument column systems, and other applications in an attempt to produce lighter-weight automobiles that meet U.S. Corporate Fuel Economy (CAFE) standards.[18] Second, low magnesium prices, which prevailed during most of the period, further encouraged the use of magnesium components in automobiles. Reducing vehicle weight is still the most common, and least expensive method employed by automakers to meet CAFE standards.[19] In 1998, the typical family vehicle contained nearly 3 kilograms (kg) of magnesium castings, compared with the 1993 level of 2.1 kg per vehicle.[20] In 1997, General Motors consumed nearly 18,000 mt of magnesium alloy in various automotive applications, up sharply from annual consumption of

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[16] USITC staff telephone interview with an official of the International Magnesium Association, July 16, 1998.

[17] "Automotive is Key to Magnesium Demand," *Purchasing*, June 4, 1998, found at Internet address http://proquest.umi.com/pqdweb, retrieved Sept. 17, 1998.

[18] The Environmental Protection Agency (EPA) presently requires automakers to achieve a CAFE standard of 27.5 miles per gallon for cars and 20.6 miles per gallon for light trucks, while also meeting various emission requirements for carbon monoxide and for nitrogen oxides.

[19] USITC staff telephone interview with an official of Ford Motor Co., Ford Research Laboratories, May 1997.

[20] Al Wrigley, "Metals Use Shifts into High Gear,"*American Metal Market*, Feb. 23, 1998, p. 4.

2,100 mt in 1993, while Ford consumed 12,000 to 14,000 mt of magnesium in 1997, compared with consumption of 8,100 mt in 1993.[21] Industry experts estimate that magnesium use in motor vehicles will grow at an average annual rate of 14 percent through the year 2000.[22]

To further emphasize their commitment to the future use of magnesium in motor vehicles, a number of automotive companies worldwide have made major investments in magnesium production facilities. Ford Motor Company is a major investor in Australian Magnesium Corporation's 90,000 mtpy production facility presently under development in Queensland, Australia and is committed to buy half of the plant's total output when completed in 2002;[23] Volkswagen is a partner in the Dead Sea Magnesium Ltd. plant in Israel; and General Motors has signed long-term supply contracts with Norsk Hydro in Norway and Solikamsk in Russia.[24]

Ford Motor Co. also announced the manufacture of its P2000 research car as part of its participation in the Partnership for a New Generation of Vehicles (PNGV).[25] The new car weighs 910 kilograms less than a Ford Taurus, contains just under 39 kilograms of magnesium compared with 4.5 kg of magnesium for a Taurus, and has a fuel economy of 63 miles per gallon of gasoline.[26] According to Ford, the prototype car is said to represent a significant advance toward the production of lightweight, environmentally responsible vehicles. Commercial demand for such vehicles should increase the use of die-cast magnesium and other lightweight materials.[27]

Several technological developments may increase demand for magnesium by improving its cost and *near-net-shape* properties relative to competing materials such as aluminum and iron and steel. Developments in *thixomolding*, a process that uses the injection molding of magnesium granules at elevated temperatures to produce near-net-shape parts with complex designs, high strength, and thin walls, progressed rapidly during 1993-97.[28] Presently, 82 thixomat machines worldwide fabricate a variety of magnesium components for the electronics and telecommunications industry.[29] A number of automotive companies have expressed interest in the

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[21] Gerald S. Cole, Rani Agarwal Finstad, John C. Grebetz, "The Potential for Magnesium in the Automotive Industry," Ford Motor Company document, 1996, p. 2.

[22] "Automotive is Key to Magnesium Demand," *Purchasing*, June 4, 1998, found at Internet address http://proquest.umi.com/pqdweb, retrieved Sept. 17, 1998.

[23] Alex Trickett, "Magnesium Burns Brighter ... For Now," *Metal Bulletin Monthly*, Nov. 1998, p. 57.

[24] According to the terms of the contract between General Motors and Norsk Hydro, Norsk Hydro will supply AM60 and AZ91 alloys to General Motors, at prices that will be renegotiated on an annual basis. Ibid.

[25] The PNGV program is a U.S. Government-U.S. auto industry effort to develop mass-producible six-passenger vehicles capable of 80 miles per gallon in fuel economy, with a driving range of at least 380 miles. The cars must also be at least 80 percent recyclable.

[26] Byron Clow, "Magnesium: Record Shipments in 1997," *Engineering and Mining Journal*, Mar. 1998, p. 51.

[27] *Ford's High-Mileage P2000 DIATA Debuts at NAIAS*, Ford Motor Company press release, Sept. 2, 1998.

[28] USITC staff telephone interview with officials of Thixomat Inc., Sept. 1998. Thixomat officials indicate that with current back orders, the number of machines worldwide producing thixomat components should jump to 200 by the end of 1999.

[29] Ibid.

technology's ability to cast near-net shape parts that are lightweight and retain the desired mechanical and structural properties.[30]

The principal obstacle to the expanded use of thixomolded components is cost, still 10 to 20 percent more than conventional automotive die-cast parts. Automotive industry resistance to new parts lacking a performance history also exists. Despite the cost disadvantage, officials at Thixomat Inc. feel that larger production volumes will eventually lead to lower unit costs for thixomolded components, making them more cost competitive with conventional components.[31]

Researchers are developing a process to use blue-light reflectance to measure the nonmetallic impurities in secondary magnesium, which could potentially lead to lower recovery costs, higher purity levels, and greater use of secondary material in structural applications. Successful commercialization of this process would allow secondary production, which totals nearly 40 percent of the level of primary production, to be applied to automotive die castings.[32]

Consumption

U.S. consumption of primary magnesium increased during 1993-1997, despite a 10 percent decline in 1994 attributed to cutbacks in domestic production and a temporary decrease in imports. A number of U.S. auto manufacturers have recently committed themselves to the use of magnesium in specific automotive applications, signing long-term supply contracts with magnesium producers, thus helping to assure a steady source of demand for magnesium over the next ten years.[33] Foreign magnesium suppliers continued to supply an increasing share of U.S. consumption. Import penetration rose from 24 percent in 1993 to 34 percent in 1997.

