SULFUR

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At the beginning of 1999, U.S. sulfur supplies were constrained as a result of technical problems at the offshore sulfur mine; emergency repairs and planned periodic maintenance at oil refineries; a mild winter, which reduced processing of natural gas; lower than normal sulfur content of imported crude oil; and strong demand for sulfur at phosphate fertilizer operations. By midyear, most of the supply factors had reversed. The offshore sulfur mine overcame production problems and approached full output. Oil refineries completed scheduled maintenance and repaired damage from fires and other emergencies. Crude oil imports increased in average sulfur content causing increased sulfur recovery at oil refineries. Late in the year, however, demand for sulfur deteriorated because cutbacks at phosphate operations, the leading consuming industry of sulfur, significantly reduced consumption.

Through its major derivative, sulfuric acid, sulfur ranks as one of the more important elements used as an industrial raw material. It is of prime importance to every sector of the world's industrial and fertilizer complexes. Sulfuric acid production is the major end use for sulfur, and consumption of sulfuric acid has been regarded as one of the best indexes of a nation's industrial development. More sulfuric acid is produced in the United States every year than any other chemical; 40.6 million metric tons (Mt), equivalent to about 13.3 Mt of elemental sulfur, were produced, 7.7% less than that of 1998 (U.S. Census Bureau, 2000).

Domestic sulfur production was slightly lower; shipments and consumption decreased. Imports and prices increased (table 1, figures 1 and 2). The United States maintained its position as the leading world producer and consumer of sulfur and sulfuric acid. The quantity of sulfur recovered during the refining of petroleum and the processing of natural gas continued the upward trend established in 1939. Sulfur produced by using the Frasch process was slightly lower than that of 1998. Frasch production data were estimated by the U.S. Geological Survey (USGS) on the basis of company reports and other public information. Production of recovered sulfur from petroleum refineries and natural gas processing operations was the same as 1998, although production from petroleum refining increased and natural gas recovery decreased. Total production of elemental sulfur in 1999 was nearly the same as in 1998, but decreased shipments resulted in a 59% increase in stocks, although from a low starting point.

Byproduct sulfuric acid from the Nation's nonferrous smelters and roasters, produced as a result of laws restricting sulfur dioxide emissions, supplied a significant quantity of sulfuric acid to the domestic merchant (commercial) acid market. Production from this sector decreased significantly because three copper smelters closed during the year.

World sulfur production increased slightly in 1999 (table 1). Frasch production was lower because of continued production cutbacks in Poland and the United States. Elemental sulfur production from recovered sources, primarily during the processing of natural gas and petroleum products, increased. More than three-quarters of the world's elemental sulfur production came from recovered sources; the quantity of sulfur supplied from these sources was dependent on the world demand for fuels, nonferrous metals, and petroleum products, not for sulfur.

World sulfur consumption remained about the same with about 50% used in fertilizer production and the remainder in a myriad of other industrial uses. World trade of elemental sulfur increased slightly from the levels recorded in 1998; an increasing number of countries were significant exporters in 1999. Worldwide inventories of elemental sulfur were higher.

Legislation and Government Programs

Considerable debate and controversy followed the announcement of the U.S. Environmental Protection Agency's (EPA) proposed new standards for sulfur in gasoline. As part of Tier 2 of the 1990 Clean Air Act Amendments, the plan would reduce the average sulfur content of gasoline to 30 parts per million (ppm) by 2004, a 90% decrease from the current (1999) average of 330 ppm (Grisham, 1999). The maximum allowable sulfur content in 1999 was 1,000 ppm (Sutikno, 1999).

The U.S. Department of Energy (DOE) cautioned that the EPA's proposed new sulfur limits might be too costly. The EPA estimated the cost of the measures to be 1.7 to 1.9 cents per gallon to produce the low-sulfur fuel, for a total cost of about $2.1 billion annually between 2004 and 2020. The DOE believed that the cost would be closer to 2.9 cents per gallon for midsized refineries and perhaps as high as 5 to 7 cents per gallon for small refineries. The capital cost per refinery was estimated at $40 million, with costs at many refineries in excess of $100 million (Hess, 1999). The oil industry projected the costs to be closer to 6 cents per gallon (Grisham, 1999).

The EPA issued the final rule for reduced sulfur content of gasoline early in 2000, with slight changes from the proposals revealed in May 1999. The standards were nationwide standards, but the time for implementation was extended for some States and for some refining facilities, as a result of comments from stakeholders. In 2006, the sulfur content in gasoline must average 30 ppm with an upper limit of 80 ppm. States in the Rocky Mountain Region and Alaska had until

2007 to reach those standards because those States generally had better air quality than other parts of the country. Small refineries with fewer than 1,500 employees or less than 155,000 barrels per day (bbl/d) of processing capacity were required to meet interim goals until 2008, when the national limits would be imposed. The 2008 deadline could be delayed until 2010, if the refiners could demonstrate a severe economic hardship. Small refineries received special consideration because the installation of new equipment in small facilities could be economically damaging (Oil & Gas Journal, 2000).

Production

Elemental Sulfur.—Production statistics are collected on a monthly basis and published in the USGS sulfur monthly Mineral Industry Surveys. Of the 120 operations to which survey requests were sent, all responded, representing 100% of the total production shown in table 1. In 1999, production was virtually the same as that of 1998. Shipments decreased 8%, but the value of shipments was higher owing to an increase in the average unit value of elemental sulfur. Trends in sulfur production are shown in figure 2.

Frasch.—Native sulfur associated with the caprock of salt domes and in sedimentary deposits is mined by the Frasch hot water method, in which the native sulfur is melted underground and brought to the surface by compressed air. Freeport-McMoRan Sulphur Inc., a subsidiary of McMoRan Exploration Co., was the last remaining Frasch producer in the United States. Freeport, the largest mined sulfur producer in the world, produced from two mines in 1999. After 30 years of production, the Culberson Mine in west Texas closed permanently on June 30 (McMoRan Exploration Co., 2000, p. 12). Beginning in 1969, production reached a maximum annual capacity of 2.9 million tons per year (Mt/yr). When production began, the reserves at the mine were reported to be 82 Mt, with expectations of producing 60 Mt of sulfur from the mine. A total of 1,782 sulfur wells were drilled over the life of the mine (Cunningham, 1999c).

The sulfur there was contained in sedimentary limestone, rather than in a salt dome formation. Production was transported 500 kilometers (km) to the port of Galveston, TX, by 66-car unit trains. At an average rate of 4,427 tons per day (t/d) for 30 years, production at Culberson approached 50 Mt, with an estimated 6 Mt of recoverable sulfur remaining. Total revenues from the deposit were $605 million. In 1999, the economics of the sulfur industry made recovery of the remaining sulfur economically unfeasible (Cunningham, 1999c).

Freeport operated a mine on a salt dome sulfur deposit in the Gulf of Mexico, about 51 km (32 miles) from the coast of Louisiana. The Main Pass offshore complex, which is more than 1.6 km (1 mile) long and is the largest structure in the Gulf, had a production capacity of more than 5,500 t/d (McMoRan Exploration Co., 2000). Early in the year, Freeport was drilling to replace wells lost during Hurricane Georges in September 1998. Production was severely impaired as a result of nine wells freezing during the weather emergency. Four new wells were completed by yearend 1998. Until the drilling was completed, production at Main Pass was limited, resulting in restricted supply in the Gulf Coast region of the United States. In order to replace a portion of the curtailed production, Freeport continued to operate the Culberson Mine. Freeport had planned to close Culberson in 1998, but kept it open until Main Pass was back to an acceptable production rate (Fertilizer Markets, 1999e). Freeport completed its replacement drilling program in the first quarter of 1999 (Green Markets, 1999i). Following completion of the drilling program, Main Pass ramped up production to reach 5,080 t/d by the end of May (Green Markets, 1999c).

As a result of deteriorating market conditions and continuing low prices, Freeport reduced its proved reserves at Main Pass from 53.2 Mt on December 31, 1998, to 13.9 Mt as of December 31, 1999. The reason stated by the company was, “Although our estimated physically producible sulphur reserves have not changed, we have reduced our estimates of commercially recoverable reserves primarily based on our expectations of decreased production rates at the mine, partially offset by an anticipated decrease in costs. A future increase in sulphur prices could result in restoration of the reserves being reduced at year-end 1999” (McMoRan Exploration Co., 2000, p. 12). Freeport’s operations also included facilities for forming, loading, remelting, and transporting sulfur in Galveston, TX; Port Sulphur, LA; and Tampa, FL.

Recovered.—Recovered elemental sulfur, a nondiscretionary byproduct from petroleum refining, natural gas processing, and coking plants, was produced primarily to comply with environmental regulations that were applicable directly to emissions from the processing facility or indirectly by restricting the sulfur content of the fuels sold or used by the facility. Recovered sulfur was produced by 50 companies at about 117 plants in 26 States and 1 plant in the U.S. Virgin Islands; most of these plants were small, with 29 reporting annual production exceeding 100,000 metric tons (t). By source, 76% of recovered elemental sulfur production came from petroleum refineries or satellite plants treating refinery gases and coking plants. The remainder was produced at natural-gas-treatment plants. The largest recovered sulfur producers, in descending order of production, were Exxon Corp., BP Amoco p.l.c., Chevron Corp., Mobil Corp., CITGO Petroleum Corp., and Motiva Enterprises LLC. The 33 plants owned by these companies accounted for 60% of recovered sulfur output during the year. Recovered sulfur production by State and region are shown in tables 2 and 3.

Five of the 15 largest refineries in the world are in the United States. They are, listed by declining refining capacity, The Hovensa L.L.C. refinery at St. Croix, U.S. Virgin Islands; Exxon Mobil Corp. (ExxonMobil), Baytown, TX; ExxonMobil, Baton Rouge, LA; BP Amoco, Texas City, TX; and BP Amoco, Whiting, IN. Refining capacity does not necessarily mean that theses refineries are the largest producers of refinery sulfur. Sulfur production depends on installed sulfur recovery capacity as well as the types of crude that are refined at the specific refineries. Large refineries that process low-sulfur crudes may have relatively low sulfur production (Chang, Thi, 1999).

Consolidation in the petroleum industry continued. On December 31, 1998, Amoco Co. and British Petroleum Co., p.l.c. merged to form BP Amoco p.l.c. (BP Amoco p.l.c., 1999). The merger, valued at nearly $50 billion, created the world's third largest oil, gas, and chemical producer. The new conglomerate was headquartered in London (Thayer and Layman, 1998). The U.S. Federal Trade Commission (FTC) required the two companies to sell about 150 retail sites and to offer termination rights for some gasoline supply contracts in Ohio and the Southeastern United States as condition for the approval of the merger (BP Amoco p.l.c., 1998).

