SULFUR

By Joyce A. Ober

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; nearly 48 million metric tons, equivalent to almost 16 million tons of elemental sulfur, were produced, virtually the same as that of 1996 (Chemical and Engineering News, 1998).

Domestic sulfur production was slightly higher, as were shipments, consumption, imports, and prices. The United States maintained its position as the leading 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, the second year the U.S. Bureau of Mines (USBM) published data on the production of this type of sulfur in its Minerals Yearbook. This data series has continued at the U.S. Geological Survey (USGS) since the minerals information activities of the USBM were transferred in 1996. Sulfur produced by using the Frasch process was slightly lower than that of 1996. The reason for the decrease was intentional cutbacks by Freeport-McMoRan Sulphur Inc., the only domestic Frasch producer, to improve the balance between supply and demand (Freeport-McMoRan Sulphur Inc., 1998, p. 19-20). Frasch production data were estimated on the basis of company reports published by Freeport. Total production of sulfur from all sources was slightly higher; shipments increased, but at a slower pace than production, which resulted in an increase in stocks.

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. The production increase of 8% over 1996 was mainly due to increased production at Kennecott Corp.'s smelter in Magna, UT, the newest copper smelter in the United States.

World sulfur production was about the same as in 1996. Frasch production was slightly higher because of increased production in Poland. Elemental sulfur production from recovered sources, primarily during the processing of natural gas and petroleum products, remained about the same. 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, petroleum products, and nonferrous metals, not on the demand for sulfur.

World sulfur consumption remained about the same with no change in the way it was divided among fertilizer production and a myriad of other industrial uses. World trade of elemental sulfur increased almost 8% from the levels recorded in 1996. U.S. sulfur inventories increased about 19%, although still relatively low as compared with stocks in the early 1990's. Worldwide inventories of elemental sulfur were slightly higher. *(See table 1 and figure 1.)*

Production

Elemental Sulfur.—Production was slightly higher than in 1996. Shipments were unchanged in 1997, but the value of shipments was slightly higher owing to an increase in the average value per ton of elemental sulfur.

Production statistics are collected on a monthly basis and published in the USGS sulfur monthly Mineral Industry Surveys. Of the 136 operations to which survey requests were sent, all responded, representing 100% of the total production shown in table 1.

Frasch.—Native sulfur associated with the cap rock 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 operated two Frasch mines, one each in Louisiana and Texas. Freeport's operations included the Culberson Mine in west Texas; sulfur-forming and sulfur-loading facilities in Galveston, TX, and Tampa, FL; and the Main Pass Mine, 27 kilometers offshore Louisiana in the Gulf of Mexico. Production at Main Pass and Culberson averaged about 5,200 and 2,400 tons per day, respectively, throughout the year (Freeport-McMoRan Sulphur Inc., 1998, p. 4-5).

Late in the year, Freeport Sulphur became an independent, publicly traded company. It was spun off as an independent company when Freeport-McMoRan Inc., previously the parent company of Freeport Sulphur, merged with IMC Global Inc. All of Freeport McMoRan Inc.'s sulfur assets and IMC's share of the Main Pass operation transferred to Freeport Sulphur as part of the agreement (Green Markets, 1997).

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 51 companies at 134 plants in 26 States, 1 plant in Puerto Rico, and 1 plant in the U.S. Virgin Islands. Most of these plants were relatively small, with only 25 reporting annual production exceeding 100,000 tons. By source, 68% was produced at 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 were Exxon Corp., Amoco Corp., Chevron Corp., Mobil Oil Corp., Star Enterprises, and Shell Oil Co. The 41 plants owned by these companies accounted for 57% of recovered sulfur output during the year. *(See tables 2 and 3.)*

Over the past few years, the oil and gas industry has undergone significant consolidation and this trend continued in 1997. Several of the small producers have merged in recent years; and in 1997, two major U.S. companies announced their intentions to merge. Shell Oil Co. and Texaco Inc. expected to combine their refining and marketing operations in early 1998. In order for the merger to be approved by the U.S. Government, Shell was required to sell one of its refineries; another was not included in the arrangement because it was partly owned by a Mexican company.