Prices

After a period of general price stability during 1993-95, the published free-market price of pure primary magnesium metal ingot declined from $4.05 to $4.16 per kilogram at the beginning of 1996 to $2.40 to $2.64 per kilogram by the end of 1996.[34] These price variations largely resulted from significant new supplies in the world market, particularly from Russia and China (see "Trade" and "Foreign Industry" sections). These nations supplied nearly 34 percent of total world production of primary magnesium in 1997 compared to only 13 percent in 1993. The price decline occurred despite strong economic growth in major industrial nations and rising demand for magnesium, as global magnesium supply outpaced demand.

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[30] Ibid.

[31] Ibid.

[32] Andrew G. Haerle, Barry A. Mikucki, William E. Mercer, "A New Technique for Quantifying Non-Metallic Inclusion Content in Magnesium," *Light Metal Age*, Aug. 1996; and Kramer, *Magnesium Mineral Industry Survey*, 1997, p. 4.

[33] Kramer, *Magnesium Mineral Industry Survey 1997*, p. 2; and Al Wrigley, "GM Plans Core Site to Hold Magnesium Resale Program," *American Metal Market*, May 4, 1997, p. 1.

[34] All prices are free market prices, as reported in *Metal Bulletin* magazine, various issues.

Despite an intermittent price recovery after 1996, the continued supply to world markets from Russia, China, and Canada has continued to put downward pressure on prices.[35] Ingot prices had stabilized at $2.46 to $2.56 per kilogram during the middle of 1997 as Russian magnesium producers withheld supply to bolster prices,[36] but by midyear 1998 magnesium prices had again fallen to $2.00 to $2.40 per kilogram. At the current price of $3.63 per kilogram for AZ91D (the most commonly used automotive grade magnesium alloy) magnesium competes favorably with aluminum AL380, priced at $0.64 per pound, in steering and instrument panel systems and in valve covers.[37]

Production

After rising 8 percent during 1993-95 to 142,000 mt ($587 million), U.S. production of primary magnesium metal declined 12 percent to 125,000 mt ($338 million) in 1997 (table 4-1) due to rising magnesium imports and the partial closure of part of Dow Chemical's magnesium production capacity.

Table 4-1
Primary magnesium metal: U.S. production, exports of domestic merchandise, imports for consumption, and apparent consumption, 1993-97, January-June 1997, and January-June 1998

Year	U.S. production	U.S. exports	U.S. imports	Apparent U.S. consumption	Ratio of imports to consumption
	Quantity (*metric tons*)				*Percent*
1993	132,000	28,013	32,128	136,115	24
1994	128,000	30,544	25,418	122,874	21
1995	142,000	26,922	22,782	137,860	17
1996	133,000	23,486	39,331	148,845	26
1997	125,000	25,048	51,390	151,343	34
January - June—					
1997	([1])	11,595	23,238	([1])	([2])
1998	([1])	14,087	31,339	([1])	([2])

[1] Not available.
[2] Not applicable.

Source: Data on U.S. production are from the U.S. Geological Survey. Trade data are compiled from official statistics of the U.S. Department of Commerce.

[35] USITC staff telephone interview with an official of International Magnesium Association, Aug. 13, 1998.

[36] "Russian Magnesium Exports May Slow to Hold Pricing," *Platt's Metals Week*, Mar. 17, 1997, p. 8; and USITC staff telephone interview with officials at Dow Magnesium, May 20, 1997.

[37] Magnesium is often substituted for aluminum in structural castings despite the fact that it sells at a price premium to aluminum and iron and steel. This is because magnesium's light weight, superior strength-to-weight ratio, and easy machinability often compensate for the difference in price. Magnesium is 78 percent lighter per unit volume than steel and 36 percent lighter than aluminum. Unlike steel, magnesium can be cast in single-piece, complex shapes that eliminate the need to fasten together various separately cast components.

The anticipated sale of the remainder of Dow Chemical's magnesium operations is expected to further reduce the role of the United States in world magnesium production. The United States accounted for 32 percent of world primary magnesium metal production of 392,000 mt in 1997, down from 49 percent of world production of 269,000 mt in 1993 (table 4-2). U.S. recovery of secondary magnesium rose steadily during 1993-97, from 58,900 mt in 1993 to 80,200 mt in 1997.

Table 4-2
Magnesium: World primary and secondary production, by country, 1993-1997
(Metric tons)

Country	1993	1994	1995	1996	1997
Primary production:					
United States	132,000	128,000	142,000	133,000	125,000
China[1]	11,800	24,000	93,600	73,100	92,000
Canada[1]	23,000	28,900	48,100	54,000	57,700
Russia[1]	24,000	30,400	31,000	34,000	39,500
Norway	27,300	27,635	28,000	28,000	28,000
France	10,982	12,280	14,450	14,000	12,000
Ukraine	14,900	12,000	10,000	10,000	10,000
Kazakstan[1]	2,000	-	9,000	9,000	8,972
Israel	-	-	-	-	8,000
All other	23,018	18,785	18,350	9,900	10,828
Total[3]	269,000	282,000	394,500	365,000	392,000
Secondary production:					
United States	58,900	62,100	65,100	70,200	80,200
Japan	13,215	19,009	11,767	21,243	22,797
Brazil	1,600	1,600	1,600	1,600	1,600
United Kingdom[1]	1,000	1,000	1,000	1,000	1,000
Russia[1]	6,000	5,000	6,000	6,000	([2])
Total[3]	80,715	88,700	85,467	100,000	106,000

[1] Estimated.
[2] Not available.
[3] Data for total is rounded and may not add to totals shown.