On November 30, 1999, the FTC approved the merger of Exxon Corp. and Mobil Corp., U.S. companies that were ranked as the second and sixth largest oil refiners worldwide, respectively, creating ExxonMobil. The combined companies surpassed the Royal Dutch/Shell Group of Companies as the world's leading refining company with 44 refineries around the world (Chang, Joseph, 1999). The companies merged to reduce costs and compete better with government-owned oil companies in other countries (Oil & Gas Journal, 1999c).

The FTC and the European Commission set specific requirements for the approval of the merger. The FTC required Exxon to sell its retail gas stations in New England and New York and Mobil to sell its stations in New Jersey, Pennsylvania, Delaware, Maryland, Virginia, and Washington, DC. Exxon also was required to sell stations in California and its Benecia, CA, refinery. The newly merged company was also required to eliminate some of its interests in oil pipelines, including Mobil's portion of the Alaska Pipeline System (Oil & Gas Journal, 1999c). Mobil was required to sell its 30% in a European refining and marketing venture with BP Amoco (Chang, Joseph, 1999). The completion of the ExxonMobil merger created a new leader in sulfur production in the United States, whose combined sulfur recovery capacity surpassed Freeport's capacity at Main Pass (Fertecon North American Sulphur Service, 1999d).

Recently merged BP Amoco proposed to buy Atlantic Richfield Company (ARCO), another major petroleum refiner with sulfur recovery capabilities. As with other mergers, this action was driven by low oil prices and an attempt to improve competitiveness. The merger required approval from the FTC (Chang, Joseph, 1999). Final FTC approval of the $38 million acquisition was expected to require divestitures, especially some of the proposed company's combined assets in Alaska. (Oil & Gas Journal, 1999c). BP Amoco and ARCO agreed to sell valuable properties in Alaska to maintain competition there; and the Governor of Alaska encouraged the FTC to approve the deal (Oil & Gas Journal, 1999b). Final rulings on the merger were pending at yearend.

Byproduct Sulfuric Acid.—Sulfuric acid production at copper, lead, molybdenum, and zinc roasters and smelters (table 4) accounted for 12% of the total domestic production of sulfur in all forms. Seven acid plants operated in conjunction with copper smelters, and six were accessories to lead, molybdenum, and zinc smelting and roasting operations. The seven largest acid plants (all at copper mines) accounted for 88% of the output. The largest producers—ASARCO Incorporated; Broken Hill Proprietary Co., Ltd. (BHP); Cyprus Miami Mining Corp.; Kennecott Utah Copper Corp.; and Phelps Dodge Corporation—operated a total of seven copper smelters.

Byproduct acid decreased 18% from that of 1998 because three of the seven copper smelters in the United States closed during the year. The closures resulted from a serious slump in the world copper industry, with adjusted copper prices lower than they had been at any time in the 20th century. With the closure of three copper smelters in Arizona, New Mexico, and Texas, the copper industry went from a sulfuric acid seller to a net buyer in a matter of months (McCoy, 1999).

Shortage of copper ore concentrates made it uneconomic for Asarco to continue operations at its El Paso, TX, copper smelter. The company expected the smelter to continue in a care-and-maintenance status for 3 years. The smelter will be able to return to production quickly should supply and market conditions improve sufficiently to justify reopening (Sulfuric Acid Today, 1999a). Asarco reported production of about 315,000 t of sulfuric acid from the smelter's two sulfuric acid plants in 1998. The closure of the smelter removes more than 300,000 t of sulfuric acid, equivalent to nearly 100,000 t of elemental sulfur, from the market for the duration of the closure (ASARCO Incorporated, 1998).

BHP suspended operations at its North American copper operations. Underground mining, milling, smelting, and refining facilities at San Manuel, AZ, and the mining and milling operations near Ely, NV, were closed (Sulfuric Acid Today, 1999b). The smelter had the capacity to recover about 1 Mt/yr of byproduct sulfuric acid (Fertecon North American Sulphur Service, 1999f). Phelps Dodge temporarily closed its Hidalgo, NM, smelter as a result of the downturn in the price of copper, causing reduced production of byproduct sulfuric acid at the site (Phelps Dodge Corporation, 1999b). Sulfuric acid capacity at Hidalgo was about 700,000 t/yr (Fertecon North American Sulphur Service, 1999i).

Consolidation was evident in the copper industry also. In the fourth quarter of 1999, Phelps Dodge, a major U.S. copper producer, acquired all shares of Cyprus Amax Minerals Co., another U.S. copper producer. The acquisition makes Phelps Dodge the second largest copper producer in the world, behind Chile's Corporación Nacional del Cobre (Codelco) (Phelps Dodge Corporation, 1999a). As a large U.S. copper producer, Phelps Dodge is also a large producer of byproduct sulfuric acid at its three copper smelters, one of which was idled in 1999.

Asarco became a wholly owned subsidiary of Grupo Mexico, S.A. de C.V., through Grupo Mexico's purchase of all outstanding shares of Asarco common stock (ASARCO Incorporated, 1999). Grupo Mexico is the largest mining group in Mexico with interests in copper, gold, lead, molybdenum, silver, and zinc. (Grupo Mexico, S.A. de C.V., undated, Who are we?, accessed October, 5, 2000, at URL http://www. grupomexico.com/gm10000i.html).

Consumption

Apparent domestic consumption of sulfur in all forms was 5.0% lower than that of 1998 (table 5). Of the sulfur consumed, 77.4% was obtained from domestic sources, such as elemental sulfur (68.0%) and byproduct acid (9.4%), compared with 79.2% in 1998 and 80.5% in 1997. The remaining 22.6% was supplied by imports of recovered elemental sulfur (19.3%) and sulfuric acid (3.3%). The USGS collected end-use data on sulfur and sulfuric acid according to the Standard Industrial Classification of industrial activities (tables 6 and 7).

Sulfur differs from most other major mineral commodities in that its primary use is as a chemical reagent rather than as a component of a finished product. This use generally requires that it be converted to an intermediate chemical product prior to its initial use by industry. The largest sulfur end use, sulfuric acid, represented 79% of reported consumption with an identified end use. Some identified sulfur end uses were tabulated in the “Unidentified” category because these data were proprietary. Data collected from companies that did not identify shipment by end use also were tabulated as “Unidentified.” A significant portion of the sulfur in the “Unidentified” category may have been shipped to sulfuric acid producers or exported, although data to support such an assumption were not available.

Because of its desirable properties, sulfuric acid retained its position as the most universally used mineral acid and the most produced and consumed inorganic chemical, by volume. Based on USGS surveys, reported U.S. consumption of sulfur in sulfuric acid (100% basis) and total sulfur consumption were virtually unchanged from that of 1998.

Agriculture was the largest sulfur-consuming industry, increasing to 9.2 Mt compared with 8.9 Mt reported in 1998. Reported consumption in phosphatic fertilizers was slightly higher than that of 1998, although the U.S. Census Bureau reported a slight decrease in production of phosphoric acid from the previous year (U.S. Census Bureau, 2000). On the basis of export data from the U.S. Census Bureau, the estimated quantity of sulfur needed to manufacture exported phosphatic fertilizers increased 3.6% to 6.0 Mt.

The second largest end use for sulfur was in petroleum refining and other petroleum and coal products. On the basis of the performance of the petroleum refining industry, petroleum refining uses would be expected to remain steady from 1998 to 1999; the 20% decrease reported for the use of elemental sulfur in this category was much greater than was expected, indicating probable inconsistencies in reporting.

Demand for sulfuric acid in copper ore leaching, the third largest end use, decreased by 11%; this use of sulfuric acid decreased for the first time since 1995 as a result of downturns in the copper industry. Planned expansions at copper leach operations, however, were expected to cause increased consumption for this use by 2001. All copper producers, even companies that closed smelter operations, continued to operate their solvent extraction/electrowinning (SX/EW) operations in which weak sulfuric acid dissolves copper as it percolates through specially prepared beds of copper minerals. The copper is then concentrated through a solvent extraction process, and the concentrated solution undergoes an electrowinning process that produces 99.99% copper cathode (Phelps Dodge Corporation, 1999c).

Phelps Dodge planned to convert all production at its Morenci, AZ, site to the solvent SX/EW process. The $220 million conversion, included expansion of the mine’s crushing and conveying system, installation of mobile stackers to disperse crushed ore on leach stockpiles, expansion of existing extraction facilities, and the construction of a new electrowinning tankhouse. SX/EW copper production was to expand from 250,000 t to 363,000 metric tons per year (t/yr). The 45% increase in SX/EW capacity will require a comparable in sulfuric acid consumption for the process. The company’s mine near Chino, NM, will supply a portion of the necessary acid with the remainder being purchased (Sulfuric Acid Today, 1999d). A survey conducted by CRU International Ltd., a minerals industry consulting firm, of SX/EW operations established an average consumption of 3.5 t of sulfuric acid per ton of copper produced (McCoy, 1999).

According to the 1998 canvass reports, company receipts of spent or contaminated sulfuric acid for reclaiming totaled 268,000 t. This figure was believed to be significantly higher than reported in USGS surveys; most of the acid, however, is recycled by companies that produce acid for consumption in their own operations and also recycle acid used in their plants. Because the recycling of acid does not involve sales or shipments of the spent sulfuric acid, many companies do not handle the acid recycling as a separate process and thus do not report it in the USGS consumption survey. The petroleum refining industry is believed to be the largest source and consumer of recycled acid for use in its alkylation process.

Stocks

Yearend inventories held by Frasch and recovered elemental sulfur producers increased to 451,000 t, about 59% more than that of 1998 (table 1). On the basis of apparent consumption of all forms of sulfur, combined yearend stocks amounted to about a 12-day supply compared with a 7-day supply in 1998, a 20-day supply in 1997, and a 17-day supply in 1996. During 1999, sulfur inventories were at the lowest levels seen since Frasch production became profitable early in the 20th century (Haynes, 1959, p. 61). Sulfur stocks varied considerably in 1999, decreasing to less than 200,000 t at the end of May, representing 3% of the quantity held in inventories at the end of 1976, when sulfur stocks peaked at 5.65 Mt, a 7.4-month supply at that time (Shelton, 1978, p. 1296). Production, however, increased in the last 6 months of the year, and stocks increased.