As part of the merger, Star Enterprises, a joint venture between Texaco and Saudi Aramco, was to become part of a new, bigger company. Briefly, Saudi Aramco, Shell, and Texaco were to merge refining and marketing capabilities under two operating units. Equilon Enterprises was established to control the new alliance's activities in the western United States and Motiva Enterprises to operate in the East (Durgin, 1998). Both new alliances should be among the top sulfur producers in the United States.

Byproduct Sulfuric Acid.—Sulfuric acid production at copper, lead, molybdenum, and zinc roasters and smelters accounted for 13% 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. (formerly Magma Copper Co.), Cyprus Miami Mining Corp., Kennecott Corp., and Phelps Dodge Corp.—operated a total of seven copper smelters. *(See table 4 and figure 2.)*

Consumption

Domestic consumption of sulfur in all forms was slightly higher than in 1996. Of the sulfur consumed, 80% was obtained from such domestic sources as elemental sulfur (70%) and byproduct acid (11%) compared with 80% in 1996 and 78% in 1995. The remaining 20% was supplied by imports of recovered elemental sulfur (15%) and sulfuric acid (5%). The USGS collected end-use data on sulfur and sulfuric acid according to the Standard Industrial Classification of industrial activities.

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 80% 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." Although there are no supporting data, it could be reasonably assumed that a significant portion of the sulfur in the "Unidentified" category was shipped to sulfuric acid producers or was exported.

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. Reported U.S. consumption of sulfur in sulfuric acid (100% basis) was unchanged from 1996. Although reported data indicated a 4% increase for total sulfur consumption, apparent consumption figures indicate that actual consumption was only slightly higher than that of 1996.

Agriculture was the largest sulfur-consuming industry despite a slight decrease to 8.2 million tons compared with 8.3 million tons reported in 1996. Reported consumption in phosphatic fertilizers was 5% lower than that of 1996. Actual consumption for phosphate fertilizer probably did not decrease that much because some or most of the "Unidentified" sulfur consumption and imported sulfuric acid is believed to have been for that end use. On the basis of export data from the Bureau of the Census, the estimated quantity of sulfur needed to manufacture exported phosphatic fertilizers increased 4% to 5.1 million tons; reports from The Fertilizer Institute, however, stated that the reported phosphate fertilizer exports were believed to be understated, and the Department of Commerce was conducting an investigation to resolve the problem (Vrooman, 1998).

The second largest end use for sulfur was in petroleum refining and other petroleum and coal products. On the basis of events in the petroleum refining industry, an increase in petroleum refining uses would be expected; the significant increases reported for the use of elemental sulfur in this category, however, indicate inconsistencies in reporting. Demand for sulfuric acid in copper ore leaching, the third largest end use, decreased 4%. *(See tables 5, 6, and 7.)*

According to the 1997 canvass reports, company receipts of spent or contaminated sulfuric acid for reclaiming totaled 576,000 tons. This figure was believed to be significantly higher than reported; most of the acid is, however, 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 about 19% from those of 1996. On the basis of apparent consumption of all forms of sulfur, combined yearend stocks amounted to about a 20-day supply compared with a 17-day supply in 1996 and a 15-day supply in 1995. *(See table 1.)*

Prices

The contract prices for elemental sulfur, at terminals in Tampa,

FL, reported weekly in Green Markets, began the year at $61 to $64 per ton. In late February prices reached $63 to $65 and went up again to $66 to $68 in mid-April. They remained steady throughout the remainder 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 $36.06 per ton, which was 6% higher than that of 1996.

Foreign Trade

Exports of elemental sulfur from the United States, including the U.S. Virgin Islands, were about 18% lower in quantity than those of 1996 and 30% lower in value because the average unit value of U.S. export material decreased, unlike the value of material used for domestic consumption. The average unit value of exported elemental sulfur decreased from $60 per ton to $51, 15% lower than in 1996. According to the Bureau of the Census, exports from the west coast were 639,000 tons, or 91% of total U.S. exports.

The United States continued to be a net importer of sulfur—imports exceeded exports by 1.36 million tons. Recovered sulfur from Canada and Mexico delivered to U.S. terminals and consumers in the liquid phase furnished about 95% of all U.S. sulfur import requirements. Total elemental sulfur imports increased about 5% in quantity; imports by rail from Canada increased 5%, and waterborne shipments from Mexico were 7% higher than those of 1996. Imports from several other countries comprised about 5% of all imported sulfur. The value of elemental sulfur imports decreased 8%.