Source: Magnesium Mineral Industry Survey: Annual Review 1997, U.S. Geological Survey.

Nearly 84 percent of total U.S. secondary magnesium was recovered from aluminum-based metal in 1997.[38] The United States accounted for 76 percent of world secondary magnesium production of 106,000 mt in 1997, up from 73 percent of world production of 80,700 mt in 1993.

[38] Kramer, *Magnesium Mineral Industry Survey, 1997*, p. 7.

U.S. Trade

Overview

The United States, which had long maintained a trade surplus in primary magnesium, recorded trade deficits of $53.4 million in 1996 and $85.9 million in 1997. Imports more than doubled to $161.7 million in 1997, reflecting large increases in imports from Canada, Russia, Israel, and China (table 4-3). With increasing production capacity for primary magnesium in these regions and continued strong domestic demand, the United States will likely maintain a trade deficit in primary magnesium metals.

U.S. Imports

Principal Suppliers and Import Levels

Annual U.S. imports of primary magnesium metal were volatile during 1993-1997 due to fluctuating U.S. demand, the availability of low-cost imports from Russia and China, and added production capacity by Norsk Hydro (Canada) and Dead Sea Magnesium (Israel). Following a decline during 1994-95 when imports fell 10 percent to 22,800 mt ($73.5 million), imports rose by 126 percent to 51,500 mt ($161.7 million) between 1995 and 1997 (table 4-4). Imports for the first six months of 1998 rose to 31,300 mt ($99.1 million), a 35 percent increase over the same period in 1997.

Canada remained the United States' leading supplier of magnesium throughout the report period, supplying 54 percent of the total quantity imported in 1997, followed by Russia with 28 percent. Israel supplied 7 percent of total U.S. imports in 1997, reflecting initial production from the start-up of Dead Sea Magnesium's operation.

Nearly 70 percent of primary magnesium metal imported by the United States is in the form of magnesium alloy, which largely satisfies the market for magnesium die castings. U.S. imports of magnesium waste and scrap rose from 2,920 mt ($4.2 million) in 1994 to 3,985 mt ($6.7 million) in 1997; nearly 66 percent of the quantity imported in 1997 originated from Canada.

Table 4-3
Primary magnesium metal: U.S. exports of domestic merchandise, imports for consumption, and merchandise trade balance, by selected countries and country groups, 1993-1997[1]

(Million dollars)

Item	1993	1994	1995	1996	1997
U.S. exports of domestic merchandise:					
Canada	19	18	10	17	19
Russia	0	0	(2)	0	0
Netherlands	20	7	6	17	29
Israel	1	1	1	1	2
Japan	19	16	21	18	13
China	0	0	0	0	(2)
Mexico	2	1	1	2	1
Australia	6	6	9	10	5
United Kingdom	(2)	(2)	1	1	1
France	1	1	(2)	1	1
All Other	10	29	25	16	6
Total	77	79	74	80	76
EU-15	28	34	29	33	33
OPEC	(2)	(2)	(2)	(2)	(2)
Latin America	3	2	1	2	2
CBERA	(2)	(2)	0	0	(2)
Asian Pacific Rim	26	24	31	28	19
ASEAN	(2)	(2)	(2)	(2)	(2)
Central and Eastern Europe	0	0	0	0	(2)
U.S. imports for consumption:					
Canada	20	27	44	71	94
Russia	37	27	20	52	39
Netherlands	(2)	0	(2)	0	(2)
Israel	0	0	0	0	11
Japan	(2)	0	(2)	(2)	(2)
China	5	2	1	1	7
Mexico	0	3	2	3	4
Australia	0	0	0	0	0
United Kingdom	2	2	3	4	3
France	(2)	1	1	1	2
All Other	12	6	4	3	2
Total	77	66	73	134	162
EU-15	3	3	3	5	6
OPEC	0	0	0	0	0
Latin America	3	4	4	5	5
CBERA	0	0	0	0	0
Asian Pacific Rim	5	2	1	1	7
ASEAN	0	0	0	0	0
Central and Eastern Europe	0	0	(2)	0	0
U.S. merchandise trade balance:					
Canada	-1	-9	-33	-55	-75
Russia	-37	-27	-20	-52	-39
Netherlands	20	7	6	17	29
Israel	1	1	1	1	-9
Japan	19	16	21	18	13
China	-5	-2	-1	-1	-7
Mexico	2	-2	-1	-1	-2
Australia	6	6	9	10	5
United Kingdom	-2	-1	-2	-3	-3
France	(2)	(2)	(2)	(2)	-1
All Other	-2	23	21	13	4
Total	(2)	13	1	-53	-86
EU-15	26	32	26	28	27
OPEC	(2)	(2)	(2)	(2)	(2)
Latin America	(2)	-2	-3	-4	-3
CBERA	(2)	(2)	0	0	(2)
Asian Pacific Rim	20	22	30	27	13
ASEAN	(2)	(2)	(2)	(2)	(2)
Central and Eastern Europe	0	0	(2)	0	(2)

[1]Import values are based on Customs value; export values are based on f.a.s. value, U.S. port of export.
[2]Less than $500,000.

Note.—Because of rounding, figures may not add to totals shown. The countries shown are those with the largest total U.S. trade (U.S. imports plus exports) in these products in 1997.

Source: Compiled from official statistics of the U.S. Department of Commerce.

