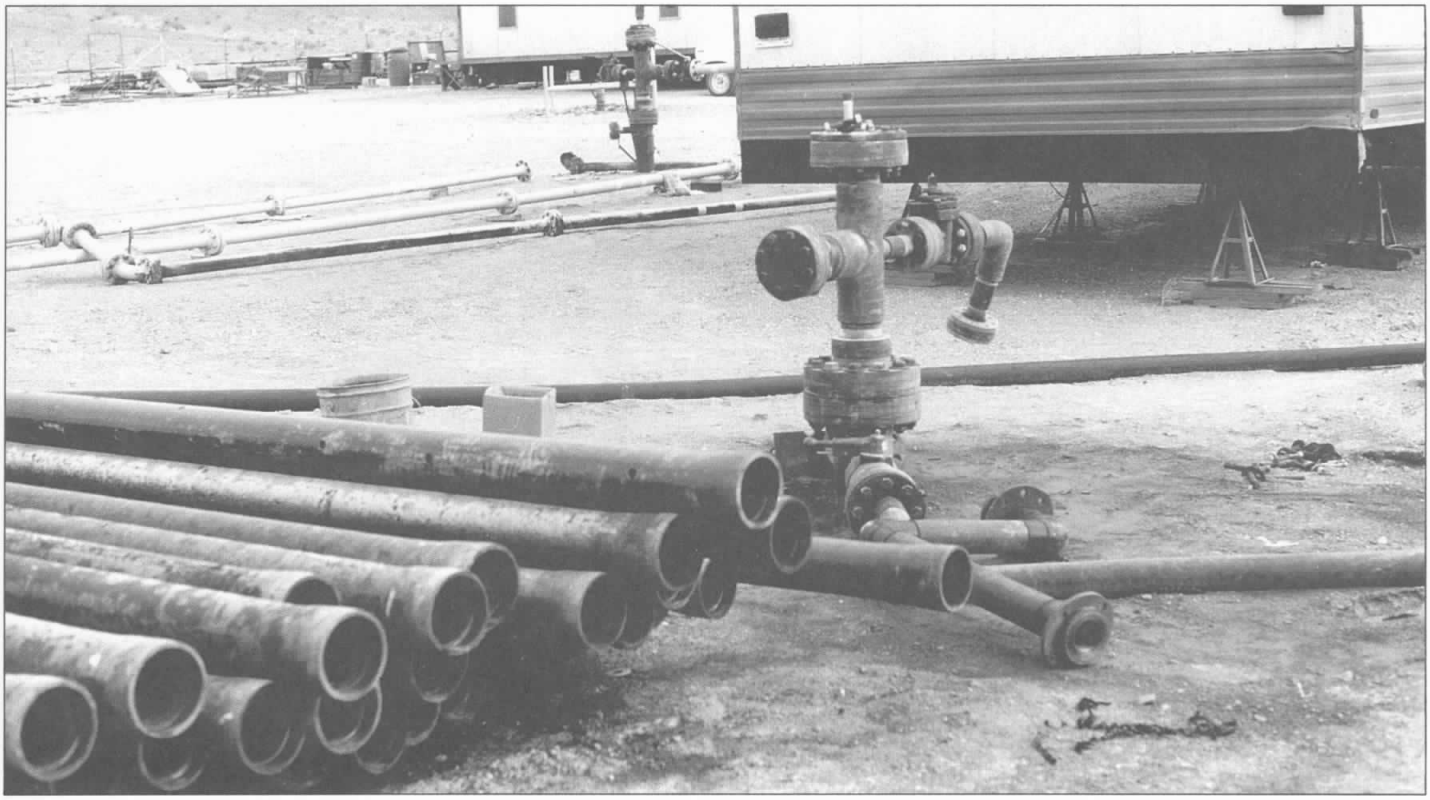
ANNUAL REPORT



Boron

By Phyllis A. Lyday

1993

U.S. DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

ANNUAL REPORT

PB94-213964

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INTERIOR

Bruce Babbitt
Secretary

BUREAU
OF
MINES

August 1994

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COVER PHOTO:
An in situ process wells installed with 178-milimeter (7-inch) fiberglass casing to a depth of 411 meters (1,350 feet) at the Fort Cady colemanite deposit, Newberry Spring, CA. (Photo is courtesy of Fort Cady Mineral Corp.)

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BORON

By Phyllis A. Lyday

Mrs. Lyday has covered boron for 15 years. Domestic survey data were prepared by Pam Shorter, statistical assistant; and international data were prepared by Harold Willis, international data coordinator.

U.S. production and sales of boron minerals and chemicals increased during the year. Domestically, glass fiber insulation was the largest use for borates, followed by sales to borosilicate glass, textile-grade glass fibers, and agriculture.

California was the only domestic source of boron minerals. The United States continued to provide essentially all of its own supply while maintaining a strong position as a source of sodium borate products and boric acid exported to foreign markets.

Supplementary U.S. imports of Turkish calcium borate and calcium-sodium borate ores, borax, and boric acid, primarily for various glass uses, continued.

DOMESTIC DATA COVERAGE

Domestic data for boron are developed by the U.S. Bureau of Mines from two separate, voluntary surveys of U.S. operations. Of the three operations to which a sold and used survey request was sent, two responded, representing 99% of the total boron sold or used shown in tables 1 and 8. A U.S. Bureau of Mines canvass of the three U.S. producers also collected data on domestic consumption of boron minerals and compounds shown in tables 3 and 4. *(See table 1.)*

BACKGROUND

Definitions, Grades, and Specifications

Few of the many minerals that contain boron are commercially valuable. Only colemanite and ulexite minerals, primarily imported from Turkey, are marketed in the United States. The boron oxide content of both minerals is usually marketed at about 40%. *(See table 2.)*

Tincal and kernite ore and brines are the U.S. source of refined borate chemical compounds. The most common refined borates, borax pentahydrate and its derivative anhydrous borax, are marketed in technical and agricultural grades. Lesser quantities of borax decahydrate are produced in technical, United States Pharmacopeia, and special quality grades.

Boric acid is a white, odorless, crystalline solid sold in technical national formulary and special quality grades as granules or powder. Boron oxide is a hard, brittle, colorless solid resembling glass that is ground and marketed most often under the name anhydrous boric acid.

Elemental boron is a dark brown powder in the amorphous form and a yellowish-brown, hard, brittle solid in the monoclinic crystalline form. Boron is marketed in grades from 90% to 99% purity.

Ferroboron is a name given to a variety of boron-iron alloys containing 0.2% to 24% boron used primarily to introduce small quantities of boron into specialty steels.

In the boron hydride series are diborane, a gas; pentaborane, a liquid; and decaborane, a solid. These compounds range from 31,220 British thermal units (Btu) per pound for diborane to 27,850 Btu per pound for decaborane.