Prices

The contract prices for elemental sulfur, at terminals in Tampa, FL, reported weekly in Green Markets, began the year at $65 to $68 per metric ton. Prices quickly increased to $69 to $72 and remained steady until August when they returned to $65 to $68 per ton. In October, prices decreased to $60 to $63, where they remained throughout the rest of the year. On the basis of total shipments and value reported to the USGS, the average value of shipments for all elemental sulfur was $37.81 per ton, which was 30% higher than that of 1998. Prices varied greatly on a regional basis, causing the discrepancies between Green Markets prices and USGS prices. Tampa prices are usually the highest prices reported because of the large sulfur demand in the central Florida area. U.S. West Coast prices are frequently $0 to $1 per ton; and in reality, however, West Coast producers may face negative values as a result of costs incurred at forming plants. These costs are necessary to make solid sulfur in acceptable forms, often known as prills, to be shipped overseas. The majority of West Coast sulfur is sent to prillers who are subsidized by the refineries and the formed sulfur is shipped overseas (Green Markets, 1999e).

As a result of strong demand for sulfur in international markets, refiners in the Los Angeles, CA, area were no longer paying for sulfur to be removed from their operations and processed into formed sulfur. Subsidies were no longer required at midyear (Green Markets, 1999f).

Foreign Trade

Exports of elemental sulfur from the United States, including the U.S. Virgin Islands, were 23% lower in quantity than those of 1998 but slightly higher in value, as shown in table 8, because the average unit value of U.S. export material increased. The average unit value of exported elemental sulfur increased from $40 to $52 per ton, which was 30% higher than in 1998. Exports from the West Coast were 625,000 t, or 91% of total U.S. exports.

The United States continued to be a net importer of sulfur—imports of elemental sulfur exceeded exports by 1.9 Mt. Recovered elemental sulfur from Canada and Mexico delivered to U.S. terminals and consumers in the liquid phase furnished about 85% of all U.S. sulfur import requirements. Total elemental sulfur imports increased about 14% in quantity and decreased 12% in value; imports by rail from Canada were 13% higher, and waterborne shipments from Mexico were slightly lower than those of 1998 (table 10). Imports from Venezuela were estimated to comprise about 8% of all imported sulfur. The United States imported 82,000 t of elemental sulfur from Saudi Arabia and 14,000 t from Poland, the first ever shipments from those countries. Freeport purchased formed sulfur from Saudi Arabia to replace tonnage lost as a result of production problems at Main Pass. The Saudi sulfur was purchased to help meet supply contracts and to replace stocks that were nearly depleted. The company also purchased prilled sulfur from the refinery in the U.S. Virgin Islands, although this material was not technically imported, because the U.S. Virgin Islands are a U.S. territory (Fertecon North American Sulphur Service, 1999a). Sulfur also was received from Germany, but these data are suppressed by the U.S. Census Bureau and do not appear in table 10.

Until Freeport received the formed sulfur from Saudi Arabia and the Virgin Islands, sulfur imports to the United States were almost entirely molten in form. But with the tight supplies, several Florida fertilizer companies were exploring the possibility of building a terminal to handle formed sulfur south of Tampa. Big Bend Transfer Company LLC (BBTC) was formed in an agreement among IMC Global Inc.; CF Industries, Inc.; and Cargill, Inc. to build a facility to import and remelt solid sulfur. In an effort "to ensure security of future sulfur supply and cost competitiveness," (Fertecon North American Sulphur Service, 1999e, p. 1) the companies banded together to create the new facility. Pending the successful completion of the permitting process, the BBTC project was expected to be operational by mid-2001, with a throughput capacity of 1.5 Mt/yr. The project will include import facilities at a 450-meter dock, remelting equipment, covered storage for 40,000 t of solid sulfur, and a 20,000 t molten sulfur tank (Fertecon North American Sulphur Service, 1999e).

The cost of BBTC was estimated at $40 million. The developers visited similar facilities in Australia, Brazil, Canada, Morocco, and South Africa to determine the best technology to meet exacting environmental standards in Florida. The BBTC facility was designed to minimize or eliminate any emissions of sulfur. All steps in the process will be enclosed and dry sulfur will be wetted to eliminate dust problems. Scrubbers will clean the air passing through the operations, and all process water will be recycled to make the plant a zero-discharge facility (Green Markets, 1999b).

Early in the year, in a review of an antidumping duty order on elemental sulfur from Canada, the U.S. International Trade Commission (ITC) determined that revoking the duty would not likely lead to a continuation or a recurrence of material injury to the domestic industry. Because Freeport was the only company to respond to the ITC's notice of the institution of the review, the review was expedited and completed without a public hearing. The ITC recommended that the U.S. Department of Commerce revoke the antidumping order, effective January 1, 2000 (Green Markets, 1999a).

In addition to elemental sulfur, the United States also had significant trade in sulfuric acid. Sulfuric acid exports were about the same as those of 1998 (table 9). Acid imports were nine times greater than exports (tables 9 and 11). Canada was the source of 63% of U.S. acid imports, most of which were probably byproduct acid from smelters. Canadian shipments to the United States came by rail and the remainder of imports came primarily by ship from Europe, Latin America, and Japan. The tonnage of imports of sulfuric acid was 33% less than that of 1998; and the value of imported sulfuric acid decreased by 28%.

World Review

The global sulfur industry remained divided into two sectors—discretionary and nondiscretionary. In the discretionary sector, the mining of sulfur or pyrites is the sole objective; this voluntary production of native sulfur or pyrites is based on the orderly mining of discrete deposits, with the objective of obtaining as nearly a complete recovery of the resource as economic conditions permit. In the nondiscretionary sector, sulfur or sulfuric acid is recovered as an involuntary byproduct, the quantity of output subject to demand for the primary product irrespective of sulfur demand. Nondiscretionary sources represented nearly 85% of the sulfur in all forms produced worldwide as shown in table 12.

Poland and the United States were the only countries that produced 1 Mt or more of native sulfur by using either the Frasch or conventional mining methods (table 12). Small quantities of native sulfur were produced in Asia, Europe, and South America. The importance of pyrites to the world sulfur supply has significantly decreased; China was the only country in the top 15 sulfur producers whose primary sulfur source was pyrites. About 72% of all pyrites production was in this country.

Of the 25 countries listed in table 12 with total sulfur production of 400,000 t or more, 17 obtain the majority as recovered elemental sulfur. These 25 countries produce 78% of the total sulfur produced worldwide. The international sulfur trade was dominated by a limited number of exporting countries, in descending order of importance—Canada, Russia, Saudi Arabia, Germany, the United Arab Emirates, and Japan; these countries exported more than 1 Mt of elemental sulfur each and accounted for 75% of sulfur trade. Major sulfur importers, in descending order, were Morocco, the United States, China, India, Tunisia, and Brazil, all with imports of more than 1 Mt.

World production of sulfur was slightly higher in 1999 than in 1998; consumption was believed to be slightly higher. Prices in most of the world were believed to have averaged higher throughout the year, but with a slight decrease at yearend. Production of Frasch was 6% lower than that of 1998 as a result of further cutbacks in Poland and the United States. Recovered sulfur production increased 6% and byproduct sulfuric acid production was about the same as those of 1998. Supply continued to exceed demand; worldwide sulfur inventories increased, much of which was stockpiled in Canada. Globally, sulfur from pyrites decreased by 12%; most of the decrease occurred in China.

Statistics compiled by the Oil & Gas Journal showed the United States possessing 20% of the world's total refining capacity and 43% of the world's sulfur recovery capacity derived from oil refineries. The publication listed 756 oil refineries in 112 countries; only 52 of these countries were reported to have sulfur recovery capacity (Radler, 1999). Although the sulfur recovery data appeared to be incomplete, analysis of the data showed that most of the countries reporting no sulfur recovery at refineries were small with developing economies and limited refining industries. In general, as refining economies improve and the refining industries mature, additional efforts are made to improve sulfur recovery and atmospheric emissions. The refining industry was actively consolidating throughout the world with mergers involving French, Italian, Japanese, and Spanish companies (Chang, Thi, 1999).

Regulations were enacted in many countries limiting the amount of sulfur allowable in fuels and the quantity of sulfur dioxide emitted into the atmosphere. Many of these regulations will result in increased sulfur recovery. Bulgaria, Canada, China, the European Union (EU), Thailand, and the United States set or proposed significant, although varied, reductions in the sulfur content of motor fuels sold in those countries. Suppliers were required to met these new standards between 2005 and 2011. Germany, already covered under EU regulations, accelerated the timetable for new EU guidelines to be met in Germany by 2001, and was pushing for more stringent limitations in the EU's next round of rulemaking (Sulphur, 1999e). Ireland banned retail sale of domestic fuel containing more than 2% sulfur (Sulphur, 1999f). Poland severely restricted sulfur dioxide emissions at petroleum refineries (Sulphur, 1999b).

In many countries, companies were installing additional capacity for recovering sulfur and byproduct sulfuric acid as well as producing low-sulfur fuels in advance of new government mandates and/or before legal requirements of existing laws. Firms in Canada, Egypt, Germany, the Netherlands, Russia, the United Arab Emirates, the United States, and Uzbekistan were reducing sulfur dioxide at their facilities. Low-sulfur fuels were offered years in advance of legal requirements in Bahrain, Kuwait, the United Kingdom, and the United States.

Not all of these developments caused significant increased production; but most created at least incremental additions to sulfur supplies. These increases in sulfur recovery, coupled with the widespread trend to higher sulfur content in crude oils promised continued growth in worldwide production of recovered sulfur and byproduct sulfuric acid. Only discretionary sulfur production was expected to decrease.

Australia.—Four smelter acid projects, which raised byproduct sulfuric acid capacity to 3.4 Mt/yr, neared or reached completion in 1999 (Stevens, 1998c, p. 34). Acid production at these sites will be equivalent to about 1 Mt of elemental sulfur. WMC Fertilizers Ltd. completed its sulfuric acid plant at Mount Isa Mines Ltd.'s copper smelter in Queensland. The Mount Isa acid supplied WMC Fertilizer's diammonium phosphate fertilizer plant at Phosphate Hill, Queensland (Fertilizer Markets, 1999d). Korea Zinc Co. Ltd. also was building a sulfuric acid plant to supply the Queensland fertilizer operation. Other projects included new sulfuric acid capacity at Port Kembla Copper Pty. Ltd.'s smelter and Western Mining Corp. Ltd.'s (WMC) Olympic Dam copper and uranium project (Stevens, 1998c, p. 36).