The U.S. Department of Commerce (DOC) completed an investigation concerning an antidumping complaint against Canadian sulfur producers regarding the period from December 1, 1994, to November 30, 1995. The DOC determined that sales were made at discounts ranging from 0.33% to 40.38% for the companies involved. Antidumping duties were assessed against any material imported from these firms (Fertilizer Markets, 1998).

The United States also had significant trade in sulfuric acid. Sulfuric acid exports were about the same as those of 1996. Acid imports were 17 times greater than exports. Canada was the source of 80% of U.S. acid imports, most of which were probably byproduct acid from smelters. Canadian shipments to the United States were shipped by rail. The remainder of imports came primarily by ship from Europe, Latin America, and Japan. The tonnage of imports of sulfuric acid decreased slightly from that of 1996; the value of imported sulfuric acid increased by 8%. *(See tables 8, 9, 10, and 11.)*

World Review

World production of sulfur was slightly higher in 1997 than that of 1996; consumption was believed to be about the same. Prices were slightly higher. Production of Frasch was slightly higher than 1996. Recovered sulfur production and byproduct sulfuric acid production were virtually unchanged from 1996. Supply continued to exceed demand; worldwide sulfur inventories increased, most of which was stockpiled in Canada.

Industry Structure.—The global sulfur industry remained divided into two sectors. 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 about 75% of the sulfur in all forms produced worldwide.

Poland and the United States were the only countries that produced 1 million tons or more of native sulfur by using either the Frasch method or conventional mining methods. Small quantities of native sulfur were produced in Asia, Europe, North America, and South America. The importance of pyrites to the world sulfur supply has significantly decreased; China and Spain were the only countries in the top 15 sulfur producers whose primary sulfur source was pyrites. About 77% of all pyrites production was in these countries.

Recovered elemental sulfur was the predominant source of sulfur in Canada, France, Germany, Iran, Russia, Saudi Arabia, and the United States. Additionally, recovered elemental sulfur was an important source in Japan and Mexico.

International sulfur trade was dominated by a limited number of exporting countries. Canada, Saudi Arabia, Japan, the former Soviet Union (individual countries unspecified), and Poland, in descending order of importance, exported more than 1 million tons of elemental sulfur each and accounted for 68% of sulfur trade. Major sulfur importers, in descending order, were Morocco, the United States, India, Tunisia, and Brazil, all with imports of more than 1 million tons.

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 10 million tons.

In addition to the large sour gas deposits in Alberta, the area contains huge oil sand deposits known as the Athabascan Oil Sands with estimated reserves of 1.7 to 2.5 billion barrels of crude oil, 300 million barrels of which are recoverable. In 1997, about 20% of Canadian crude oil production came from oil sands. These deposits also contain 4% to 5% sulfur that must be removed during processing. Several major projects to expand exploitation of oil sands were announced, representing proposed investments of nearly $13 billion. Sulfur production from oil sands contributed nearly 700,000 tons to total Canadian output in 1997; completion of the proposed new projects could produce an additional 1 to 2 million tons per year (Stevens, 1998).

Chile.—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. By the end of the century, Chile was expected to have the capacity to produce more than 3 million tons of sulfuric acid, reducing sulfur emissions by more than 1 million tons. The capture of sulfur emissions from

smelters in Chile ranged from a meager 5% to 70%. Modernization projects were designed to increase recovery up to 95% at some operations. Increased Chilean sulfuric acid was expected to enter the world market; increases at copper ore leaching operations, however, absorbed most of the acid, and future growth could necessitate acid imports (Horseman, 1997).

China.—Sulfuric acid production in China more than doubled in the 10 years prior to 1996 in conjunction with the growth of the country's chemical industry, especially agricultural chemicals. China is the one of the few remaining countries to use pyrites as the dominant raw material for sulfuric acid production. In 1994, China began importing elemental sulfur for producing sulfuric acid. The primary reasons for this change were environmental concerns including the waste disposal problems associated with burning pyrites, poor air quality caused by the pyrites acid plants, and particulate emissions during material handling. Lesser considerations were the inability to obtain consistent high quality pyrites and the lack of capacity to transport large quantities of material long distances.