Boron nitride, a soft, white, highly refractory solid resembling graphite, can withstand significant oxidation to temperatures up to 650°C. Boron nitride produced in fibrous form equals glass fibers in strength and modules of elasticity, but is lighter in weight and more resistant to high temperature. When subjected to extremely high pressure and temperature, boron nitride forms cubic crystals that rival the hardness of diamond. Boron carbide, produced by reacting carbon and boric acid at 2,300° C, is a highly refractory material and one of the hardest substances known. Most commonly used for both abrasive and abrasion-resistant applications as well as nuclear shielding, boron carbide is marketed in technical and high-purity grades.

Geology

At the Kramer borate deposit of the Boron open pit mine, tincal consists of more than 80% of high-grade beds, with claystone only between the crystals. In low-grade beds, tincal is less than 50% of the beds and is disseminated in a claystone matrix. The lower portions of the beds consist of kernite, a secondary mineral formed by the dehydration and recrystallization of borax resulting from high temperature and pressure. Probertite is found radiating prismatic crystals, or rosettes, commonly within claystone and exclusively where kernite is the dominant sodium borate. The sodium borate facies is enveloped by ulexite, colemanite, and barren claystone facies. The barren facies contain calcareous nodules but are barren of borates.[1]

Searles Lake in southeastern California is a closed structural basin filled with alluvian and lacustrine evaporites. The flat area of about 100 square kilometers overlies two separate salt structures. The evaporite beds were formed during periods of high evaporation and low rainfall. Mud beds were formed during full lake conditions. The upper salt structure is 21 to 27 meters thick and the lower one is 8 to 12 meters thick. The brines in these salt structures are high in sodium carbonate and low in sodium chloride. The important chemical ions are bicarbonate, carbonate, borate, chloride, potassium, and sulfate as halite, hanksite, trona, nahcolite, burkeite, borax, and thenardite. An impervious mud parting layer 4 meters thick divides the upper and lower salt layers. The upper brine contains 1.63% borax and is rich in potash. The lower brine contains 1.97% borax and more carbonate.[2]

The Fort Cady colemanite deposit is in the Mojave Desert near Barstow, CA. The known deposit extends over 154 hectares at an average depth of 411 meters from the surface. The deposit is encapsulated in clay beds, which make it an ideal setting for in situ mining technology. Ground water in the ore body is brackish with a total dissolved solids figure in the 20,000-milligram-per milliliter range.[3]

Technology

Problems with the discovery, processing, and transporting of boron minerals and compounds from remote and hostile locations became a part of the history of the borax industry. The location of the ore and the methods of production remained a guarded secret for many centuries. It was not until the end of the 17th century when Amsterdam had replaced Venice as the center of borax production that the mineral source and methods of process were commonly known. Producers of boric acid from the steam vents of Tuscany, Italy, prospered because of a lack of competition in the world market. Large reserves of borates were found in Turkey in 1865 and in the Western United States in 1856. With the discovery of new minerals, new processes were developed. The history of boron production and processing has continued for thousands of years because of the benefits derived from using the product. The use and processing have varied little over the past 100 years. Modern changes in processing are a result of improved equipment and processing controls.

Byproducts and Coproducts

More than four-fifths of the U.S. production comes from mineral deposits mined only for their boron content. The remainder is produced from lake brines, which also supply sodium carbonate, sodium sulfate, potassium sulfate, and potassium chloride. Turkish colemanite, ulexite, and tincal ores are worked only for their boron content. Most Soviet borates also are mined only for their boron content, but the Gulf of Kara-Bagaz-Gol and the Sivash (lagoon) borates are extracted with coproduct chloromagnesium from brines. South American boron has been mined from ores and also has been produced as a coproduct of nitrate and iodine production.

Economic Factors

Costs.—Energy costs are especially high for producing anhydrous products. The anhydrous products were originally introduced to decrease freight costs per ton of contained boron oxide. Domestic producers now use cogeneration facilities to reduce the cost of energy for processing and supplying excess electricity for sale.

Depletion Provisions.—The domestic and foreign depletion allowances for boron are 14% of gross income and may not exceed 50% of net income without the depletion deduction.

Operating Factors

Occupational Safety and Health Administration's (OSHA) Hazard Communication Standard went into effect November 1985 and May 1986. It is OSHA's most comprehensive worker protection regulation. It provides for information and training for workers encountering chemical exposures in the workplace. The standard requires the use of labels and material safety data sheets for all regulated chemicals. Part of the standard includes the Threshold Limit Values (TLV) from the American Conference of Governmental Industrial Hygienist. TLV's refer to airborne concentrations of substances and represent conditions under which nearly all workers might be repeatedly exposed day after day without adverse effect. The only hazard listed for boron chemicals produced at the mine site was a Time Weighted Average for borax decahydrate, listed as 5 milligrams per cubic meter per 8-hour workday, 40-hour workweek, to which nearly all workers may be repeatedly exposed without adverse effect. Sodium borates, boric acid, and boron oxide are not present to any significant degree in air and are placed in the same hazard category as general dust.[4]

Small quantities of boron are essential for all plant life. Boron is added in trace levels to fertilizers; however, quantities well below concentrations affecting humans and animals are so extremely toxic to vegetation that boron compounds also are used commercially as herbicides. Concentrated boric acid is used to control certain insects and in dilute solutions as a preservative to control the growth of bacteria.

Owens-Corning detailed the results of four new studies on fiberglass and human health, which were completed. One of the four studies was an extensive animal inhalation study. The studies, in conjunction with epidemiology, provided strong evidence that working with fiberglass does not pose a significant human health risk. These studies were consistent with the results of animal inhalation studies. Direct injection of fibers into test animals has produced tumors, but the relevance has been challenged most recently by the World Health Organization.[5]

ANNUAL REVIEW

Legislation and Government Programs

The Senate Energy Committee approved a bill October 5 for the California Desert Protection Act. Under the proposed bill, 1.8 million hectares (4.3 million acres) of public land would be designated wilderness. In addition to the wilderness designation, the bill would add 0.5 million hectares (1.3 million acres) of Federal lands to the existing Death Valley National Monument and 83,000 hectares (200,000 acres) to the Joshua Tree National Monument. The land under discussion contains numerous mineral deposits, including most known boron reserves. At yearend, H.R. 2929 had passed the House and was sent to the Senate for further consideration. The U.S. Bureau of Mines published OFR 62-92 (NTIS:PB 92-238237/AS) in May 1992 that presents nine case histories to highlight the diversity of deposits, commodities, and markets represented in the California Desert Conservation Area.

The Department of the Interior, Bureau of Land Management, published in the December 23, 1993, Federal Register the availability of Final Environmental Impact Report/Environmental Impact Statement (EIR/EIS) for the Fort Cady Minerals Corp. borate solution mining project. The decisions generated from the EIR/EIS will be consistent with the California Desert Conservation Plan as Amended.