Table 4-4
Primary magnesium metal: U.S. imports for consumption, by principal sources, 1994-97, January - June 1997, and January - June 1998

Source	1994	1995	1996	1997	January - June 1997	January - June 1998
	Quantity (*metric tons*)					
Canada	8,900	14,361	21,116	27,684	13,588	14,794
Russia	11,765	5,665	15,767	14,789	7,928	7,576
Israel	0	0	0	3,362	226	4,155
China	800	384	208	2,857	842	3,317
Mexico	994	686	734	976	275	470
United Kingdom	257	320	571	371	203	400
France	224	203	244	728	141	313
Brazil	361	534	736	579	0	338
Germany	0	1	0	128	61	0
Finland	0	0	0	19	19	31
All other	2,170	674	37	3	3	9
Total	25,471	22,830	39,413	51,497	23,287	31,405
	Value (*1,000 dollars*)					
Canada	26,934	43,785	71,333	93,994	45,392	50,992
Russia	26,643	19,767	51,582	39,000	21,291	20,744
Israel	0	0	0	10,622	720	13,058
China	1,506	517	599	6,633	1,955	8,323
Mexico	2,641	1,631	2,574	3,714	1,087	1,521
United Kingdom	1,802	2,596	3,766	3,284	1,627	2,302
France	651	649	965	2,111	431	981
Brazil	912	2,393	2,922	1,604	0	1,035
Germany	0	3	0	716	176	0
Finland	0	0	0	45	45	102
All other	5,401	2,147	138	24	23	44
Total	66,490	73,489	133,879	161,745	72,745	99,102
	Unit value (*dollars per kilogram*)					
Canada	3.03	3.05	3.38	3.40	3.34	3.45
Russia	2.26	3.49	3.27	2.64	2.69	2.74
Israel	([1])	([1])	([1])	3.16	3.19	3.14
China	1.88	1.35	2.88	2.32	2.32	2.51
Mexico	2.66	2.38	3.51	3.81	3.95	3.24
United Kingdom	7.02	8.10	6.60	8.85	8.02	5.75
France	2.91	3.20	3.96	2.90	3.06	3.13
Brazil	2.52	4.48	3.97	2.77	([1])	3.06
Germany	([1])	6.49	([1])	5.57	2.87	([1])
Finland	([1])	([1])	([1])	2.35	2.35	3.30
All other	2.49	3.18	3.73	7.11	7.04	4.93
Average	2.61	3.22	3.40	3.14	3.12	3.16

[1]Not applicable.

Note.–Because of rounding, figures may not add to the totals shown.

Source: Compiled from official statistics of the U.S. Department of Commerce

U.S. Trade Measures

U.S. rates of duty applicable to imports of primary magnesium metal and magnesium waste and scrap under the HTS as of January 1, 1998, are provided in table 4-5. The 1997 average trade-weighted ad valorem column-1 rate of duty for primary magnesium was 7.01 percent; NAFTA-origin imports enter duty free and imports eligible for treatment under the Generalized System of Preferences (GSP) also enter duty free.

Table 4-5
Primary and secondary magnesium metal: Harmonized Tariff Schedule subheading; description; U.S. column-1 rate of duty as of Jan. 1, 1998; U.S. exports, 1997; and U.S. imports 1997

		Col.-1 rate of duty as of Jan. 1, 1998			
HTS subheading	Description	General	Special[1]	U.S. exports, 1997	U.S. imports, 1997
				------Thousand dollars------	
8104.11.00	Unwrought magnesium, containing at least 99.8 percent by weight of magnesium	8%	Free (A*, CA,E, IL, J, MX)	47,289	54,717
8104.19.00	Other unwrought magnesium	6.5%	Free (A+, CA,E, IL, J,MX)	28,563	107,029
8104.20.00	Magnesium waste and scrap	Free	-	25,647	6,701

[1] Products under which special tariff treatment may be provided, and the corresponding symbols for such programs as they are indicated in the "Special" subcolumn, are as follows: Generalized System of Preferences (A) ; (A*) indicates that certain beneficiary developing countries (Russia) are not eligible for GSP treatment; (A+) indicates that all least-developed beneficiary countries are eligible for preferential treatment; North American Free-Trade Agreement, Goods of Canada (CA) and Mexico (MX); Caribbean Basin Economic Recovery Act (E); United States-Israel Free Trade Area (IL); and Andean Trade Preference Act (J);.

Source: U.S. exports and imports compiled from official statistics of the U.S. Department of Commerce.

U.S. Government Trade-Related Investigations

Imports of pure and alloy magnesium from Canada and pure magnesium from China, Russia, and Ukraine are currently subject to antidumping orders, and imports of alloy magnesium from Canada are, in addition, subject to a countervailing duty order as a result of investigations conducted by the U.S. Department of Commerce (Commerce) and the U.S. International Trade Commission (Commission).[39] In August 1992, Commerce issued antidumping orders covering imports of pure and alloy magnesium and a countervailing duty order against imports of alloy magnesium from Canada after Commerce found such imports

[39] The countervailing duty and antidumping laws are set out in title VII of the Tariff Act of 1930, 19 U.S.C. 1671, et seq.

to be sold in the United States at less than fair value (dumped) and to be subsidized, and the Commission determined that an industry in the United States is materially injured by reason of such dumped and subsidized imports.[40] In May 1995, Commerce issued antidumping orders covering imports of pure magnesium from China, Russia, and Ukraine after Commerce found such imports to be dumped, and the Commission determined that an industry in the United States is materially injured by reason of such dumped imports.[41] In December 1997, the Court of Appeals for the Federal Circuit issued a decision reversing the Court of International Trade's decision that had affirmed the Commission's affirmative final injury determination with respect to imports of pure magnesium from Ukraine.[42] In June 1998, the U.S. Court of International Trade remanded the case to the Commission to review its final injury determination. On remand, the Commission submitted to the court a negative injury determination. The matter is still under review by the court.