A few projects in Western Australia requiring large quantities of sulfuric acid were completed in 1999. Three nickel operations in Western Australia produced their first nickel in 1999. These projects use a pressure acid leach (PAL) process to produce nickel and cobalt from nickel laterite ores. This process had previously only been used at Moa Bay in Cuba. PAL uses sulfuric acid at elevated temperature and high pressure to remove nickel and cobalt from the silica lattice of the ore. The Preston Resources Ltd. project at Bulong was designed to produce 9,000 t/yr of high-quality nickel and 870 t/yr of 99.9% cobalt. WMC contracted to supply the necessary 256,000 t/yr of sulfuric acid from its Kalgoorlie nickel smelter. The Bulong project was expected to consume about 500 kilograms of acid for each ton of ore processed. Acid consumption at Centaur Mining and Exploration Ltd.'s Cawse Nickel Project was expected to be 360 kilograms per ton of ore processed in the production of 9,000 t/yr of nickel and 1,500 t/yr of cobalt as cobalt sulfide. Total sulfuric acid consumption was estimated at 180,000 t/yr; WMC was the supplier for this acid also (Connock, 1999a).

The largest single train sulfuric acid plant in the world was built by Enviro-Chem Systems, a Monsanto Co. subsidiary, to supply Anaconda Nickel Ltd.'s Murrin Murrin PAL project. The acid plant can produce 4,400 t/d, requiring about 500,000 t/yr of elemental sulfur to maintain production. Anaconda contracted with Canadian suppliers for its sulfur supply. Initial capacity at Murrin Murrin was 45,000 t/yr nickel and 3,000 t/yr cobalt with plans to increase production to 115,000 t/yr nickel and 9,000 t/yr cobalt in a second stage of development. Increased sulfuric acid capacity will be required to meet goals for expansion; the company was planning the construction of another acid plant to produce an additional 6,900 t/d of acid bringing annual sulfur consumption to 1.25

Mt for Murrin Murrin alone (Connock, 1999a).

Canada.—Second only to the United States in sulfur production in all forms, Canada led the world in the production of byproduct sulfur, exports of elemental sulfur, and stockpiled material. The majority of the sulfur production came from natural gas plants in Alberta where sulfur inventories reached nearly 12.5 Mt (McMoRan Exploration Co., 2000, p. 9).

When Alberta, Canada's Energy and Utilities Board (EUB) issued guidelines for sulfur recovery at sour gas plants in 1988, facilities built before the guidelines went into effect were not required to install sulfur recovery equipment. New equipment was required only if the operation increased production capacity or extended its operating life by connecting to new gas resources. In 1999, the EUB was considering revisions to these conditions that would require older gas plants to begin sulfur recovery or close. The EUB also explored other strategies for improving emissions at all natural gas plants in Alberta. Although still in the initial stages of rulemaking, final regulations were likely to result in restricting sulfur emissions and increasing production of recovered sulfur (Sulphur, 1999g).

Other new environmental regulations were likely to increase recovered sulfur production; Environment Canada, Canada's environmental ministry, set regulations to lower the limit of sulfur in gasoline to 150 ppm by 2002 and 30 ppm by 2005 (Sulphur, 1999d). One Canadian oil refiner, Petro-Canada expected to spend C$180 million to upgrade its three refineries to meet new Canadian restrictions on sulfur content of gasoline. The cost of upgrading a typical refinery to meet the new standards was C$60 million (Fertecon North American Sulphur Service, 1999c). With 22 refineries in Canada (Radler, 1999, p. 46), costs to install appropriate sulfur reduction equipment was expected to exceed C$1.3 billion. Projected changes to sulfur recovery capacity were not expected to be huge; but similar growth in all areas implementing new regulations meant additional sulfur supplies in an already unbalanced market.

In addition to the large reserves of high-sulfur natural gas, Alberta has huge deposits of oil sands with estimated reserves of 300 million barrels of recoverable crude oil that also contain 4% to 5% sulfur (Stevens, 1998b). The Athabasca Oil Sands are a mixture of sand, water, clay, and bitumen, a naturally occurring viscous mixture of heavy hydrocarbons. Because of its complexity, bitumen is difficult or impossible to refine at most oil refineries. It must be upgraded to a light-oil equivalent before further refining, or it must be processed at facilities specifically designed for processing bitumen. Oil sands with more than 10% bitumen are considered rich; those with less than 7% bitumen are not economically attractive (Oil & Gas Journal, 1999a).

Progress was made at a number of projects to develop these deposits, although some were delayed because of the low crude oil prices throughout the year. Late in the year, the partnership, led by Shell Canada Ltd. (60%), developing an oil sands project decided to proceed with the C$3.5 billion undertaking that should be completed in late 2002 (Shell Canada Ltd., 1999). The joint venture was incorporated as Albian Sands Energy Inc. Minority partners in the project were Chevron Canada Resources Ltd. and Western Oil Sands Inc. The EUB approved the development of the Muskeg River Mine near Fort McMurray, Alberta, early in the year. Separate approvals were required from the EUB for the heavy oil upgrader at Shell's Scotford refinery and the double pipeline between the mine and the refinery. Plans for Albian included production of 500,000 t/yr of molten sulfur (Fertecon North American Sulphur Service, 1999j).

Suncor Energy Inc. accelerated its expansion plans to complete the upgrade late in 2001 instead of 2002 (Fertecon North American Sulphur Service, 1999b). Suncor was doubling its sulfur production at its Project Millennium near Fort McMurray to almost 440,000 t/yr; further expansions would take sulfur recovery to 1.5 Mt/yr by 2005 (Stevens, 1998a). Syncrude Canada Limited considered delaying the 2002 completion of its C$6 billion oil sands expansion for 1 year because of the low oil prices. Mobil Oil Canada delayed its oil sands project until ExxonMobil determined how to proceed following the merger of Exxon and Mobil (Fertecon North American Sulphur Service, 1999b).

Chile.—As the world's largest producer of copper, Chile's sulfur production came entirely in the form of byproduct sulfuric acid from seven copper smelters and one molybdenum smelter. Environmental concerns prompted significant improvements in desulfurization capabilities at the smelters, and production of byproduct acid has increased significantly in recent years, exceeding the equivalent of 1 Mt of sulfur production in 1999.

Having recently installed a 1,500 t/d-sulfuric acid plant at its El Teniente smelter, Codelco planned a new sulfuric acid at its Catelones copper smelter, about 100 km southeast of Santiago. The project will reduce sulfur dioxide emissions to meet new environmental regulations in Chile. When completed in January 2001, the plant will have the capacity to produce 2,350 t/d or about 850,000 t/yr, the equivalent of 280,000 t of sulfur (Sulfuric Acid Today, 1999c).

China.—One of the few countries whose primary domestic source of sulfur is pyrites, China was working to convert much of its sulfuric acid capacity from pyrites burning to elemental sulfur. Some new elemental sulfur-based acid plants were built, but much of the conversion was through adapting existing pyrites operations to use solid sulfur. The conversions were driven by economic and environmental reasons (Fertilizer Markets, 1999a). As sulfur burning grew, sulfur imports increased as well, especially from Canada and Japan (Cunningham, 1999a).

Environmental regulations were beginning to affect industry in China. New regulations required that gasoline sold in Beijing, Guangzhou, and Shanghai contain 0.08% sulfur by 2000, down from 0.15%. Gasoline in other cities was restricted to 0.1% in 2000, and 0.08% by 2005. (Sulphur, 2000). These sulfur limits were higher than many set in other countries, but major advances for China.

China was working to modernize and expand its petroleum refining industry. Chinese crude petroleum is relatively sweet with little sulfur recovered at refineries. In fact, only 1 of China's 95 refineries had any sulfur recovery capacity, amounting to just over 100,000 t/yr. Restructuring of the refining industry included plans for large-scale increases in sulfur recovery capacity. Joint ventures with major oil producers willing to make investments in the Chinese industry were a large part of the strategy for reducing imports of oil products and improving the refining technology (Cunningham, 1999a).

India.—Prior to 1999, India's 1.7-Mt/yr sulfur requirement was nearly all imported. Domestic recovered sulfur production was very small. Paradeep Phosphate Ltd.'s existing diammonium phosphate operation required about 216,000 t of elemental sulfur for its 660,000 t/yr sulfuric acid plant. Another plant opened late in the year, increasing the Indian demand for sulfur and sulfuric acid (Cunningham, 1999b). Oswal Chemicals & Fertilizers Ltd. completed a new diammonium phosphate and blended fertilizer complex at Paradeep. Initially, the company imported most of its necessary raw materials. Phosphate rock was of Chinese origin; sulfur was from various locations including Canada, the Middle East, and Russia (Fertilizer Markets, 1999b). At full capacity, the Oswal complex could consume nearly 900,000 t/yr of sulfur at its sulfuric acid plant (Green Markets, 1999g).

Other developments in India resulted in increased capacity for sulfur recovery at petroleum refineries. With the goal of achieving economic self-reliance, the India Government supported doubling India's refining capacity to replace imports of low-sulfur diesel with domestically produced fuels. Proposed expansions required large-scale sulfur recovery capabilities for the first time. New sulfur production from refineries was to supply phosphate fertilizer operations that would still require additional imported sulfur to meet annual requirements. By the end of 1999, three new petroleum refineries with sulfur recovery capacity totaling 550,000 t/yr were completed. Expansions and improvements at existing refineries brought Indian sulfur capacity to 1 Mt/yr. Other refinery projects were delayed as a result of funding problems; but resolution of the situation was expected to result in further expansion of refining and sulfur recovery capabilities (Cunningham, 1999b).

Iraq.—Questions remain about Frasch and other sulfur production in Iraq. Before Iraq invaded Kuwait precipitating Operation Desert Shield in 1990 and Operation Desert Storm (the Gulf War) in 1991, Frasch production at the Mishraq Mine was around 1 Mt/yr, with plans to expand capacity to 2 Mt. Some recovered sulfur was also produced in Iraq. Since that time, with the imposition of economic sanctions by the United Nations and very limited public information of any kind coming from Iraq, little is known of sulfur production in that country. Mishraq was not believed to be damaged during the war and could be operating at or near capacity, although that scenario is doubtful. The most likely situation is that Mishraq has produced consistently since 1990, but at a greatly reduced rate. Recovered sulfur production has probably continued. With little outlet for any products as a result of the sanctions, Iraq may have amassed a sizable stockpile that could enter the world market when more normal trade resumes.

Mexico.—A former Frasch producer from 1954 when mining began at San Cristobal (Larson and Marks, 1955, p. 1136-1137) until 1993 when the Texistepec Mine closed (Ober, 1994, p. 1172), Mexico was the second largest supplier of imported recovered sulfur to the United States. Petróleos Mexicanos S.A. de C.V. (Pemex), the Mexican Government's oil company, produced high-sulfur Maya crude oil that typically contained about 0.7% sulfur (Cunningham, 1999e).