The Environmental Protection Agency published a proposed rule on Boric Acid and its Salts, Borax (Sodium Borate Decahydrate), Disodium Octaborate Tetrahydrate, Boric Oxide (Boric Anhydride), Sodium Borate and Sodium Metaborate; Tolerance Exemptions in the Federal Register on June 30. The document proposes an exemption from the requirements of a tolerance to be established in or on raw agricultural commodities when used as an active ingredient in insecticides, herbicides, or fungicides preharvest or postharvest in accordance with good agricultural practices.

The Department of Health and Human Services ordered a review of research that concludes fiberglass insulation is a possible carcinogen. Scientists believe that fiberglass insulation may cause cancer in humans. The health threat is to construction workers who install the insulation, not to occupants of the dwelling.

Congress continued to debate the fate of the Mining Law of 1872 as amended and its affect on the hard-rock mineral industry. Boron is leasable as sodium borate. Other colemanite and probertite minerals are locatable because they also contain calcium and are deposited as placer deposits. Changes in the mining law will probably affect royalty rates for minerals, including these locatable industrial minerals in addition to the commonly thought of hard-rock minerals such as gold and copper.

Production

The majority of boron production continued to be from Kern County, with the balance from San Bernardino and Inyo Counties, CA.

American Borate Co. (ABC), a wholly owned subsidiary of Owens-Corning, was sold in December 1990 to a private firm. ABC renewed its mine permits and began to mine small amounts of colemanite and ulexite from the Billie Mine. Colemanite was processed at Lathrop Well, NV. Storage and grinding facilities were at Dunn, CA.

North American Chemical Co. operated the Trona and Westend plants at Searles Lake, in San Bernardino County, to produce refined sodium borate compounds and boric acid from the mineral-rich lake brines. North American is owned by the Harris Chemical Group, with corporate headquarters in New York City and operating headquarters in Overland Park, KS. At the Trona plant, a differential evaporative process produced borax with potash as a byproduct. Boric acid was produced by solvent extraction. The Westend plant used two lines to supply brines to the plant. The first line fed lake brine to the Argus plant where sodium carbonate was produced. The effluent borax-rich brine then is pumped to the Westend plant where it supplied about two-thirds of the brine feed. The effluent was blended with fresh lake brine from a second feed line that supplied about one-third of the brine feed. The blended brine was then cooled to 18° C to precipitate decahydrate borax. The effluent was cooled to 8° C, and the precipitated Glauber's salt was used to produce sodium sulfate. North American was in the process of evaluating technical changes in it production operation that were to be implemented during 1993.

U.S. Borax, Inc. (Borax), a part of Borax Consolidated Ltd. of the RTZ Corp. PLC of London, United Kingdom, continued to be the primary world supplier of sodium borates. RTZ is traded on the New York Stock Exchange. Borax combined its corporate headquarters and Research Center and moved to Valencia, CA, in March 1993.

Borax mined and processed crude and refined sodium borates, their anhydrous derivatives, and anhydrous boric acid at Boron, in Kern County, CA. A second plant at Boron used a proprietary process to produce technical-grade boric acid from Borax's extensive kernite ore reserves. The boric acid was produced to compete with imported colemanite used in glass manufacture.

The majority of material was shipped to Borax's storage in Wilmington, CA. Products made at Wilmington included ammonium borates, potassium borates, sodium metaborates, and zinc borate.

Consumption and Uses

U.S. consumption of borates increased. Glass accounts for three major borate applications as follows: glass fiber insulation, textile glass fiber, and borosilicate glass.

The use of borates in glass fiber thermal insulation, primarily used in new construction, was the largest area of demand for borates and the principal insulating material used in the construction industry. Composed of very thin fibers spun from molten glass, its purpose is to trap and hold air. Typically between 4% and 5% boron oxide is incorporated in the formulation to aid melting, inhibit devitrification, and improve the aqueous durability of the finished product. Cellulosic insulation, the ninth largest area of demand, increased.

The fifth major market for borates, manufacturing high-tensile-strength glass fiber materials for use in a range of products, showed a decrease in demand. The process of producing glass fiber uses a borosilicate E-glass formulation that is continuously drawn through platinum alloy bushings into continuous filaments of between 9 to 20 microns in diameter. The plastic industry uses roving or chopped strand fibers and the textile industry uses yarn fibers.[6] E-Glass, or textile fiber glass, typically contains between 6% and 8% boron oxide.

Originally these glasses were used for electrical purposes, and low sodium levels were important. Now their major applications are reinforcements for plastics, but the low sodium tolerance still applies. The nonconductive and low dielectric properties of high-strength glass-reinforced materials make them transparent to radar and thus valuable for "stealth" applications. Carbon-fiber-reinforced resins can be stronger than metals and, with higher modules, more stable. Although composites can be 10 times more expensive than typical aerospace-grade aluminum, the flexibility they offer in design and consolidation of parts allows large, complex structures to be fabricated to exacting specifications. In addition, their light weight and ability to withstand high temperatures have made them the material of choice for a variety of aerospace applications.

Annual production of fiber glass was reported to be 2 million metric tons per year at a value of $2.3 billion. This represented 18% of the total energy used to produce glass products. Typical glass industry cost for an 80-ton-per-day-capacity fiberglass plant was estimated at $45 million for a product that sells for $750 per ton.[7]

Owens-Corning planned to reopen its Jackson, TN, glass fiber plant that closed in 1987. Capital investment was between $30 and $40 million to install new equipments. When the plant reopens in 1994, it will employ about 80 people and produce wet-process mat glass fiber for use in making roofing shingles.[8]

Consumption of borates in borosilicate glasses remained the third major end use, and demand decreased. Boron added in amounts of between 10% and 13% to glass reduced the viscosity of the melt, assisted with fiber formation during processing, allowed for improved specific optical properties, increased resistance to aqueous or chemical attack, enhanced certain mechanical properties, and reduced the thermal expansion coefficient and thermal shock resistance of the product. Scientific glassware products are usually fabricated in Pyrex borosilicate glass. This type of glass is resistant to heat up to 400° C and to chemical corrosion from liquids and gases.[9]

Construction of the Nation's first facility to produce a borosilicate glass from solid nuclear waste was completed at Savannah River Site, Aiken, SC. High-level nuclear waste that has accumulated during 35 years will be reprocessed and stored in stainless steel canisters for temporary storage before interment in a geologic repository. Boron and lithium are added to the sludge to improve the viscosity of the glass. The viscosity of the borosilicate glass is a function of temperature. Viscosity determines the rate of melting of the raw feed, the rate of glass bubble release (foaming and fining), the rate of homogenization, and therefore, the quality of the final glass product. If the viscosity is too low, excessive convection currents can occur, increasing corrosion and erosion. After vitrification at 1150° C, the glass is pored into the stainless steel canisters for interim storage.[10]