As the result of a study completed in 1995, the Chinese Government began to import elemental sulfur to meet a portion of the country's demand for sulfuric acid production. Imports in 1996 reached more than 800,000 tons. Imports decreased in 1997 to about 500,000 tons, but further increases were expected to reach 1.5 million tons by 2000. The majority of the imports were from Canada and Japan (Hasegawa, 1997).

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 were surface mines using conventional mining methods. The third and subsequent mines use the Frasch method with modifications to meet the geologic conditions in Poland. At the peak of the Polish sulfur production, more than 5 million tons of sulfur could be produced from three mines. Three of the mines have closed and are being recultivated as lakes and other recreation areas.

Polish sulfur entered the global market in 1961, when the sulfur shipping facilities in Gdansk were completed. In 1980, when production was at its highest, about 3.8 million tons (nearly 75%) of Polish production was exported, mostly to other European countries. Low global prices since the early 1990's 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. By 1997, exports had decreased to about 1 million tons and production was cut as a result. Polish Frasch production was estimated at 1.7 million tons in 1997 and was expected to remain at about that level for the foreseeable future (Karolak, 1997).

Venezuela.—A producer of high-sulfur crude oil, Venezuela became an increasingly important sulfur producer from its petroleum refineries and upgraders and an increasingly important supplier of sulfur to the U.S. market. PCS Phosphates, Inc. completed a long-term contract to purchase molten sulfur from Lagoven, SA, a Venezuelan company. The material will be shipped from Lagoven's Amuay refinery to PCS's Morehead City, NC, phosphoric acid plant. During the first 2 years of the 10-year contract, Lagoven will supply 140,000 tons to 150,000 tons per year to PCS. In subsequent years, shipments will increase to 260,000 tons to replace some of the sulfur PCS currently purchases from Canadian producers. The Venezuelan sulfur will be transported to the United States via a 10,000-ton vessel leased by PCS. Lagoven has recently revamped its desulfurization complex to enable it to meet the contract commitments (Fertilizer Markets, 1997). *(See table 12.)*

Outlook

The longer term outlook for the sulfur industry was unchanged—increased output with slower growth in consumption resulting in variable prices and growing inventories. Specific details are much more difficult to predict. Which producers will suffer most from the oversupply situation is a question that can be answered only over time. It is obvious, however, that discretionary producers are in a more vulnerable position than nondiscretionary producers.

World sulfur demand is forecast to increase at an annual rate of about 2% per year for the next 10 years. Growth of sulfur consumption in the United States is expected to be modest. The phosphate fertilizer industry has not announced expansions; expectations for growth will reflect only slight improvements in efficiency at operating plants and periodic changes in production caused by opening and closing of marginal facilities in response to market conditions. Industrial consumption should remain fairly steady with the only serious possibility of increases in nonferrous ore leaching.

About 65% of sulfur consumption in the United States was for agricultural uses. More than 80% of U.S. agricultural sulfur demand and almost 60% of world agricultural sulfur consumption were for the manufacture of phosphoric acid. World demand for phosphate fertilizers is forecast to increase at a rate of about 2.7% per year for the next 10 years. It is assumed that more than 80% of the growth will be for the production of phosphoric acid to produce high-analysis fertilizers; the increased production will directly affect world sulfur demand. Consumption of sulfur for phosphate fertilizer manufacture in the United States is divided into two components—demand for phosphate fertilizers consumed by domestic farmers and demand for exported phosphate fertilizers. Fertilizer consumption is reasonably stable, and exports are expected to remain strong. Exports, however, are dependent upon the economies of the importing countries. The serious economic problems in much of the world, especially Asia, could have a negative impact on fertilizer trade.

The broad-spectrum industrial or nonagricultural sulfur use category accounted for less than 34% of U.S. sulfur consumption and about 40% of world sulfur demand. Although significant variations in demand for the diverse elements within this broad category are expected in the United States and other geographic areas, world industrial demand is expected to continue to grow very slowly.

The necessity for the removal of sulfur from solid, liquid, and gaseous effluents for environmental protection has caused the production of sulfur and sulfur compounds from these sources to exceed production from primary sources of supply. The long-term prospect is that 85% or more of the world sulfur supply will come

from environmentally regulated sources and that output from these sources will be produced regardless of world sulfur demand. As a result, it is probable that no new operation that produces sulfur as its primary product will be developed and that more voluntary operations will be curtailed. In 1980, voluntary sources of production—Frasch, native sulfur, and pyrites—accounted for 50% of the world output of about 55 million tons. In 1997, these same sources supplied only 24% of the world production of 53.6 million tons.