Pemex planned upgrades for three refineries. Long-term plans aimed to expand Pemex's ability to process its own heavy Maya crude and increase output of high-quality gasoline. Additional sulfur recovery expansions were important parts of the projects (Fertecon North American Sulphur Service, 1999g). The company also has several long-term supply contracts with U.S. refiners. Clark Refining & Marketing Inc., Exxon Mobil, and Marathon Ashland Petroleum LLC were upgrading and adding sulfur recovery capacity at their Port Arthur, TX; Garyville, LA; and Baytown, TX; refineries, respectively, to handle imports from Pemex (Cunningham, 1999e).

Shell Oil Co. and Pemex were expanding their joint-venture Deer Park, TX, refinery from 280,000 bbl/d to 340,000 bbl/d. Maya crude will make up 65% of the throughput. Additional sulfur recovery capacity was to bring annual sulfur capacity to about 200,000 t/yr (Fertecon North American Sulphur Service, 1999h).

Poland.—As in many countries with improving economies, oil refineries in Poland were upgrading their sulfur recovery units to meet air quality regulations forbidding the release of SO_2 into the atmosphere (Sulphur, 1999b). Recovered sulfur, however, remains a secondary source of sulfur in Poland.

Rich sulfur deposits were discovered in Poland in 1954, and production began at the first surface mine late in that decade. Since that time, five native sulfur mines have been developed in Poland. The first two, Piaseczno and Machów, were surface mines using conventional mining methods. The other three mines, Grzybów, Jeziórko, and Osiek, used the Frasch method with modifications to meet the geologic conditions in Poland. At the peak of Polish sulfur production in 1980, more than 5 Mt of sulfur could be produced from three mines, Grzybów, Jeziórko, and Machów. Three of the mines closed and were being recultivated as lakes and other recreation areas, leaving Jeziórko and Osiek operating in 1999 (Karolak, 1997).

There were concerns that an abandoned sulfur mine in eastern Poland was a potential threat to the environment. The mine at Basznia was last operated by a British/Polish joint-venture company, called SulphurQuest of Poland L.L.C. When the economics of the industry made the operation too costly, the company management disappeared without performing the operations necessary to reclaim. Polish authorities were concerned with the possibility of hydrogen sulfide eruptions in waters of the abandoned mine. No one, however has acknowledged responsibility for environmental remediation at the site (Green Markets, 1999d).

Polish sulfur entered the global market in 1961, when the sulfur shipping facilities in Gdańsk were completed. In 1980, about 3.8 Mt (nearly 75%) of Polish production was exported, mostly to other European countries. Since the early 1990's, low global prices have made it extremely difficult for the discretionary sulfur producers to compete in the global market, and those markets have dwindled for the Polish industry (Karolak, 1997). Frasch production in Poland has decreased rapidly during the past few years, with only 1.2 Mt produced in 1999 and little expectation for improvement.

Russia.—Astrakhangazprom (AGP), a Russian natural gas and petroleum producer, completed installation of a sulfur priller capable of forming 750,000 t/yr of sulfur in a form that is acceptable for shipment worldwide. AGP produced more than 3 Mt of sulfur in 1998, the last year for which data were available, only a small portion of which was prilled (Fertilizer Markets, 1999c). Already a major sulfur exporter, the completed installation of the sulfur forming equipment made Russia better able to complete in the world market with a higher quality solid sulfur product. Previously, much of Russia's exports were formed or broken sulfur, a form that can create a large quantity of dust during handling. Sulfur dust can be a fire hazard and is undesirable and unacceptable at many ports.

Venezuela.—Petróleos de Venezuela S.A. (PdVSA), the Venezuelan State oil company, was involved in several joint ventures with U.S. companies to ensure outlets for its upgraded crude. Phillips Petroleum Co. formed a joint venture with PdVSA at its Sweeny, TX, refinery. ExxonMobil had a joint venture with PdVSA at the former Mobil refinery in Chalmette, LA. CITGO is a wholly owned subsidiary of PdVSA with a refinery in Corpus Christi, TX, and part interests in others (Cunningham, 1999e). PdVSA was a partner with Amerada Hess Corp. in Hess's St. Croix, U.S. Virgin Islands, refinery (Amerada Hess Corp., 1998). PdVSA had long-term supply agreements with ExxonMobil at Baytown, TX, and Baton Rouge, LA (Cunningham, 1999e).

Heavy oil upgrader projects progressed in Venezuela that should result in an additional 600,000 t/yr of sulfur available for export. Large oil reserves found in the Orinoco Belt were low-quality oil (Cunningham, 1999d) with high sulfur content averaging about 4% sulfur (Fertecon North America Sulphur Service, 1998). To make the material attractive for the open market, it was upgraded to a higher quality crude with lower sulfur content before it was shipped to foreign markets for further refining (Cunningham, 1999d).

Four separate projects were being developed at the José refinery complex on the Caribbean coast in Anzoategui State. All the projects were joint ventures between PdVSA and major international oil companies. The joint ventures varied in throughput capacity and sulfur production as well as expected time of completion. The first project was expected to come on-stream in mid-2001, two projects were slated for completion in 2002, with the final plant's anticipated opening in 2004 (Cunningham, 1999d). The United States was expected to be the recipient of most of the upgraded Venezuelan oil (Fertecon North America Sulphur Service, 1998) with an average sulfur content of 0.7% (Cunningham, 1999e). The Venezuelan national oil company was considering the next step in its heavy oil upgrading projects. Options to deliver molten sulfur to port facilities via pipeline or to install forming equipment to produce solid sulfur were considered (Green Markets, 1999h).

New Technology

Underground Storage.—In an effort to identify an alternative to aboveground storage of elemental sulfur stocks, Alberta Sulfur Research Ltd. was testing the viability of underground storage at a site provided by Syncrude. Underground storage would minimize the amount of land area tied up as a result of sulfur stockpiles an could eliminate some of the unwanted reactions that sulfur undergoes when exposed to the atmosphere. If the tests were successful, sulfur could be stored in exhausted surface mines. Upon reaching capacity, with proper reclamation techniques, the land over the stockpiles could be returned to agricultural use. When the time came that the sulfur was required, it could be recovered more efficiently than from above ground storage (Sulphur, 1999c).

Acid Gas Reinjection.—One possible disposal route for excess sulfur is reinjection of acid gas. About 20 sour gas plants in Alberta were reinjecting hydrogen sulfide (H_2S) and/or carbon dioxide in 1999. Growth could eventually result in about 250,000 t of sulfur being reinjected, and thus removing that quantity from market (Sulphur, 1999c). These gas processing plants were using this method on a small scale. Ramping it up to handle thousands of tons present challenges, including recompression, metallurgy, and reservoir chemistry. There were drawbacks to the process, including the large quantity of energy consumed and the need for large reservoirs located near the plants or refineries (Hyne, 1999).

Biodesulfurization.—Shell International Oil Products and Paques Bio Systems BV of the Netherlands developed a bacteria-based sulfur removal system for natural gas processing. The process uses a naturally occurring bacteria to remove H_2S from natural gas by converting it to sulfur. The process successfully produced 15 t/d from gases containing up to 80% H_2S. The developers believed that expanding the process to commercial scale would be relatively simple (Oil & Gas Journal, 1999d).

Adsorption-Catalysis Desulfurization.—Phillips Petroleum developed a new desulfurization process to meet the proposed EPA requirements for sulfur in gasoline. It differed from the more common hydrodesulfurization processes in that it had less detrimental effects on the quality of the gasoline processed. It was a combined adsorption-catalysis reaction in which sulfur-bearing hydrocarbons and other sulfur compounds were selectively adsorbed on the surface of a solid catalyst. On the catalyst, excess hydrogen replaced sulfur in the hydrocarbon compounds that exit the reactor. The sulfur remained on the catalyst, which was regenerated through converting the sulfur to sulfur dioxide by burning in air. The sulfur dioxide was routed through existing sulfur recovery units or to a sulfuric acid plant. Phillips completed a test at a pilot plant and was working on a demonstration unit at its Borger, TX, refinery to be completed in 2001 (Connock, 1999b).

Outlook

The outlook for the sulfur industry continues on its path of increased production, slower growth in consumption, higher stocks, and expanded world trade. U.S. production from petroleum refineries is expected to increase substantially in the next few years as expansions, upgrades, and new facilities at existing refineries are completed, enabling refiners to increase thoughput of crude oil and to process higher sulfur crudes. Production from natural gas operations varies annually, but is usually between 2.0 and 2.2 Mt. Output is expected to remain about at that level. Worldwide recovered sulfur should continue to increase. Refineries in developing countries should begin to improve environmental protection measures and eventually approach the environmental standards of plants in Japan, North America, and Western Europe.

Byproduct sulfuric acid production will remain depressed in the United States as long as the copper smelters remain idle. With the copper industry's switch to lower cost production processes and producing regions, it could be many years before U.S. byproduct acid production again approaches the level reached in 1998. Worldwide, the outlook is different. Copper production costs in many countries are lower than in the United States, so that acid production from those countries has not decreased as drastically as domestically and increased production is more likely. Environmental controls have been less of a concern in developing countries in the past. Many copper producers, however, in these and even in developed countries are installing more efficient sulfuric acid plants to limit sulfur dioxide emissions at new and existing smelters. Planned and in-progress improvement projects could increase byproduct acid production to 52 Mt by 2010 or the equivalent of about 17 Mt of sulfur (Sulphur, 1999a), from 10 Mt (3.3 Mt of sulfur) in 1999.

Frasch and pyrites production, however, have little chance of significant long-term increases. Because of the continued growth of elemental sulfur recovery for environmental reasons rather than demand, discretionary sulfur has become increasingly less important. Frasch sulfur has become the high-cost process for sulfur production. Pyrites, with significant direct production costs, is an even higher cost raw material for sulfuric acid production when the environmental aspects are considered. Discretionary sulfur output should show a steady decline. The decreases will be pronounced when large operations are closed outright for economic reasons.

Sulfur and sulfuric acid will continue to be important in agricultural and industrial applications, although consumption will not equal production. World sulfur demand for fertilizer is forecast to increase at about 2.6% per year for the next 10 years; industrial demand is predicted to grow at 2.3%.

The most important changes in sulfur consumption will be in location. Phosphate fertilizer production, where most sulfur is consumed, is projected to increase about 2.5% per year through 2010. With phosphate fertilizer capacity in Australia, China, and India, sulfur demand will grow in these areas at the expense of some phosphate operations elsewhere, thus transferring sulfur demand rather than creating new. The effects are already beginning to be felt to some extent in the U.S. phosphate industry, reflected in the permanent closure of some facilities. U.S. phosphate products supply domestic requirements, but a large portion of U.S. production is exported. China and India are primary markets for U.S. fertilizers. As the phosphate fertilizer industries develop in these countries, some of the markets for U.S. material could be lost. Sulfur will be required for phosphate production at new operations, and more producers will be competing for those markets.