Glazes and enamels are the thin, glassy coatings fused onto ceramics and metals, respectively. Examples include wall and floor tiles, tableware, earthenware, bone china and porcelain, cookers, washing machines, pots and pans, and architectural panelling. The surface decoration of glass articles can now be made with lead-free enamels. A glass enamel composition has a low softening point glass frit and inorganic pigment in a ratio of approximately 9:1. Traditional frits are composed of boric acid, lead, and silica. Traditional lead-bearing frits fired between 540° C to 740° C allow the glass enamel manufacturer to meet requirements of the hand-blown and bent glass industries. Metal in various forms give different colors, such as cobalt silicate for a deep blue; zinc and alumina for lighter shades of blue; chrome oxide for green; and iron, zinc, chrome, and aluminum oxides for brown. Durability can be improved by the addition of titanium dioxide or zirconium oxide. The most common lead-free decorating formulations in frits are zinc borosilicate and bismuth borosilicate, although some barium is being used as a lead replacement. The only difference in lead-bearing enamels is the inability to develop the cadmium sulfoselenide series of yellows, oranges, and reds. At firing, the frit softens and approaches a molten state and wets the pigment and the surface of the article being decorated, thus permanently bonding the glass substrate. Low lead release frits fire at higher temperatures and have low levels of leachability of the lead pigments.[11]

Boron compounds continued to find application in the manufacture of biological growth control chemicals for use in water treatments, algicides, fertilizers, herbicides, and insecticides. Boron can be applied as a spray and incorporated in herbicides, fertilizers, and irrigation water. Sodium polyborate can be used in carpets to control fleas.[12] The Potash & Phosphate Institute of Atlanta, GA, recommended 0.9 kilogram (one-half pound) of boron for every ton of expected yield of alfalfa in the spring 1992 Agi-Briefs. The brief recommended that micronutrient levels in the soil be monitored by soil testing. The Tennessee Valley Authority published Commercial Fertilizer 1993 that list total boron compounds consumed as secondary and micronutrients by region in the United States for 1992 and 1993 as 14,666 and 16,350 metric tons, respectively.

A growing and important use of zinc borate, ammonium pentaborate, and boric oxide is as fire retardants in the cellulosic materials such as chipboard, cellulose insulation, and cotton mattresses. Zinc borate is of commercial importance in synthetic polymers.

Boron compounds also were used in metallurgical processes as fluxes, shielding slag in the nonferrous metallurgical industry, and components in electroplating baths. Small amounts of boron and ferroboron were constituents of certain nonferrous alloys and specialty steels, respectively.

Neodymium-iron-boron alloys used in magnets are produced commercially by melt spinning and sintering. In melt spinning, molten alloy is ejected onto a rotating disk where a ribbon 30 to 50 micrometers thick and 1 to 3 millimeters wide of solid material "spins" off the disk. The process is conducted in an inert atmosphere. In the sintered process, the alloy powder is oriented in a magnetic field, pressed, and sintered. The ingots of the alloy are crushed, milled, and pulverized to a powder of about 3 micrometers in diameter. The alloys of the nonmetal boron and the metals neodymium and iron produces the strongest magnetic material known. The magnets then are used in automotive direct-current motors, computer disk drives, portable power tools, and home appliances.[13]

Boron also is used as a bleaching agent in detergents and cleaning products, such as compact washing powders. Perborates carry active oxygen that forms hydrogen peroxide in solution. Perborate tetrahydrate has been displaced by perborate monohydrate, which is more soluble in cool laundry wash temperature conditions. In the United States, two companies now produce a low-temperature activate perborate bleach.

Recycling

Research attempts have been made at recycling fiber-reinforced plastics, but at present it is not economical. Canada's Enviromental Ministry funded in 1992 a recycling plant reportedly to be the first of its kind in North America. The facility will create new raw materials from old fiberglass boat hulls, bathtubs, and auto parts by separating the glass fibers from the resins.

Prices

Prices for Turkish colemanite and ulexite increase slightly. The price for high-purity boric acid decreased 52%. All other reported prices remained the same. *(See table 5.)*

Foreign Trade

The majority of material from the Borax facility in Boron was shipped to storage, loading, and shipping facilities at Wilmington, CA. A large part of the output was exported to Western Europe from Wilmington to Botlek, Netherlands.

Imports of Turkish colemanite ore totaled 81,650 tons, primarily destined for Owens-Corning Fiberglass, Toledo, OH, through a port in Moreheady City, NC. Carolina Shipping of Charleston, SC, also imported two shiploads through the port of Charleston.

Colemanite exports totaled 16,597 tons. American Borate, Virginia Beach, VA, shipped 8,487 tons of that amount to Keelung and Kaohsiung, China. A company named ITC Inc., Balitmore, MD, shipped 3,146 tons to the Republic of Korea and 887 tons to Hong Kong. American Borate also shipped 2,268 tons to Australia and 1,052 tons to the Republic of South Africa.

Imports of Turkish ulexite ore totaled 135,071 tons, primarily destined for Owens-Corning Fiberglass through the port at Morehead City, NC. A small amount of ulextie from Chile was imported by F & S Alloys & Minerals Corp., New York, NY, through the port of Houston, TX. *(See tables 6 and 7.)*

World Review

Argentina.—The Argentina Mining Plan was announced. The plan changed the collection of taxes to encourage foreign investment. FMC Corp. will begin development of a lithium and boron production facility at the Salar del Hombre Muerto in the northern region because of the new mining plan. FMC plans to utilize new extraction technologies for the brine that will be developed from the salar.

Boroquimica SA continued production of tincal from the Salar del Hombre Muerto and boric acid from Tincalayu in Salta Province. Tincal between 16% and 18% boron oxide is concentrated by washing and crystallizing to a 99.9% borax product. At Sijes in Salta Province, hydroboracite and colemanite are produced. Ulexite is produced by Boroquimica at Cauchari in Jujuy Province and at Diablillos in Salta Province.[14]

Bolivia.—During March 1992, Boron International Inc. entered into an agreement with Teck Corp. to finance an $8 million expansion at Capina for the production of 60,000 tons per year of calcium borate manufactured from ulexite. Current mining in the area of 30,000 tons annually resulted in 8,000 tons of ulexite (40% boron oxide), 4,000 tons of boric acid, and 1,500 tons per year of sodium octaborate.[15]

Compania Minera Tierra Ltd., a small company formed in 1988 for producing borates in an area of the Department of Potosi, has important concessions of ulexite and sulfur near the Chilean border in the southwestern tip of the country. About 120,000 tons per year of ulexite is exported to Brazil and other neighboring countries. In 1990, the company employed 120 persons. In 1993, a boric acid plant was operational and producing 10,000 tons per year.