In late 1994, the Uruguay Round Agreements Act amended the antidumping and countervailing duty laws to require that all antidumping and countervailing duty orders be reviewed at 5-year intervals to determine whether revoking such orders would be likely to lead to a continuation or recurrence of dumping or subsidies and material injury. Under special transition provisions that apply to orders issued prior to 1995, the antidumping and countervailing duty orders involving imports of magnesium from Canada are scheduled to be reviewed beginning in August 1999.[43]

U.S. Exports

Principal Markets and Export Levels

U.S. exports of primary magnesium metal declined 18 percent to 25,000 mt ($75.9 million) during 1994-97, reflecting competition in foreign markets from emerging suppliers, particularly Russia and China (table 4-6). Much of the additional magnesium supplied to world markets during this period displaced U.S. exports to Japan and Western Europe. U.S. exports of primary magnesium metal declined from a peak of 30,600 mt ($79.3 million) in 1994 to 25,100 mt ($75.9 million) in 1997. Exports increased in the first six months of 1998, compared with 1997, rising 22 percent to 14,100 mt ($40.8 million). The Netherlands, Canada, and Japan were the leading U.S. markets for primary magnesium during 1997, accounting for 46 percent, 20 percent, and 19 percent of U.S. exports, respectively. Most magnesium entering the Netherlands and Belgium is consumed in the major aluminum alloy and die-casting markets in Germany. U.S. exports of magnesium waste and scrap increased from 1,840 mt ($4.3 million) in 1994 to 11,209 mt ($25.6 million) in 1997. Nearly 98 percent

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[40] *Magnesium from Canada*, inv. Nos. 701-TA-309 and 731-TA-528, USITC Pub. 2550, August 1992. For notice of the Commerce orders, *see* 57 F.R. 39392 (Aug. 31, 1992).

[41] *Magnesium from China, Russia, and Ukraine,* inv. Nos. 731-TA-696-698, USITC Pub. 2885, May 1995.

[42] *Gerald Metals, Inc. v. U.S.*, 132 F.3d 716 (Fed. Cir. 1997), rehearing denied, in banc suggestion declined (Apr. 13, 1998), vacating *Gerald Metals, Inc. v. U.S.*, 937 F. Supp. 930 (CIT 1996).

[43] *See* U.S. Department of Commerce notice, "Transition Orders: Final Schedule and Grouping of Five-Year Reviews," published at 63 F.R. 29372 (May 29, 1998).

of magnesium scrap is exported to Canada, where it is largely consumed in the production of aluminum alloys.

Table 4-6
Primary magnesium metal: U.S. exports of domestic merchandise, by principal markets, 1994-97, January - June 1997 and January - June 1998

Source	1994	1995	1996	1997	January - June 1997	January - June 1998
	Quantity (*metric tons*)					
Netherlands	4,030	2,657	5,902	11,506	4,189	6,467
Canada	6,959	3,958	4,568	5,081	2,428	4,076
Japan	6,320	6,781	5,498	4,668	2,498	2,086
Australia	3,107	3,003	3,126	1,693	1,561	365
Israel	86	61	43	157	98	48
Hong Kong	1	22	6	448	158	464
Mexico	316	195	390	479	222	117
Italy	39	33	22	61	27	40
France	76	23	68	71	44	45
United Kingdom	38	168	91	142	60	33
All other	9,637	10,070	3,820	794	335	375
Total	30,608	26,970	23,534	25,100	11,620	14,117
	Value (*1,000 dollars*)					
Netherlands	6,965	6,327	16,661	28,690	11,401	16,527
Canada	18,358	10,413	16,680	18,771	9,613	13,420
Japan	16,216	21,193	17,644	12,546	6,750	5,271
Australia	5,931	8,545	9,770	4,862	4,405	892
Israel	638	977	731	2,068	1,194	698
Hong Kong	19	87	41	1,594	740	1,305
Mexico	1,054	814	1,679	1,475	738	375
Italy	882	692	468	874	433	205
France	668	442	793	805	456	418
United Kingdom	466	765	580	601	300	105
All other	28,096	24,169	15,424	3,565	1,652	1,561
Total	79,292	74,424	80,471	75,852	37,684	40,778
	Unit value (*dollars per kilogram*)					
Netherlands	1.73	2.38	2.82	2.49	2.72	2.56
Canada	2.64	2.63	3.65	3.69	3.96	3.29
Japan	2.57	3.13	3.21	2.69	2.70	2.53
Australia	1.91	2.85	3.13	2.87	2.82	2.45
Israel	7.43	16.11	17.10	13.17	12.20	14.41
Hong Kong	23.54	4.01	7.45	3.56	4.68	2.82
Mexico	3.34	4.18	4.30	3.08	3.32	3.20
Italy	22.44	20.89	20.99	14.37	15.89	5.07
France	8.77	18.89	11.70	11.26	10.28	9.20
United Kingdom	12.35	4.57	6.35	4.25	4.97	3.17
All other	2.92	2.40	4.04	4.49	4.94	4.16
Average	2.59	2.76	3.42	3.02	3.24	2.89

Note.–Because of rounding, figures may not add to the totals shown.