Voluntary production of sulfur should continue to decline, while recovered sulfur production will continue to expand at a faster pace than demand. As more countries enact and enforce environmental legislation on a par with North American and European laws, tremendous new quantities of sulfur could be recovered. More-stringent regulation and compliance will be long-term developments and cannot be quantified at the current time, but changes are inevitable. In fact, the impact of projects to improve sulfur recovery, especially at copper smelters, is already being felt.

References Cited

Chemical and Engineering News, 1998, Production—Strong growth: Chemical and Engineering News, v. 76, no. 26, June 29, p. 44.

Durgin, Hillary, 1998, Marketing, refining pact signed—Texaco, Aramco, Shell teaming up: Houston Chronicle, May 5, p. B-1.

Fertilizer Markets, 1997, PCS Phosphate awarded sulphur contract in Venezuela: Fertilizer Markets, v. 8, no. 19, December 1, p. 3.

———1998, Husky, Mobil continue to face S duties for Canada-U.S. trade: Fertilizer Markets, v. 7, no. 51, July 21, p. 2-3.

Freeport-McMoRan Sulphur Inc., 1998, Freeport-McMoRan Sulphur Inc. annual report and Form 10-K: Freeport-McMoRan Sulphur Inc., 38 p.

Green Markets, 1997, IMC Global and Freeport-McMoRan Inc. agree to merge: Green Markets, v. 21, no. 30, August 4, p. 1, 12.

Hasegawa, Tamikiyo, 1997, Chinese sulfur supply and demand: Sulphur, no. 250, p. 19-21.

Horseman, Martin, 1997, Copper projects boost sulphuric acid industry in Chile: Sulphur, no. 251, p. 31-36.

Karolak, Jozef, 1997, The Polish sulphur industry: International Fertilizer Industry Association Production and International Trade Committee Meeting, Warsaw, 1997, Proceedings, vol. III, p. 85-92.

Stevens, Jason, 1998, Oil sands projects gather pace: Sulphur, no. 254, p. 27-30.

Vrooman, H.L., 1998, June 1998 import/export data: Fertilizer Record, August 18, p. 1.

SOURCES OF INFORMATION

U.S. Geological Survey Publications

Sulfur. Ch. in Mineral Commodity Summaries, annual.[1]

Sulfur. Ch. in Minerals Yearbook, annual.[1]

Sulfur. Ch. in United States mineral resources, U.S. Geological Survey Professional Paper 820, 1973.

Sulfur. Mineral Industry Surveys, monthly.[1]

Other

Chemical and Engineering News, weekly.

Chemical Engineering, weekly.

Chemical Market Reporter, weekly.

Chemical Week, weekly.

European Chemical News (London), weekly.

Fertilizer Focus (London), monthly.

Fertilizer International (London), monthly.

Fertilizer Markets, weekly.

Green Markets, weekly.

Industrial Minerals (London), monthly.

The Oil & Gas Journal, weekly.

Phosphorus & Potassium (London), bimonthly.

Sulfur. Ch. in Mineral facts and problems, U.S. Bureau of Mines Bulletin 675, 1985.

Sulphur (London), bimonthly.

Sulphur Newsletter—Fertecon North America Sulfur Service, monthly.

[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)