The company has interest in ulexite mineral concessions that cover an area of 4,800 hectares, and reserves have been estimated by the company to exceed 13 million tons of raw ulexite with grades ranging from 20% to 37%. Ulexite is extracted and dried by plowing with a tractor. The dried ulexite is washed and roasted. The processed ulexite of about 42% borate content is bagged and exported by trucks and rail.

Various borate deposits are in the southwestern part of the Altiplano. Llipi Llipi, in the south of Salar de Uyuni, contains an estimated 12 million tons of ulexite. Copla Ltda. was mining ulexite for export. Production of ulexite in 1989 was 9,609 tons.[16]

The Salar de Uyuni is the largest salt flat in the Central Andes salt basin. The flat is composed of lithium, potassium, and boron salts in the form of brines. In 1988, the Ministry of Mines and Metallurgy and the Complejo Industrial de los Recursos Evaporiticos del Salar de Uyuni (Ciresu) began negotiation with Lithium Corp. of America (LITHCO), a subsidiary of FMC. FMC announced on January 15, 1993, to the Ministry that it was ending plans to explore and develop the brine of the Salar de Uyuni.[17]

Chile.—New legislation in 1992 allowed Corporación Nacional del Cobre de Chile (Codelco) to associate with private national and international firms for exploration and development. State-owned Empresa Nacional de Minería (ENAMI) will be given some smaller prospects at yearend.

Boratom Quimica Processes Ltda. had operated in Chile since 1986 by providing technology and sales support to producers. In 1986, Boratom shipped 3,000 tons of ulexite to the United States in connection with Borichem Inc. The ulexite mines are in the I and II Regions of Chile. Boratom operates a refining plant near Iquique. In March 1992, Boratom's assets and technology were sold to Boron International Inc. (Canada). In November, Boron entered into an agreement with Teck Corp. called Boron Chemicals Processes Chile S.A.[18]

Quimica & Industrial del Borax (Quiborax) was the main producer of boric acid and concentrated ulexite. The second stage of an expansion was completed in 1992. Included in the expansion were about 70,000 square meters of evaporation ponds, a ulexite washing plant, a water purification osmosis plant, and a boric acid plant. Quiborax operated a mine at Surire, Parindacta, with a crude annual output of 1,000,000 tons per year of ulexite. The ulexite is washed and upgraded from 30% to 40% boron oxide by centrifugal action and flotation prior to filtration. Calcium borate is produced by adding calcium hydroxide to the washed ulexite.[19] Beginning in 1993, the boric acid production was estimated to be 20,000 tons and calcium borate production was expected to be 20,000 tons. The plant facilities are at El Aguila, Arica.[20]

The National Boraxx Corp. (Cleveland, OH) packages and distributes boric acid in the United States for Quimica E Industrial del Borax Ltda. (Quiborax Ltda.).[21]

Compania Minera Salar de Atacama (Minsal) is a joint-venture project between AMAX Inc. of the United States, Molibdenos Y Metales (Molymet) of Chile, and Corporacian de Fomento de la Produccion (CORFO). CORFO established the joint venture as a result of an international public licitation in 1986, in which LITHCO was the only other bidder. The project was designed to produce lithium carbonate, potassium chloride, potassium sulfate, and boric acid from the Salar de Atacama in the II Region. Future production was expected to be 26,000 tons of boric acid per year. In February 1991, the project was placed on hold for a second year, under the terms of AMAX's original contract. Sociedad Quimica y Minera del Chile (SQM) acquired the 63.75% stake held by AMAX. Plans were to limit the production to about 300,000 tons per year of potassium chloride and possibly lithium. SQM indicated a target date of mid-1995 for production.[22]

China.—The borates in the salt lakes of China are mainly found on the Qinghai-Xizang (Tibet) Plateau. Boron is distributed in many saline lakes from the southern side of the Gilian Mountains to the north side of the Gangdisi-Tanggula Mountains.

In Liaoning Province, 700,000 tons of ore was mined in 1991. Other provinces where borax was reported were Beijing, Hebei, Heilongjiang, Jilin, Qinghai, Shaanxi, and Tianjin.[23]

France.—An agreement between Callery Chemical Co. and the French Sipsy division of Jouveinal was finalized to develop and produce chemical reagents. Callery is a producer of borane reagents.[24]

Iran.—At Deh-e-Shotoran near Sirjan, the region is of tourmaline-rich granites that have invaded metamorphosed sandstones. Ulexite is found in depressions. At Tonkar near Sabzevar, there are several sources of borates in consolidated sediments of thin beds of limestone, marl, and clays. Ulexite also occurs close to the village of Ashin near Anarak.[25]

Italy.—In 1992, EniChem, part of Ente Nazionale Idrocarburi SpA (ENI), the state-owned petroleum company, announced a plan that provides for the sale of nonstrategic operations in the core business of chemicals, oil, and gas. In 1992, negotiations began on the sale of Societa Chimica Larderello (SCL), Tuscany, a producer of ultrahigh-purity boric acid and other boron compounds. The sale was finalized in 1993 when SCL became part of the Harris European affiliates of the D. George Harris & Associates holding company. High-purity boric acid produced at Larderello was marketed in the United States by EniChem Americas Inc. SCL exported about 50% of production to more than 30 countries worldwide, primarily for use in ceramics, borosilicate glasses, for the production of fluoborates, and other boron compounds. The company was founded in 1818 and extracted boric acid from geothermal sources. These fumaroles now supply electrical energy and chemicals, such as carbon dioxide and ammonia, to the plant. The first chemical plant in Italy to produce boric acid from imported colemanite ores was built in 1963 with a capacity of 11,000 tons per year. A newer plant was built in 1981 with a capacity of 66,000 tons per year of refined boric acid and approximately 16,500 tons per year of high-purity sodium borate pentahydrate, decahydrate, and other boron specialties. In 1984, SCL developed Boric Acid NS 99.99% (nuclear grade), which is marketed to nuclear power companies because it exceeds PD Specifications 52205 AP Revision F. No. 79500 for use in powerplant applications.

Mexico.—The 1992 Mining Law eliminated the National Mining Reserves and released more than 3 million hectares into the public lands that are now concessionable by mining companies. Foreign companies can invest and participate in exploration and exploitation of governmental concessionable mineral deposits through investment trusts with 100% ownership. Without the investment trust, a foreign investor is limited to 49% ownership.