Source: Compiled from official statistics of the U.S. Department of Commerce

Foreign Trade Measures

Applied tariff rates in 1998 are generally low in the major foreign markets for U.S. exports of primary magnesium metal. Tariffs on magnesium entering the Netherlands are 5.3 percent ad valorem for HTS 8104.1100 and 4.3 percent ad valorem for HTS 8104.1900. Primary magnesium exported to Japan faces tariffs of 2.6 to 4.4 percent ad valorem for both HTS 8104.1100 and 8104.1900. U.S.-origin imports are assessed tariffs of 0.4 percent in Canada and enter Mexico duty free under the NAFTA. There are no known nontariff barriers that affect U.S. exports of primary magnesium metal.

Foreign Industry

Principal foreign magnesium producing countries include Western Europe, Canada, and Japan, which have highly developed markets for aluminum alloying, automotive die castings, and iron and steel desulfurization. Worldwide demand for primary magnesium metal advanced rapidly during 1993-97, growing from nearly 250,000 mt in 1993 to 305,000 mt by 1995,[44] driven largely by growth in demand for magnesium die castings. Worldwide demand fell to 295,000 mt in 1996, largely attributed to a reduction of existing inventories by aluminum alloyers in response to sluggish demand, before reaching 334,000 mt in 1997 as inventories were restocked.[45] At the present time, the use of magnesium in automobiles by foreign automakers is significantly less than the average of 2.7 kg per vehicle used by U.S. automakers. However, a number of foreign automakers, including Mercedes Benz, Volkswagen, and Toyota, are increasing the magnesium content in their automobiles. As a result, the use of magnesium by foreign automakers should begin to approximate U.S. automotive usage after the year 2000.[46]

Spurred by rising demand, annual global production of primary magnesium metal grew 46 percent to 392,000 mt during 1993-1997, with China accounting for most of the increase during this period; Chinese production rose from 11,800 mt to an estimated 92,000 mt. In addition, annual global production capacity of primary magnesium rose 23,000 mt to 523,000 mt during the same period with the addition of new production facilities in China and Israel (figure 4-4).

Norway and Canada

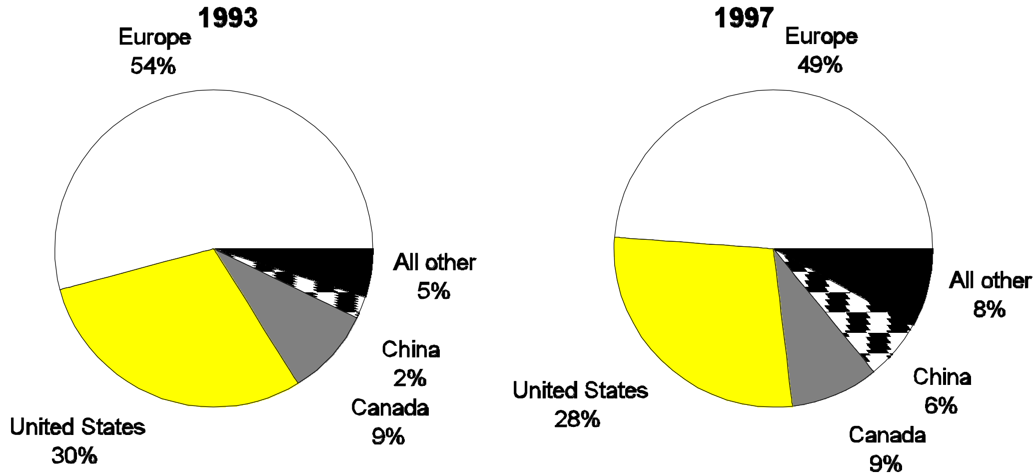
With the gradual decline in Dow Magnesium's production (see "U.S. Producers" section), Norsk Hydro (Norway), through its magnesium subsidiary Hydro Magnesium, has emerged as the world's leading producer of magnesium metal. In 1997, Hydro Magnesium announced plans to double the annual capacity of its plant in Quebec to 86,000 mt by 2000. Hydro Magnesium's production operations in Quebec reportedly benefit from low-cost electrical energy. When the plant expansion is completed, combined magnesium capacity of Hydro

[44] Figures published by International Magnesium Association, McLean, VA.

[45] Robert vanFleteren, "Magnesium Supply and Demand," The Dow Chemical Co., 1997, pp. 2-3.

[46] Dwain Magers, "A Global Review of Magnesium Parts in Automobiles," paper presented at Magnesium Automobile Parts Seminar, Tokyo, Japan (May 31, 1996).

Figure 4-4
Primary magnesium metal: World annual capacity, by source, 1993 and 1997



Source: Data supplied by U.S. Geological Survey.

Magnesium's Canadian and Norwegian operations will reach 130,000 mt, or nearly 25 percent of 1997 global capacity.[47]

Russia[48]

Solikamsk Magnesium Works and Avisma were the principal Russian producers of primary magnesium during 1993-97. Solikamsk is completing a 6,000-8,000 mtpy granules plant as part of a joint venture with a German magnesium producer. Completion of the plant is expected to increase the firm's magnesium production from 16,800 mtpy to 42,000 mtpy. Avisma's production of magnesium totaled approximately 14,000 mt in 1996. Both firms have been active suppliers of primary magnesium to world markets during 1993-97.

China[49]

Chinese annual capacity to produce primary magnesium has been estimated to be as high as 200,000 mt. However, due to the inconsistent nature of much of Chinese magnesium production, annual production has been variously estimated at between 12,000 and 90,000 mt. Combined annual production of China's three largest producers has been estimated at 12,000 mt; however, China has a number of small producers with annual production capacities of less than 200 mt who produce intermittently. Most of China's production is either consumed domestically in aluminum alloying applications or is exported to Japan.

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[47] Clow, "Magnesium: Record Shipments in 1997."

[48] Information from Deborah A. Kramer, "Magnesium in the first quarter of 1998," *Mineral Industry Surveys*, USGS, May 1998, p. 2.