Use of sulfur directly or in compounds as fertilizer should increase, but this use will be dependent on agricultural economies and increased acceptance of the need for sulfur in plant nutrition. If widespread use of plant nutrient sulfur is adopted, sulfur consumption in that application could be significant; thus far, growth has been slow.

Industrial sulfur consumption has more prospects for growth than in recent years, but still less than agriculture and not enough to consume any surplus production. Conversion to, or increases in, copper leaching by producers bodes well for the sulfur industry, requiring significantly more sulfuric acid for the leaching operations. Pressure acid leaching of nickel ores could require in excess of 4 Mt/yr of sulfuric acid by 2001 (Sulphur, 1999a). Changes in the preferred methods for producing oxygenated gasoline, especially in Canada and the United States, might result in additional alkylation capacity that would require additional sulfuric acid. Other industrial uses show less potential for expansion. Estimates show sulfur production exceeding consumption by 3 Mt/yr for the next 20 years, and worldwide inventories reaching 80 Mt by 2020 (Hyne, 1999).

Unless significant new uses for elemental sulfur are implemented, the oversupply situation will result in tremendous stockpiles accumulating around the world. In the 1970's and 1980's, research was conducted that showed the effectiveness of sulfur in several construction uses that held the promise of consuming huge quantities of sulfur in sulfur-extended asphalt and sulfur concretes. In many instances, these materials were found to be superior to the more traditional products; but their use has been very limited. It may be necessary to revisit these proposals to avoid building mountains of sulfur in the not-too-distant future.

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

TABLE 1
SALIENT SULFUR STATISTICS 1/

(Thousand metric tons, sulfur content, and thousand dollars unless otherwise specified)

	1995	1996	1997	1998	1999
United States:					
Production:					
Frasch e/	3,150	2,900	2,820	1,800	1,780
Recovered 2/	7,250	7,480	7,650	8,220	8,220
Other forms	1,400	1,430	1,550	1,610	1,320
Total e/	11,800	11,800	12,000	11,600	11,300
Shipments:					
Frasch	W	W	W	W	W
Recovered 2/ 3/	10,700	10,400	10,400	10,500	9,800
Other forms	1,400	1,430	1,550	1,610	1,320
Total	12,100	11,800	11,900	12,100	11,100
Exports:					
Elemental 4/	906	855	703	889	685
Sulfuric acid	56	38	39	51	51
Imports:					
Elemental	2,510	1,960	2,060	2,270	2,580
Sulfuric acid	628	678	659	668	447
Consumption, all forms	14,300	13,600	13,900	14,100	13,400
Stocks, December 31, producer, frasch and recovered	583	646	761	283	451
Value:					
Shipments, f.o.b. mine or plant:					
Frasch	W	W	W	W	W
Recovered 2/ 3/	$476,000	$355,000	$375,000	$306,000	$371,000
Other forms	$86,400	$85,800	$98,100	$77,100 r/	$66,400
Total	$562,000	$441,000	$473,000	$383,000 r/	$437,000
Exports, elemental 4/ 5/	$66,200	$51,700	$36,000	$35,400	$35,800
Imports, elemental	$143,000	$70,200	$64,900	$58,400	$51,600
Price, elemental, dollars per metric ton, f.o.b. mine or plant	$44.46	$34.11	$36.06	$29.14	$37.81 e/
World, production, all forms (including pyrites)	54,000 r/	55,200 r/	57,100 r/	56,700 r/	57,100 e/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Recovered."
1/ Data are rounded to no more than three significant digits, except prices; may not add to totals shown.
2/ Includes Puerto Rico and the U.S. Virgin Islands.
3/ Includes corresponding Frasch sulfur data.
4/ Includes exports from the U.S. Virgin Islands to foreign countries.
5/ Includes value of exports from the U.S. Virgin Islands to foreign countries.

TABLE 2

RECOVERED SULFUR PRODUCED AND SHIPPED IN THE UNITED STATES, BY STATE 1/

(Thousand metric tons and thousand dollars)

State	1998 Production	1998 Shipments Quantity	1998 Shipments Value	1999 Production	1999 Shipments Quantity	1999 Shipments Value
Alabama	358	362	11,800	336	336	12,700
California	1,100	1,080 r/	6,960	1,070	1,070	5,270
Illinois	404	404 r/	7,560 r/	418	417	11,300
Louisiana	914	2,600 2/	W	1,110	2,590 2/	W
Michigan and Minnesota	126	126	2,600	33	33	818
Mississippi	460	466 r/	11,000	527	528	10,200
New Mexico	51	50	302	47	47	253
North Dakota	54	54	208	51	51	487
Ohio	47	48	1,670	80	80	2,300
Texas	2,750	3,340 2/	107,000 2/	2,610	2,770 2/	153,000
Washington	114	114	1,100	95	96	224
Wyoming	1,070	1,060	12,100	1,080	1,050	21,700
Other 3/	788	801 r/	144,000 r/	763	736	152,000
Total	8,220	10,500	306,000	8,220	9,800	371,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."

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

2/ Includes corresponding Frasch sulfur data.

3/ Includes Arkansas, Colorado, Delaware, Florida, Indiana, Kansas, Kentucky, Louisiana (value), Montana, New Jersey, Pennsylvania, Utah, Virginia, Wisconsin, Puerto Rico, and the U.S. Virgin Islands.

TABLE 3

RECOVERED SULFUR PRODUCED AND SHIPPED IN THE UNITED STATES, BY PETROLEUM ADMINISTRATION FOR DEFENSE (PAD) DISTRICT 1/

(Thousand metric tons)

District and source	1998 Production	1998 Shipments	1999 Production	1999 Shipments
PAD 1:				
Petroleum and coke	233	231	228	220
Natural gas	47	47	45	45
Total	280	278	272	265
PAD 2:				
Petroleum and coke	889	891	821	820
Natural gas	55	56	53	53
Total	944	946	874	873
PAD 3: 2/				
Petroleum	3,620	W	3,880	W
Natural gas	1,000	W	847	W
Total	4,630	6,930 3/	4,730	6,350 3/
PAD 4 and 5:				
Petroleum	1,320	1,300	1,280	1,270
Natural gas	1,060	1,060	1,070	1,040
Total	2,380	2,360	2,350	2,310
Total petroleum and coke	6,060	W	6,210	W
Total natural gas	2,160	W	2,010	W
Grand total	8,220	10,500 3/	8,220	9,800 3/

W Withheld to avoid disclosing company proprietary data.

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

2/ Includes Puerto Rico and the U.S. Virgin Islands.

3/ Includes corresponding Frasch sulfur data.

TABLE 4
BYPRODUCT SULFURIC ACID PRODUCED
IN THE UNITED STATES 1/ 2/

(Thousand metric tons, sulfur content, and thousand dollars)

Type of plant	1998	1999
Copper 3/	1,430	1,130
Zinc 4/	121	124
Lead and molybdenum 4/	68	70
Total	1,610	1,320
Value	$77,100	$66,400

1/ Includes acid produced from imported raw materials.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.
3/ Excludes acid made from pyrites concentrates.
4/ Excludes acid made from native sulfur.

TABLE 5
CONSUMPTION OF SULFUR IN THE UNITED STATES 1/ 2/

(Thousand metric tons)

	1998	1999
Total elemental:		
Shipments 3/	10,500	9,800
Exports	889	685
Imports	2,270	2,580
Total	11,900	11,700
Byproduct sulfuric acid:		
Shipments 3/	1,610	1,320
Exports 4/	51	51
Imports 4/	668	447
Grand total	14,100	13,400

1/ Crude sulfur or sulfur content.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.
3/ Includes Puerto Rico and the U.S. Virgin Islands.
4/ May include sulfuric acid other than byproduct.

TABLE 6
SULFUR AND SULFURIC ACID SOLD OR USED IN THE UNITED STATES, BY END USE 1/

(Thousand metric tons, sulfur content)

		Elemental sulfur 2/		Sulfuric acid (sulfur equivalent)		Total	
SIC 3/	End use	1998	1999	1998	1999	1998	1999
102	Copper ores	--	--	818	726	818	726
1094	Uranium and vanadium ores	--	--	3	8	3	8
10	Other ores	--	--	126	75	126	75
26, 261	Pulpmills and paper products	W	W	134	138	134	138
28, 285, 286, 2816	Inorganic pigments, paints and allied products, industrial organic chemicals, other chemical products 4/	80	97	174	174	254	271
281	Other inorganic chemicals	W	--	202	195	202	195
282, 2822	Synthetic rubber and other plastic materials and synthetics	W	W	69	68	69	68
2823	Cellulosic fibers, including rayon	--	--	5	5	5	5
283	Drugs	--	--	3	3	3	3
284	Soaps and detergents	--	--	1	1	1	1
286	Industrial organic chemicals	--	--	93	90	93	90
2873	Nitrogenous fertilizers	--	--	213	210	213	210
2874	Phosphatic fertilizers	--	--	7,590 r/	7,770	7,590 r/	7,770
2879	Pesticides	--	--	17	19	17	19
287	Other agricultural chemicals	1,070	1,200	31	32	1,100	1,240
2892	Explosives	--	--	5	4	5	4
2899	Water-treating compounds	--	--	75	64	75	64
28	Other chemical products	--	--	38	39	38	39
29, 291	Petroleum refining and other petroleum and coal products	1,450	1,400	632	508	2,080	1,910
331	Steel pickling	--	--	14	13	14	13
333	Nonferrous metals	--	--	38	38	38	38
33	Other primary metals	--	--	45	48	45	48
3691	Storage batteries (acid)	--	--	12	11	12	11
	Exported sulfuric acid	--	--	6	9	6	9
	Total identified	2,610 r/	2,720	10,300	10,200	12,900	13,000
	Unidentified	1,190 r/	1,100	236	185	1,430 r/	1,290
	Grand total	3,800 r/	3,820	10,600 r/	10,400	14,400	14,300

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Unidentified." -- Zero.

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

2/ Does not include elemental sulfur used for production of sulfuric acid.

3/ Standard Industrial Classification.

4/ No elemental sulfur was used in inorganic pigments and paints and allied products.

TABLE 7
SULFURIC ACID FROM SMELTERS SOLD OR USED IN THE UNITED STATES,
BY END USE 1/

(Thousand metric tons of 100% H_2SO_4)

SIC 2/	Use	1998	1999
102	Copper ores	2,400	2,120
10	Other ores	W	W
26, 261	Pulp mills and other paper products	W	W
28, 281, 282, 283, 286, 2816	Miscellaneous chemicals	182 r/	W
2873	Nitrogenous fertilizers	W	W
2874	Phosphatic fertilizers	W	W
287, 2879	Pesticides and other agricultural chemicals	97	100
2899	Water-treating compounds	195	162
291	Petroleum refining	W	W
3691	Storage batteries (acid)	W	W
33, 331, 333, 1094	Miscellaneous metal usage	167 r/	189
	Unidentified 3/	1,850 r/	865
	Total	4,890	3,440

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Unidentified."
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Standard Industrial Classification.
3/ Includes exports.