Metamin Enterprises Inc., with the support of Dauntless Developments, has terminated two claims, Carlos and Carlos Uno, in the Tubutama evaporite basin. The claims, covering beds of colemanite and gypsum, are about 31 kilometers south of the U.S. border in the State of Sonora. Work by the Government organization Consejo de Recursos Minerales identified a reserve of all classes of about 30 million tons grading 8.33% boron oxide. The 160-hectare area covered by the Carlos claims has a potential for an open pit colemanite deposit of up to 40 million tons. The mineralization occurs as beds of colemanite and possibly howlite, with clay and silt bands, and gypsum and celestite beds. Chemical analysis indicates very low values of arsenic between 2 and 7 parts per million. Mining costs were expected to be less than $5 per ton.[26]

U.S. Borax continued as a partner with Vitro Corp. for the Magdelena colemanite deposit. The processing development work had been halted because of high arsenic content in the ore that was difficult to remove. Vitro was in the process of selling U.S. Borax's ownership in the deposit.

U.S. Borax acquired claims to the Tubutama colemanite reserve, which surrounded the Carlos claims of Ainsworth Jenkins, when the Government eliminated the National Mining Reserves in 1992.[27]

Netherlands.—Morton International planned to transfer sodium hydride manufacturing operations from Beverley, MA, to Delfzijl where Morton now produces sodium borohydride. When the plant is completed in 1994, Morton planned to stop production in the United States and supply that market from the Delfzijl plant.[28]

The Silenka glass fiber factory in Hoogezand, northern Holland, was founded in 1961 as a joint venture between PPG and Akzo. The state-owned Development Co. for the Northern Netherlands assisted by purchasing a 30% share in 1977 when the company was struggling because of rising energy costs. PPG purchased the remaining shares in 1990 and renamed the site PPG Industries Fiber Glass bv. PPG is the second biggest fiberglass manufacturer in Western Europe.

Peru.—The quantity and number of minerals produced in Peru and the likelihood of significant deposits to be discovered attracted attention to the privatization plants. The Government continued its privatization program to reactivate the entire mining sector selling many properties at prices below comparable resources in the international market. Boron continued to be produced in Arequipa by Compania Minera Ubinas S.A. A total of 34 metric tons of sodium borate and sodium calcium borates was imported by Fertilizer Corp. of America into Miami, FL, and Wilmington, NC.

Russia.—Primorsky Industrial Amalagmation, in Dalnegorsk, produces boron minerals from datolite containing 20% boron oxide. Amalgamation is part of the Russian Agricultural Joint Stock Co. known as ROSAGROCHIM. ROSAGROCHIM coordinates the activities of about 100 companies.

Boron minerals also were reported to be produced in Kazakhstan, the second largest newly independent republic of the former U.S.S.R. The Government was actively pursuing foreign investment to increase production capacity by improving efficiency to increase exports.[29]

Turkey.—Turkey's boron operations are under the control of the Government corporation Etibank. Colemanite is mined at Bigadic, Emet, and Kestelek; tincal at Kirka; and ulexite at Bigadic. Etibank was reported to have an ore production capacity of 8,000 tons of colemanite, 500,000 tons of tincal, and 115,000 tons of ulexite. Etibank operates refining facilities to produce refined sodium borates and boric acid from tincal concentrates at Bandirma and Kirka. Boron minerals and compounds are shipped from the Port of Bandirma on the Sea of Marmara and Izmir on the Aegean Sea. Bandirma can produce 55,000 tons of borax, 35,000 tons of boric acid, and 20,000 tons of sodium perborate per year. Kirka can produce 50,000 tons of borax, 160,000 tons of pentahydrate borax, and 50,000 tons of anhydrous borax per year.[30]

The Government announced that Etibank would become two separate divisions as a prelude to privatization of the banking business. Sixty days after the July 13 announcement, the two divisions became affiliated companies and the process will begin for privatization of the banking division.

The Turkish Government now owns all boron and trona minerals, and private concessions of these minerals could not be sold to private investors. Boron is a profitable operation for Etibank and the privatization of this sector is unlikely.[31]

United Kingdom.—Borax Consolidated, a subsidiary of RTZ Corp., was building a 5,580-square-meter (60,000-square-foot) technical center at the University of Surrey Research Park, near Guildford. The move will involve a total of 120 people from the research, technical, and development functions and the technical marketing operations.[32]

Imperial Chemical Industires Plc planned to close the 38,000 tons per year Sodium perborate plant at Runconm at yearend. The remaining sodium perborate capacity will be supplied by German producer Degussa A.G. and Netherlands producer Interox S.A. with 285,000 and 240,000 tons per year of capacity, respectively.[33]

Current Research

The use of oxygen-fuel firing of glass melting furnaces has been in use for several decades. Sixteen States have one oxy-fuel conversion and some States have several conversion plants. Twenty-one plants using borosilicate glass have converted to oxy-fuel—9 were fiberglass and 12 were lighting, tableware, and television conversions. Both types of conversions were designed to limit particulate matter. Advancements in technology and the need to reduce air emissions have been an added incentive to the conversions. Glass melting will be affected by titles I, II, and V of the Federal Clean Air Act Amendment of 1990 (CAAA). Oxy-fuel conversions are a way to decrease capital expenditures for post-treatment systems such as electrostatic precipitators or bag houses required under title I of the CAAA.[34]

A group of research chemists developed a triply bonding silicon using a borate anion that offers new synthesis routes for certain types of silicones. The silicon cation already has been used to catalyze the formation of silicones of commercial importance. A boron compound was chosen as the anion for the tricoordinate silicon because it is stable in toluene and does not react with silicon cations.[35]

A typical glass wool formation uses

5% boron oxide. Virtually any borate can be used for the boron oxide source, although refined pentahydrate borax is preferred. Studies reinforced the uniqueness of boron oxide in improving glass durability and assisting melting in fiberglass formation by reducing the viscosity-related temperature. Increasing the alumina content increased the aqueous durability of glass wool. Increasing sodium oxide greatly reduces the durability. Other alkali oxides have small positive or negative effects.[36]

A new automated instrument is able to decrease the time needed to separate sugars using a sodium cyanoborohydride solution. Previous separations took weeks or months using mass and nuclear magnetic resonance. The new instrument can have a "fingerprint" of the glycoproteins (proteins bonded to carbohydrates) in 48 hours that can be used in research on many biochemical functions such as cell interaction with hormones, antibodies, and other cells.[37]

Two independent research teams have verified superconductivity for the first time in quaternary intermetallic compounds. The new compounds have the potential for better superconducting wires than the niobium compounds now in use. Both mixtures consist of four elements that are both metals and nonmetals. The two new compounds are mixture of yttrium-nickel-boride carbide and yttrium-palladium-boride carbide.[38]

Adding boron to polymers can transform low-cost polymers to material that rival engineering plastics such as polycarbonate. Normally, polyolefins do not adhear to carbon and glass fibers. The addition of boron can yield polyolefins that cling without interferring with the production of the raw material or the processing of the polymer into finished products.[39]

Studies on the effect of boron content for the mass manufacture of rectangular pipes for the storage of spent nuclear fuel resulted in the manufacture of a 19%Cr-8%NI-0.6%B steel. Hot workability of steel decreases with increasing boron content after 0.76% mass percent but is improved by forging. The decrease in hot workability with increasing boron content is due to precipitates of iron and chrome borides.[40]

OUTLOOK

Production of boron minerals and compounds have decreased between 1983 and 1993. One reason is that production and imports reported in 1 year may be utilized over a period of years. In addition, environmental concerns may change the demand for boron significantly in a short period. The regulation of fire retardants in products has resulted in changes in boron usage as a fire retardant. More recent decreases in domestic consumption have been attributed to decreases in glass consumption because of less demand resulting from a recession. Moreover, one-half of domestic production is exported. Because of increases in production in other coutries, this amount has decreased significantly during the past few years.