[49] Information from Deborah A. Kramer, *Magnesium Mineral Industry Survey, Annual Review - 1996*, USGS, p. 3.

Other Countries[50]

The principal addition to worldwide production capacity during the past 5 years has been the addition of Dead Sea Magnesium's 27,500 mtpy plant in Israel, which began ingot production in late 1996. The company produced nearly 10,000 mt of magnesium in 1997. Other producers anticipated to enter the market or add to capacity in the near future include Australian Magnesium Corporation, which plans to add 90,000 mt of capacity by 2004, and Noranda (Canada), which has approved the construction of a $500 million, 58,000 mt plant in Quebec to be completed by mid-2000. Icelandic Magnesium Project (IMP) is presently going forward with a feasibility study for a 50,000 mt plant in Iceland which, if approved, is scheduled to be completed during the second half of 1999. Finally, Canadian firms Congo Minerals and Clavos Enterprises Inc. merged to form Magnesium Alloy Corporation, which has undertaken a feasibility study for a 50,000 mt magnesium plant in the Republic of the Congo.

Outlook

The anticipated completion of these numerous projects during the next decade is expected to have a number of implications for the global magnesium industry, including further significant increases in global capacity, the elimination of higher-cost production facilities, continued low prices for primary magnesium metal, and continued pressure on U.S. production. In terms of magnesium demand, low prices are expected to further encourage the trend to use magnesium die castings in automotive applications.[51]

[50] Information from Kramer, *Magnesium Mineral Industry Survey - 1996*, pp. 2-3.
[51] "Automotive is Key to Magnesium Demand."

APPENDIX A
EXPLANATION OF TARIFF AND TRADE AGREEMENT TERMS

TARIFF AND TRADE AGREEMENT TERMS

In the ***Harmonized Tariff Schedule of the United States*** (HTS), chapters 1 through 97 cover all goods in trade and incorporate in the tariff nomenclature the internationally adopted Harmonized Commodity Description and Coding System through the 6-digit level of product description. Subordinate 8-digit product subdivisions, either enacted by Congress or proclaimed by the President, allow more narrowly applicable duty rates; 10-digit administrative statistical reporting numbers provide data of national interest. Chapters 98 and 99 contain special U.S. classifications and temporary rate provisions, respectively. The HTS replaced the *Tariff Schedules of the United States* (TSUS) effective January 1, 1989.

Duty rates in the ***general*** subcolumn of HTS column 1 are most-favored-nation (now referred to as normal trade relations) rates, many of which have been eliminated or are being reduced as concessions resulting from the Uruguay Round of Multilateral Trade Negotiations. Column 1-general duty rates apply to all countries except those listed in HTS general note 3(b) (Afghanistan, Cuba, Laos, North Korea, and Vietnam), which are subject to the statutory rates set forth in ***column 2***. Specified goods from designated general-rate countries may be eligible for reduced rates of duty or for duty-free entry under one or more preferential tariff programs. Such tariff treatment is set forth in the ***special*** subcolumn of HTS rate of duty column 1 or in the general notes. If eligibility for special tariff rates is not claimed or established, goods are dutiable at column 1-general rates. The HTS does not enumerate those countries as to which a total or partial embargo has been declared.

The ***Generalized System of Preferences*** (GSP) affords nonreciprocal tariff preferences to developing countries to aid their economic development and to diversify and expand their production and exports. The U.S. GSP, enacted in title V of the Trade Act of 1974 for 10 years and extended several times thereafter, applies to merchandise imported on or after January 1, 1976 and before the close of June 30, 1999. Indicated by the symbol "A", "A*", or "A+" in the special subcolumn, the GSP provides duty-free entry to eligible articles the product of and imported directly from designated beneficiary developing countries, as set forth in general note 4 to the HTS.

The ***Caribbean Basin Economic Recovery Act*** (CBERA) affords nonreciprocal tariff preferences to developing countries in the Caribbean Basin area to aid their economic development and to diversify and expand their production and exports. The CBERA, enacted in title II of Public Law 98-67, implemented by Presidential Proclamation 5133 of November 30, 1983, and amended by the Customs and Trade Act of 1990, applies to merchandise entered, or withdrawn from warehouse for consumption, on or after January 1, 1984. Indicated by the symbol "E" or "E*" in the special subcolumn, the CBERA provides duty-free entry to eligible articles, and reduced-duty treatment to certain other articles, which are the product of and imported directly from designated countries, as set forth in general note 7 to the HTS.

Free rates of duty in the special subcolumn followed by the symbol "IL" are applicable to products of Israel under the ***United States-Israel Free Trade Area Implementation Act*** of 1985 (IFTA), as provided in general note 8 to the HTS.

Preferential nonreciprocal duty-free or reduced-duty treatment in the special subcolumn followed by the symbol "J" or "J*" in parentheses is afforded to eligible articles the product of designated beneficiary countries under the ***Andean Trade Preference Act*** (ATPA), enacted as title II of Public Law 102-182 and implemented by Presidential Proclamation 6455 of July 2, 1992 (effective July 22, 1992), as set forth in general note 11 to the HTS.

Preferential free rates of duty in the special subcolumn followed by the symbol "CA" are applicable to eligible goods of Canada, and rates followed by the symbol "MX" are applicable to eligible goods of Mexico, under the ***North American Free Trade Agreement***, as provided in general note 12 to the HTS and implemented effective January 1, 1994 by Presidential Proclamation 6641 of December 15, 1993. Goods must originate in the NAFTA region under rules set forth in general note 12(t) and meet other requirements of the note and applicable regulations.