TABLE 8
U.S. EXPORTS OF ELEMENTAL SULFUR, BY COUNTRY 1/ 2/

(Thousand metric tons and thousand dollars)

	1998		1999	
Country	Quantity	Value	Quantity	Value
Argentina	18	555	(3/)	9
Australia	(3/)	10	18	452
Brazil	356	9,800	184	5,160
Canada	35	4,170	36	4,160
Colombia	5	510	(3/)	79
India	--	--	44	1,160
Korea, Republic of	3	3,350	6	5,840
Mexico	57	2,540	132	5,020
Morocco	85	2,250	--	--
Senegal	176	4,170	28	847
Other	154	8,090 r/	237	13,100
Total	889	35,400	685	35,800

r/ Revised. -- Zero.
1/ Includes exports from the U.S. Virgin Islands.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.
3/ Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 9
U.S. EXPORTS OF SULFURIC ACID (100% H_2SO_4), BY COUNTRY 1/

Country	1998 Quantity (metric tons)	1998 Value (thousands)	1999 Quantity (metric tons)	1999 Value (thousands)
Canada	122,000	$6,870	133,000	$7,220
China	2,520	474	444	359
Costa Rica	3	5	--	--
Dominican Republic	5,110	302	1,830	186
Israel	3,830	606	2,960	815
Japan	32	50	93	120
Korea, Republic of	47	28	1	9
Mexico	8,940	3,540	1,450	288
Netherlands	74	66	66	65
Netherlands Antilles	2,860	211	509	265
Panama	1,000	42	--	--
Saudi Arabia	1,210	2,490	2,000	4,150
Singapore	451	247	709	406
Taiwan	1,640	537	832	452
Trinidad and Tobago	13	23	72	22
United Kingdom	150	29	35	85
Venezuela	233	623	190	22
Other	5,360	2,010	10,700	2,390
Total	155,000	18,100	155,000	16,800

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

Source: U.S. Census Bureau.

TABLE 10
U.S. IMPORTS OF ELEMENTAL SULFUR, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country	1998 Quantity	1998 Value 2/	1999 Quantity	1999 Value 2/
Canada	1,440	16,900	1,640	12,500
Mexico	559	26,900	543	27,000
Other	268	14,600	403	12,100
Total	2,270	58,400	2,580	51,600

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Declared customs valuation.

Source: U.S. Census Bureau; as adjusted by the U.S. Geological Survey.

TABLE 11
U.S. IMPORTS OF SULFURIC ACID (100% H_2SO_4), BY COUNTRY 1/

Country	1998 Quantity (metric tons)	1998 Value 2/ (thousands)	1999 Quantity (metric tons)	1999 Value 2/ (thousands)
Argentina	859	$117	--	--
Canada	1,550,000	60,800	865,000	$27,100
Germany	30,700	1,060	69,600	2,100
Japan	203,000	11,400	162,000	12,200
Mexico	50,100	2,930	107,000	6,810
Spain	10,200	288	8,150	245
Other	194,000	10,200	157,000	14,100
Total	2,040,000	86,800	1,370,000	62,600

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Declared c.i.f. (cost, insurance, and freight paid by shipper) valuation.

Source: U.S. Census Bureau.

TABLE 12
SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE 1/ 2/

(Thousand metric tons)

Country and source 3/	1995	1996	1997	1998	1999 e/
Australia, byproduct: e/					
Metallurgy	263	327	474	507	441
Petroleum	35	35	35	35	34 4/
Total	298	362	509	542	475
Belgium, byproduct, all sources e/	347	406	430	428	408
Canada, byproduct:					
Metallurgy	980 r/	1,044 r/	1,072 r/	1,153 r/	1,156 p/
Natural gas, petroleum, and tar sands	7,973 r/	8,446 r/	8,408 r/	8,541 r/	8,960 p/
Total	8,953 r/	9,490 r/	9,480 r/	9,694 r/	10,116 p/
Chile, byproduct, metallurgy e/	588	587	768	899	1,040
China: e/					
Elemental	160	170	200	210	250
Pyrites	5,930	5,990	6,040	4,490	3,860
Byproduct, metallurgy	940	1,100	1,400	1,450	1,580
Total	7,030	7,260	7,640	6,150	5,690
Finland:					
Pyrites	422	425	373	380 e/	380
Byproduct:					
Metallurgy	215	291	307	296 e/	300
Petroleum	38	38	50	45 e/	45
Total	675	754	730	721 e/	725
France, byproduct:					
Natural gas	825	755 e/	697	600 r/ e/	600
Petroleum	240	235 e/	263	245 r/ e/	250
Unspecified e/	100	99	100	261 r/	250
Total e/	1,170	1,090	1,060	1,110 r/	1,100
Germany, byproduct: e/					
Metallurgy	20 4/	20	25	25	25
Natural gas and petroleum	1,000	1,000	1,085 4/	1,100	1,100
Unspecified	90	90	50	50	60
Total	1,110	1,110	1,160	1,180	1,190
Iran, byproduct: e/					
Metallurgy	50	50	50	50	60
Natural gas and petroleum	840	840	850	850	850
Total	890	890	900	900	910
Italy, byproduct: e/					
Metallurgy	190	216	229	199	193
Petroleum	340	335	380	425	485
Total	530	551	609	624	678
Japan:					
Pyrites e/	88 r/	45 r/	39 r/	23 r/	41
Byproduct:					
Metallurgy	1,342 r/	1,314 r/	1,331 r/	1,322 r/	1,363 4/
Petroleum e/	1,680	1,790	2,010	2,080	2,060
Total e/	3,110 r/	3,150 r/	3,380 r/	3,430 r/	3,460
Kazakhstan: e/					
Pyrites	71	71	--	--	--
Byproduct:					
Metallurgy	131	139	139	212	245
Natural gas and petroleum	255	515	778	933	1,070
Total	457	725	917	1,150	1,320
Korea, Republic of, byproduct: e/					
Metallurgy	255	260	265	270	280
Petroleum	200	200	200	200	200
Total	455	460	465	470	480
Kuwait, byproduct, natural gas and petroleum e/	559	595	675 4/	665	675
Mexico, byproduct:					
Metallurgy	359	359	417	474 e/	450
Natural gas and petroleum	882	921	923	913	860 4/
Total	1,241	1,280	1,340	1,387 r/	1,310

See footnotes at end of table.

TABLE 12--Continued
SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE 1/ 2/

(Thousand metric tons)

Country and source 3/	1995	1996	1997	1998	1999 e/
Netherlands, byproduct: e/					
Metallurgy	167	119	127	131	129
Petroleum	317	380	450	432	445
Total	484	499	577	563	574
Poland: 5/					
Frasch	2,425	1,783	1,676 r/	1,348 r/	1,175 4/
Byproduct: e/					
Metallurgy	131	98	256 r/	261	260
Petroleum	25	25	44 r/	57 r/	74
Gypsum e/	10	10	-- r/	-- r/	--
Total	2,591	1,916	1,976 r/	1,666 r/	1,510
Russia: e/ 6/					
Native	80	70	50	50	50
Pyrites	450	400	400	254	300
Byproduct, natural gas	2,970	3,000	2,950	3,940 r/	4,410
Other	335	325	350	411	510
Total	3,840	3,800	3,750	4,650 r/	5,270
Saudi Arabia, byproduct, all sources e/	2,400 r/	2,300 r/	2,400 r/	2,300 r/	2,400
South Africa:					
Pyrites	159	184	167	152	141 4/
Byproduct:					
Metallurgy	67	91	37 r/	100 e/	100
Petroleum 7/	233	232 r/	256 r/	178 r/	164 4/
Total	459	507 r/	460 r/	430 r/	406 4/
Spain:					
Pyrites	404	438	424	430	388
Byproduct: e/					
Coal (lignite) gasification	2	2	2	2	2
Metallurgy	305	428	456	461	455
Petroleum	75	75	85	100	110
Total	786	943	967	993	955
United Arab Emirates: Abu Dhabi, byproducts, natural gas and petroleum e/	257	780	967	967	1,090
United States:					
Frasch e/	3,150	2,900	2,820	1,800	1,780
Byproduct:					
Metallurgy	1,400	1,430	1,550	1,610	1,320 4/
Natural gas	2,210	2,100	2,420	2,160	2,010 4/
Petroleum	5,040	5,370	5,230	6,060	6,210 4/
Total e/	11,800	11,800	12,000	11,600	11,300 4/
Uzbekistan, byproduct:					
Metallurgy	150	145	165 e/	170	175
Natural gas and petroleum	320	250	250 e/	275	280
Total	470	395	415 e/	445	455
Venezuela, byproduct, natural gas and petroleum	180	250	319	425	450
Other: 8/					
Frasch	22	25	20	25 r/	25
Native 9/	583 r/	485 r/	471 r/	463 r/	446
Pyrites	617 r/	558 r/	431 r/	303 r/	223
Byproduct:					
Metallurgy	669 r/	686 r/	631 r/	658 r/	638
Natural gas	155	150	130	206	215
Natural gas, petroleum, tar sands, undifferentiated	8,132 r/	8,598 r/	8,566 r/	8,705 r/	9,120
Petroleum	449 r/	488 r/	567 r/	583 r/	519
Unspecified sources	650 r/	750 r/	810 r/	879 r/	886
Total	11,278 r/	11,741 r/	11,627 r/	11,821 r/	12,100

See footnotes at end of table.

TABLE 12--Continued
SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE 1/ 2/

(Thousand metric tons)

Country and source 3/	1995	1996	1997	1998	1999 e/
Grand total	54,000 r/	55,200 r/	57,100 r/	56,700 r/	57,100
Of which:					
Frasch	5,600 r/	4,710 r/	4,520 r/	3,170 r/	2,980
Native 10/	823 r/	725 r/	721 r/	723 r/	746
Pyrites	8,140 r/	8,110 r/	7,880 r/	6,030 r/	5,330
Byproduct:					
Coal (lignite) gasification e/	2	2	2	2	2
Metallurgy	8,220 r/	8,700 r/	9,700 r/	10,300 r/	10,200
Natural gas	6,160	6,000 r/	6,200 r/	6,900 r/	7,230
Natural gas, petroleum, tar sands, undifferentiated	12,400 r/	13,800 r/	14,400 r/	14,800 r/	15,500
Petroleum	8,670 r/	9,200 r/	9,570 r/	10,400 r/	10,600
Unspecified sources	3,920 r/	3,970 r/	4,140 r/	4,330 r/	4,510
Gypsum e/	10	10	-- r/	-- r/	--

e/ Estimated. p/ Preliminary. r/ Revised. -- Zero.