Agriculture

Boron usage in agriculture increased significantly in 1993. The primary reason was attributed to the decline in the number of farms during the same time period. Farming exports are showing increased strength, and demand for boron usage in agriculture increased during 1993.

Ceramics and Glass

Reported consumption of boron minerals in glass and ceramic uses was 211,656 tons of boron oxide content representing 60% of total demand consumed. This was down from the 214,411 tons representing 62% of total demand consumed in 1992. Ceramics and glass both have faced competition with polymers. The U.S. fiberglass industry was reported to be feeling the effects of recessionary pressures. The sagging economy produced a decline in demand for fiberglass reinforcements. Fiberglass is closely related to construction and transportation.

Coatings and Plating

Primarily used as a protective coating for steel products and as a glazing on ceramic tiles, boron usage increased 37% during the year.

Fabricated Metal Products

Boron usage decreased in metal products during the year. Many traditional metal products that require soldering now are produced from polymers as one piece. Usage in specialized metal was expected to increase.

Soaps and Detergents

This usage declined primarily as chlorine bleaches and cold water washes replace boron soap powders. Recent concern for environmental effects of chlorine has reversed the decline. Perborate bleaches have returned to name brand soap products. The usage of boron in soaps and bleaches was expected to increase by 4% per year during the next 5 years.

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TABLE 1
SALIENT STATISTICS OF BORON MINERALS AND COMPOUNDS

(Thousand metric tons and thousand dollars)

	1989	1990	1991	1992	1993
United States:					
Sold or used by producers:					
Quantity:					
Gross weight[1]	1,114	1,094	1,240	1,009	1,055
Boron oxide (B_2O_3) content	562	608	626	554	574
Value	$429,806	$436,175	$442,532	$338,700	$372,839
Exports:					
Boric acid:[2]					
Quantity	42	39	47	80	74
Value	$32,613	$31,679	$35,457	$53,652	$50,498
Sodium borates:					
Quantity	[3]646	[3]585	[4]554	[4]489	[4]481
Value	[e]$361,000	[e]$208,433	[e]$205,722	[4]$159,492	[4]$181,310
Imports for consumption:[4]					
Borax:					
Quantity	7	5	10	16	40
Value	$2,114	$1,570	$3,260	$5,328	$1,226
Boric acid:					
Quantity	3	6	5	6	17
Value	$2,197	$3,921	$3,784	$4,337	$11,910
Colemanite:					
Quantity	15	12	18	30	90
Value	$4,202	$3,310	$4,389	[r]$16,050	$48,600
Ulexite:					
Quantity	27	29	16	42	149
Value	$5,940	$7,360	$4,060	[r]$11,340	$40,677
Consumption: Boron oxide (B_2O_3) content	315	319	262	345	354
World: Production	[r]2,993	[r]2,886	[r]2,865	[r]2,660	[e]2,178

[e]Estimated. [r]Revised.
[1]Minerals and compounds sold or used by producers, including both actual mine production and marketable products.
[2]Includes orthoboric and anhydrous boric acid.
[3]Source: The Journal of Commerce Port Import/Export Reporting Service.
[4]Source: Bureau of the Census.

TABLE 2

BORON MINERALS OF COMMERCIAL IMPORTANCE[1]

Mineral	Chemical composition	B_2O_3 weight percent
Boracite (stassfurite)	$Mg_6B_{14}O_{26}Cl_2$	62.2
Colemanite	$Ca_2B_6O_{11} \bullet 5H_2O$	50.8
Hydroboracite	$CaMgB_6O_{11} \bullet 6H_2O$	50.5
Kernite (rasortie)	$Na_2B_4O_7 \bullet 4H_2O$	51.0
Priceite (pandermite)	$CaB_{10}O_{19} \bullet 7H_2O$	49.8
Probertite (kramerite)	$NaCaB_5O_9 \bullet 5H_2O$	49.6
Sassolite (natural boric acid)	H_3BO_3	56.3
Szaibelyite (ascharite)	$MgBO_2(OH)$	41.4
Tincal (natural borax)	$Na_2B_4O_7 \bullet 10H_2O$	36.5
Tincalconite (mohavite)	$Na_2B_4O \bullet 5H_2O$	47.8
Ulexite (boronatrocalcite)	$NaCaB_5O_9 \bullet 8H_2O$	43.0

[1]Parentheses include common names.

TABLE 3

U.S. CONSUMPTION OF BORON MINERALS AND COMPOUNDS, BY END USE

(Metric tons of boron oxide content)[1]

End use	1992	1993
Agriculture	9,186	16,261
Borosilicate glasses	29,288	38,488
Enamels, frits, glazes	8,230	11,302
Fire retardants:		
Cellulosic insulation	9,451	10,657
Other	1,394	1,421
Insulation-grade glass fibers	124,950	117,035
Metallurgy	2,624	2,058
Miscellaneous uses	23,130	35,951
Nuclear applications	455	9,775
Soaps and detergents	38,460	15,237
Sold to distributors, end use unknown	37,575	41,026
Textile-grade glass fibers	60,173	56,133
Total	344,916	355,344

[1]Includes imports of borax, boric acid, colemanite, and ulexite.

TABLE 4
U.S. CONSUMPTION OF ORTHOBORIC ACID,[1] BY END USE

(Metric tons of boron oxide content)

End use	1992	1993
Agriculture	497	533
Borosilicate glasses	2,704	14,919
Enamels, frits, glazes	2,477	3,157
Fire retardants:		
Cellulosic insulation	1,506	1,944
Other	1,349	1,420
Insulation-grade glass fibers	2,758	—
Metallurgy	154	241
Miscellaneous uses	12,760	12,343
Nuclear applications	454	9,759
Soaps and detergents	79	1,718
Sold to distributors, end use unknown	13,133	15,071
Textile-grade glass fibers	18,625	8,258
Total	56,496	69,363

[1]Includes imports.