Other special tariff treatment applies to particular ***products of insular possessions*** (general note 3(a)(iv)), ***products of the West Bank and Gaza Strip*** (general note 3(a)(v)), goods covered by the ***Automotive Products Trade Act*** (APTA) (general note 5) and the ***Agreement on Trade in Civil Aircraft*** (ATCA) (general note 6), ***articles imported from freely associated states*** (general note 10), ***pharmaceutical products*** (general note 13), and ***intermediate chemicals for dyes*** (general note 14).

The ***General Agreement on Tariffs and Trade 1994*** (GATT 1994), pursuant to the Agreement Establishing the World Trade Organization, is based upon the earlier GATT 1947 (61 Stat. (pt. 5) A58; 8 UST (pt. 2) 1786) as the primary multilateral system of disciplines and principles governing international trade. Signatories' obligations under both the 1994 and 1947 agreements focus upon most-favored-nation treatment, the maintenance of scheduled concession rates of duty, and national treatment for imported products; the GATT also provides the legal framework for customs valuation standards, "escape clause" (emergency) actions, antidumping and countervailing duties, dispute settlement, and other measures. The results of the Uruguay Round of multilateral tariff negotiations are set forth by way of separate schedules of concessions for each participating contracting party, with the U.S. schedule designated as Schedule XX. Pursuant to the **Agreement on Textiles and Clothing** (ATC) of the GATT 1994, member countries are phasing out restrictions on imports under the prior "Arrangement Regarding International Trade in Textiles" (known as the **Multifiber Arrangement** (MFA)). Under the MFA, which was a departure from GATT 1947 provisions, importing and exporting countries negotiated bilateral agreements limiting textile and apparel shipments, and importing countries could take unilateral action in the absence or violation of an agreement. Quantitative limits had been established on imported textiles and apparel of cotton, other vegetable fibers, wool, man-made fibers or silk blends in an effort to prevent or limit market disruption in the importing countries. The ATC establishes notification and safeguard procedures, along with other rules concerning the customs treatment of textile and apparel shipments, and calls for the eventual complete integration of this sector into the GATT 1994 over a ten-year period, or by Jan. 1, 2005.

APPENDIX B
GLOSSARY

Anode - The positive terminal of an electrolytic cell. In metal refining, impure metal or metal-bearing substances are formed into anode shapes which dissolve into the electrolytic solution and plate onto the cell's cathode.

Babbitt metal - A lead-base alloy containing 1 to 10 percent tin and 10 to 15 percent antimony. May also contain some arsenic.

Briquette - A block of compressed mineral. Mineral commodities are bound together under pressure, with or without a binding agent, into a block for further processing.

Calcining - Roasting of an ore in an oxidizing atmosphere, usually to expel sulfur or carbon dioxide.

Concentrate - The end mineral product of a concentration process.

Concentration - Any process of separating desired minerals (i.e., minerals containing metals) from waste minerals.

Dross - Scum that forms on the surface of molten metals because of oxidation or the rising of impurities to the surface.

Evaporative deposit - A sediment that is deposited from aqueous solution as a result of extensive or total evaporation of the solvent.

Flotation - A process of separating minerals. Minerals are ground into fine particles, mixed with water, and put into a tank. Air bubbles are introduced at the bottom of the tank. Certain minerals adhere to these bubbles as they float to the surface, where the froth is scrapped off. Chemicals may be added to the solution to cause the desired minerals to adhere to the air bubbles.

Galvanizing - The process for coating iron or steel with zinc to retard rust and corrosion.

Galvalume - A blend of 45 percent zinc and 55 percent aluminum.

Gravity concentration - A process of separation where mineral (metal) particles of mixed sizes, shapes, and specific gravities are sorted by the force of gravity or by centrifugal force. This method operates by virtue of the differences in density of the subject minerals (metals). The greater the differences in density among the minerals, the more easily they can be separated.

Hydrometallurgy - Treatment of ores, concentrates, or other metal-bearing substances by wet processes; usually involves dissolving material and subsequent recovery from a solution.

London Metal Exchange - One of the world's leading commodity exchanges where contracts for exchange of base metals are based on standardized weight and purity. Transaction prices often use the London Metal Exchange price as a basis for negotiations.

Matte - Intermediate product of pyrometallurgical processing of sulfide ores or concentrates. Usually composed of metals and minerals.

[Metal] oxides - Compounds of oxygen bonded with another element (such as nickel, lead, zinc, or magnesium) at elevated temperatures.

Near-net-shape - A semimanufactured part that is processed close to the shape required for the final manufactured part. Processing a part to a near-net-shape eliminates or reduces the need for extensive grinding or other finishing operations.

Pyrometallurgical processing - Process of extracting metal from ores, concentrates, or other metal-bearing substances by the use of heat.

Roasting - Heating concentrates in preparation for smelting. Roasting usually converts part of the sulfide minerals to oxide form.

Sintering - Fusing particles by heating without melting.

Slag - Waste-containing substance in smelting that floats to the surface of the melt.

Smelting - A metallurgical operation in which metal is separated from impurities by melting. Most commonly conducted in a blast, reverberatory, or electric furnace.

Speiss - Metallic arsenides and antimonides smelted from cobalt and lead ores.

Sulfides - A compound of sulfur with more than one element in which the basic radical is a metal. (Radical is defined as the metal element that is the chief constituent of the molecules comprising a compound; the group of molecules act as a single element incapable of independent existence.)

Terne bearing - Sheet iron or steel coated with an alloy of about 4-parts lead to 1-part tin.

Thixomolding - The injection molding of magnesium granules at elevated temperatures to produce
near-net shape parts with complex designs, high strength, and thin walls.

Toll smelting - A contractual agreement for processing between mineral ore or concentrate producers and a smelting facility.