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through September 1, 2000.

3/ The term "Source" reflects the means of collecting sulfur and the type of raw material. Sources listed include the following: (1) Frasch recovery, (2) native, comprising all production of elemental sulfur by traditional mining methods (thereby excluding Frasch), (3) pyrites (whether or not the sulfur is recovered in the elemental form or as acid), (4) byproduct recovery, either as elemental sulfur or as sulfur compounds from coal gasification, metallurgical operations including associated coal processing, crude oil and natural gas extraction, petroleum refining, tar sand cleaning, and processing of spent oxide from stack-gas scrubbers, and (5) recovery from the processing mined gypsum. Recovery of sulfur in the form of sulfuric acid from artificial gypsum produced as a byproduct of phosphatic fertilizer production is excluded, because to include it would result in double counting. It should be noted that production of Frasch sulfur, other native sulfur, pyrites-derived sulfur, mined gypsum-derived sulfur, byproduct sulfur from extraction of crude oil and natural gas, and recovery from tar sands are all credited to the country of origin of the extracted raw materials. In contrast, byproduct recovery from metallurgical operations, petroleum refineries, and spent oxides are credited to the nation, where the recovery takes place, which is not the original source country of the crude product from which the sulfur is extracted.

4/ Reported figure.

5/ Official Polish sources report total Frasch and native mined elemental sulfur output annually, undifferentiated; this figure has been divided between Frasch and other native sulfur on the basis of information obtained from supplementary sources.

6/ Sulfur is believed to be produced from Frasch and as a petroleum byproduct; however, information is inadequate to formulate estimates.

7/ Includes byproduct production from synthetic fuels.

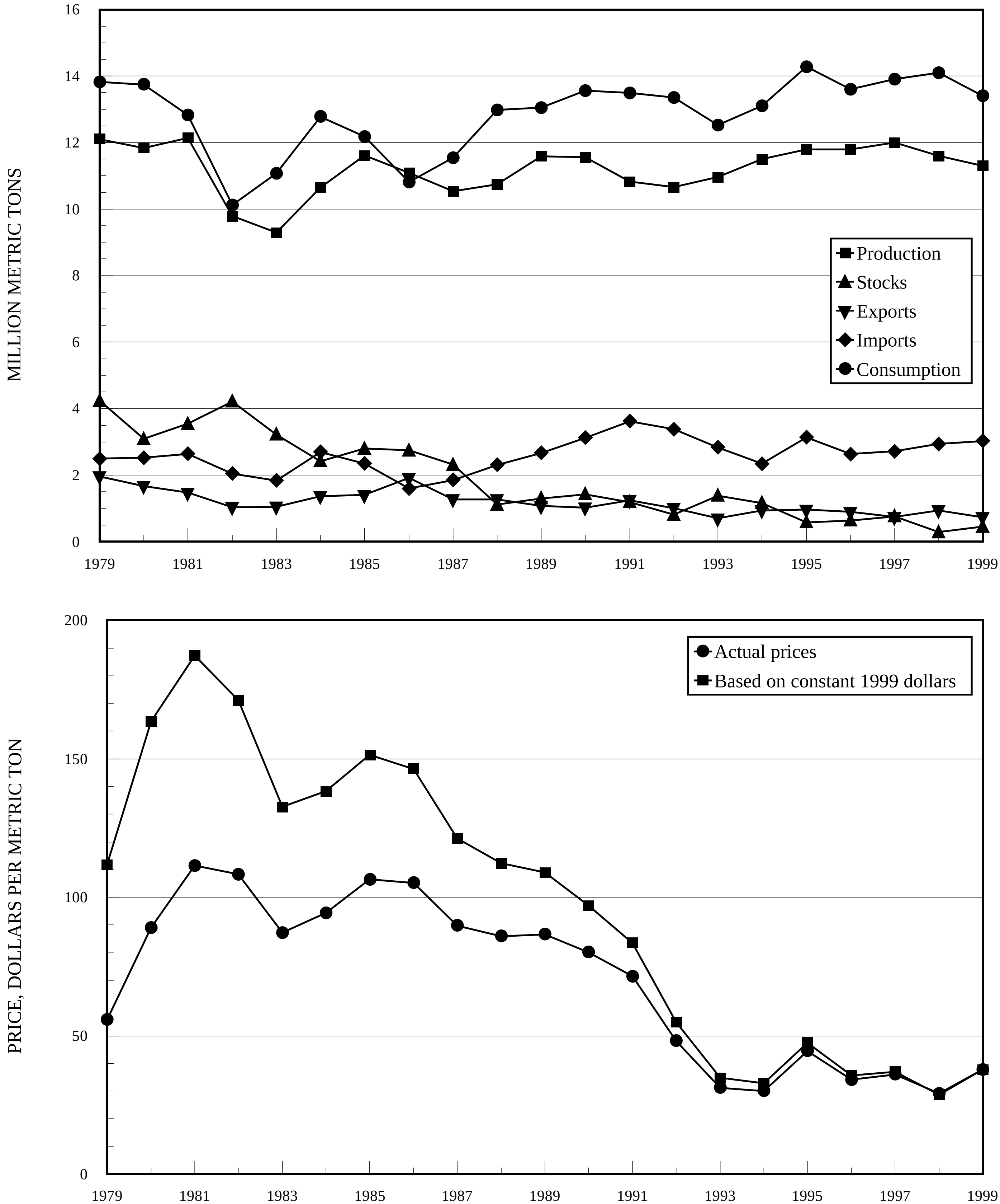
8/ "Other" includes all countries, except the above mentioned: Australia, Belgium, Canada, Chile, China, Finland, France, Germany, Iran, Italy, Japan, Kazakhstan, the Republic of Korea, Kuwait, Mexico, the Netherlands, Poland, Russia, Saudi Arabia, South Africa, Spain, the United Arab Emirates, the United States, Uzbekistan, and Venezuela.

9/ Includes "Iraq, elemental, all sources." "Iraq, Frasch and byproduct, natural gas and petroleum" were revised to zero.

10/ Includes "China, elemental" and "Iraq, elemental, all sources."

FIGURE 1

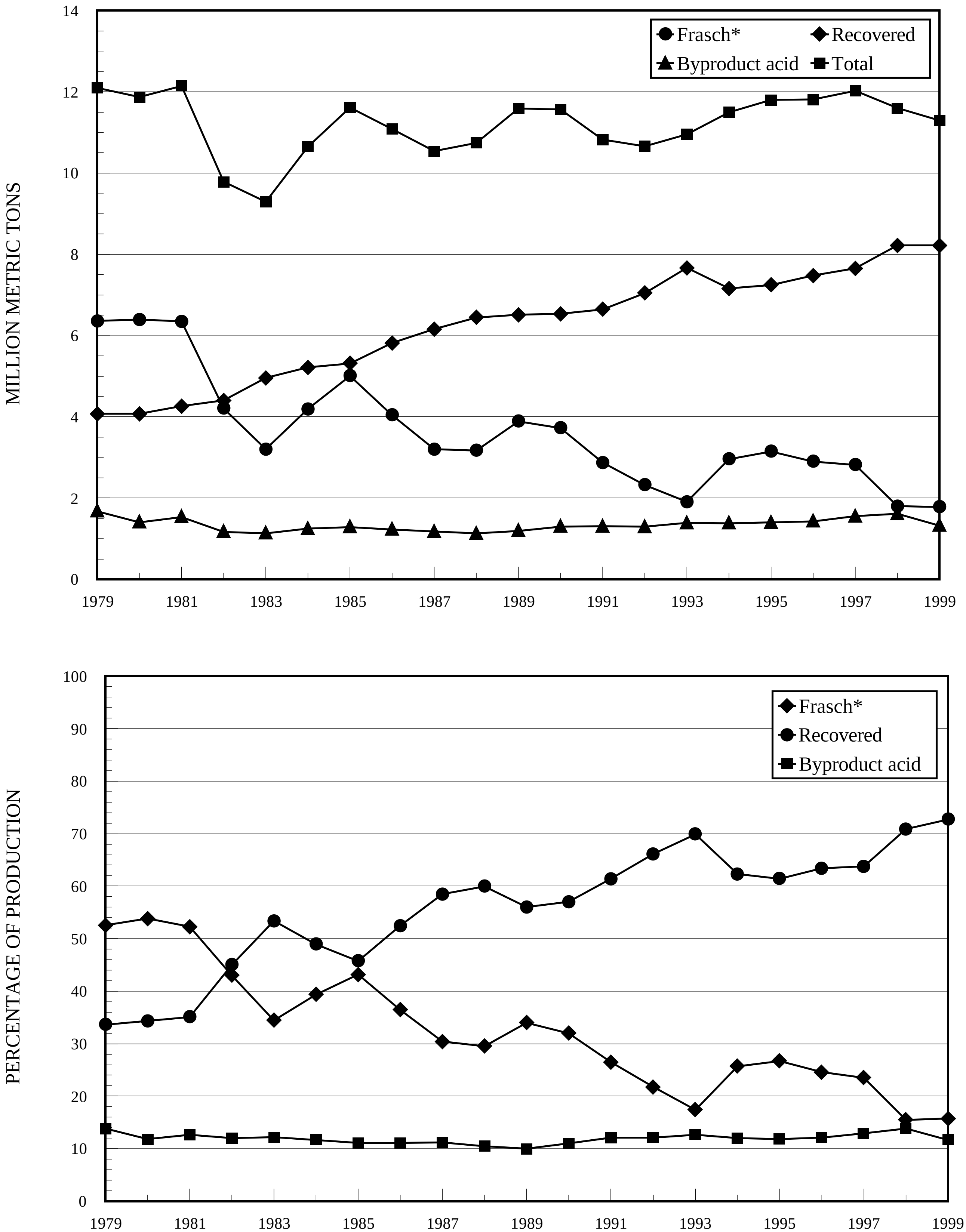
TRENDS IN THE SULFUR INDUSTRY IN THE UNITED STATES



Based on the average reported values for elemental sulfur (Frasch and recovered), f.o.b. mine and/or plant, these prices reflect about 90% of the shipments of sulfur in all forms from 1978 through 1998.

FIGURE 2

TRENDS IN THE PRODUCTION OF SULFUR IN THE UNITED STATES



*Includes 10 months of Frasch data for 1993; the other 2 months are included with the recovered sulfur data to conform with proprietary data requirements. Data are estimates for 1994 through 1998.