TABLE 5
YEAREND 1993 PRICES FOR BORON MINERALS AND COMPOUNDS PER METRIC TON[1]

Product	Price, Dec. 31, 1992 (rounded dollars)[2]	Price, Dec. 31, 1993 (rounded dollars)
Borax, technical, anhydrous, 99%, bulk, carload, works[3]	626- 633	626- 633
Borax, technical, anhydrous, 99%, bags, carload, works[3]	689	689
Borax, technical, granular, decahydrate, 99%, bags, carload, works[3]	259- 367	259- 367
Borax, technical, granular, decahydrate, 99.5%, bulk, carload, works[3]	218	218
Borax, technical, granular, pentahydrate, 99.5%, bags, carload, works[3]	291- 346	291- 346
Borax, technical, granular, pentahydrate, 99.5%, bulk, carload, works[3]	250	250
Boric acid, technical, granular, 99.9%, bags, carload, works[3]	664- 671	664- 671
Boric acid, technical, granular, 99.9%, bulk, carload, works[3]	623	623
Boric acid, United States Borax & Chemical Corp., high-purity anhydrous, 99% B_2O_3, 100-pound bags, carlots	2,345	1,125
Colemanite, Turkish, 42% B_2O_3, ground to a minus 70-mesh, f.o.b. railcars, Kings Creek, SC[4]	535	540
Ulexite, Turkish, 38% B_2O_3, ground to a minus 6-mesh, f.o.b railcars, Norfolk, VA[4]	270	273

[1]U.S. f.o.b. plant or port prices per metric ton of product. Other conditions of final preparation, transportation, quantities, and qualities not stated are subject to negotiation and/or somewhat different price quotations.
[2]Figures revised to reflect metric tons.
[3]Chemical Marketing Reporter. V. 242, No. 26, Dec. 1992, p. 23; v. 245, No. 1, Dec. 1993, p. 24.
[4]American Borates Co.

TABLE 6

U.S. EXPORTS OF BORIC ACID AND REFINED SODIUM BORATE COMPOUNDS, BY COUNTRY

Country	1992			1993		
	Boric acid[1]		Sodium borates[2] (metric tons)	Boric acid[1]		Sodium borates[2] (metric tons)
	Quantity (metric tons)	Value (thousands)		Quantity (metric tons)	Value (thousands)	
Australia	1,110	$704	7,818	1,235	$997	7,153
Belgium	1,267	427	104	—	—	3,665
Brazil	251	178	896	2,013	784	509
Canada	5,295	3,277	29,199	5,504	3,616	33,182
China	34	32	864	34	23	896
Colombia	170	148	565	115	103	2,843
Costa Rica	32	16	688	63	31	88
Dominican Republic	26	12	2	—	—	9
Ecuador	—	—	1,172	—	—	864
Egypt	—	—	54	—	—	1
El Salvador	—	—	—	6	7	23
France	2,293	906	15	313	438	40
Germany	63	63	100	27	11	52
Guatemala	—	—	2,358	4	3	47
Honduras	—	—	10	9	9	20
Hong Kong	828	511	3,195	871	485	2,607
India	—	—	—	—	—	5,224
Indonesia	2,606	1,374	6,541	2,598	1,679	7,587
Israel	61	56	401	61	54	243
Jamaica	—	—	8	—	—	—
Japan	26,243	20,120	28,689	22,309	18,202	25,926
Korea, Republic of	8,571	4,778	13,971	9,701	6,148	14,734
Malaysia	2,837	1,396	7,319	1,993	972	4,920
Mexico	4,378	3,180	28,676	3,898	2,691	25,613
Netherlands	4,269	4,457	292,149	3,135	3,077	257,027
New Zealand	441	268	2,570	275	171	2,968
Pakistan	368	212	—	240	121	—
Panama	1	4	34	1	4	—
Papua New Guinea	—	—	16	—	—	32
Peru	—	—	—	—	—	259
Philippines	2,722	1,036	48	2,507	561	1,294
Saudi Arabia	9	14	1,216	—	—	—
Singapore	2,030	1,428	955	1,325	641	2,194
South Africa, Republic of	58	49	379	92	94	321
Spain	—	—	41,743	2,406	1,172	54,445
Taiwan	11,453	7,535	10,653	10,753	6,367	9,594
Thailand	1,444	974	4,005	1,764	1,251	5,043
United Kingdom	65	76	673	243	206	9,313
Uruguay	—	—	—	64	20	1
Venezuela	656	421	1,177	810	497	1,308
Zimbabwe	—	—	44	98	63	92
Other	—	—	816	—	—	787
Total	79,581	53,652	489,123	74,467	50,498	480,924

[1]HTS code No. 2440.11.0000.
[2]HTS code Nos. 2840.19.0000, 2840.30.0000, and 2840.20.0000.

Source: Bureau of the Census.

TABLE 7

U.S. IMPORTS FOR CONSUMPTION OF BORIC ACID, BY COUNTRY

Country	1992		1993	
	Quantity (metric tons)	Value[1] (thousands)	Quantity (metric tons)	Value[1] (thousands)
Belgium	1	$3	—	—
Bolivia	—	—	318	$137
Canada	40	25	64	56
Chile	2,310	1,086	5,173	3,403
China	—	—	17	12
France	1	1	4	11
Germany	7	7	34	40
Italy	3,587	2,762	9,353	6,903
Japan	84	193	159	212
Netherlands	12	19	205	134
Norway	—	—	1	3
Russia	—	—	235	298
Switzerland	—	—	11	8
Taiwan	—	—	4	3
Turkey	300	158	1,000	473
United Kingdom	72	83	167	217
Total	6,414	4,337	16,745	11,910

[1]U.S. Customs declared values.

Source: Bureau of the Census.

TABLE 8

BORON MINERALS: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Country	1989	1990	1991	1992	1993[e]
Argentina	261	[r]123	[r]113	[r]143	143
Bolivia (ulexite)	10	3	14	[r]23	11
Chile (ulexite)	131	132	97	[r]203	100
China[e 2]	74	75	[r]93	[r]95	100
Germany (borax)[e]	4	4	3	2	2
Iran (borax)[3]	([4])	2	1	[r]([4])	1
Kazakhstan	—	—	—	[e]100	90
Peru	25	20	26	[r]27	27
Turkey[5]	[r]1,175	1,253	[r]1,117	[r]1,059	650
U.S.S.R.[e 6]	200	180	160	[r]—	—
United States[7]	1,114	1,094	1,240	1,009	[8]1,055
Total[9]	[r]2,993	[r]2,886	[r]2,865	[r]2,660	2,178

[e]Estimated. [r]Revised.
[1]Table includes data available through May 25, 1994.
[2]B_2O_3 equivalent.
[3]Data are for years beginning Mar. 21 of that stated.
[4]Less than 1/2 unit.
[5]Concentrates from ore.
[6]Dissolved in Dec. 1991.
[7]Minerals and compounds sold or used by producers, including both actual mine production and marketable products.
[8]Reported figure.
[9]Data may not add to totals shown because of independent rounding.