	1993	1994	1995	1996	1997
United States:					
Production:					
Frasch	1,900 2/	2,960 e/	3,150 e/	2,900 e/	2,820 e/
Recovered 3/	7,720 4/	7,160 e/	7,250	7,480 r/	7,650
Other forms	1,430	1,380	1,400	1,430	1,550
Total	11,100	11,500 e/	11,800 e/	11,800 r/ e/	12,000 e/
Shipments:					
Frasch	1,480 2/	W	W	W	W
Recovered 3/	7,580 4/	10,300 5/	10,700 5/	10,400 5/	10,400 5/
Other forms	1,430	1,390	1,400	1,430	1,550
Total	10,500	11,700	12,100	11,800	11,900
Exports:					
Elemental 6/	656	899	906	855	703
Sulfuric acid	46	46	56	38	39
Imports:					
Elemental	2,040	1,650	2,510	1,960 r/	2,060
Sulfuric acid	797	696	628	678	659
Consumption, all forms	12,600	13,100	14,300	13,600 r/	13,900
Stocks, Dec. 31: Producer, Frasch and recovered	1,380	1,160	583	639	761
Value:					
Shipments, f.o.b. mine or plant:					
Frasch	$101,000	W	W	W	W
Recovered 3/	$167,000 r/	$296,000 r/ 5/	$468,000 r/ 5/	$360,000 r/ 5/	$365,000 5/
Other forms	$62,000 r/	$82,800 r/	$86,400 r/	$85,800 r/	$98,100
Total	$330,000 r/	$379,000 r/	$554,000 r/	$446,000 r/	$463,000
Exports, elemental 6/ 7/	$39,700	$48,400	$66,200	$51,700	$36,000
Imports, elemental	$49,800	$62,000	$143,000	$70,200 r/	$64,900
Price, elemental, dollars per metric ton, f.o.b. mine or plant	$31.20 r/	$30.08 r/	$44.46 r/	$34.11 r/	$36.06
World: Production, all forms (including pyrites)	51,600 r/	52,800 r/	53,100 r/	53,400 r/	53,600 e/

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

1/ Data are rounded to three significant digits except prices.

2/ Includes 10 months of Frasch sulfur data. Two remaining months of Frasch data included with "Recovered" to avoid disclosing company proprietary data.

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

4/ Includes corresponding Frasch sulfur data for November and December.

5/ Includes corresponding Frasch sulfur data.

6/ Includes exports from the U.S. Virgin Islands to foreign countries.

7/ 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	1996			1997		
		Shipments			Shipments	
	Production	Quantity	Value	Production	Quantity	Value
Alabama	398	400	14,100	366	363	12,600
California	828	834	6,770 r/	845	839	4,200
Illinois	353	351	8,700	400	400	13,200
Louisiana	877	W	W	853	W	W
Michigan and Minnesota	254	255	749	123	122	684
Mississippi	471	468	10,800	552	538	11,300
New Mexico	44	44	252	51	49	335
North Dakota	50	50	288	42	41	180
Ohio	68	68	1,680	57	57	1,590
Texas	2,230	3,180 2/	122,000 2/	2,510	3,410 2/	130,000 2/
Washington	112	113	899	109	109	331
Wyoming	1,080	1,060	23,900 r/	1,060	1,040	19,700
Other 3/	706	3,590	170,000	684	3,420	171,000
Total	7,480 r/	10,400	360,000 r/	7,650	10,400	365,000

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

1/ Data are rounded to 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 (shipments and 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	1996		1997	
	Production	Shipments	Production	Shipments
PAD 1:				
Petroleum and coke	217	225	224	223
Natural gas	51	51	50	50
Total	267	276	274	273
PAD 2:				
Petroleum and coke	927	925	826	826
Natural gas	50	49	42	41
Total	977	975	868	867
PAD 3: 2/				
Petroleum and coke	3,140	W	3,120	W
Natural gas	988 r/	W	1,280	W
Total	4,120	7,070 3/	4,410	7,180 3/
PAD 4 and 5:				
Petroleum and coke	1,090	1,100	1,060	1,050
Natural gas	1,010	992	1,040	1,030
Total	2,100	2,090	2,100	2,080
Total petroleum	5,370	W	5,230	W
Total natural gas	2,100 r/	W	2,420	W
Grand total	7,480 r/	10,400 3/	7,650	10,400 3/

r/ Revised. W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to 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	1996	1997
Copper 3/	1,240	1,370
Zinc 4/	118	120
Lead and molybdenum 4/	68	66
Total	1,430	1,550
Value	85,900	105,000

1/ Includes acid from foreign materials.
2/ Data are rounded to 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)

	1996	1997
Total elemental:		
Shipments 3/	10,400	10,400
Exports	855	703
Imports	1,960 r/	2,060
Total	11,500 r/	11,700
Byproduct sulfuric acid:		
Shipments 3/	1,430	1,550
Exports 4/	38	39
Imports 4/	678	668
Total, all forms	13,600 r/	13,900

r/ Revised.
1/ Crude sulfur or sulfur content.
2/ Data are rounded to 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)

SIC 3/	End use	Elemental sulfur 2/		Sulfuric acid (sulfur equivalent)		Total	
		1996	1997	1996	1997	1996	1997
102	Copper ores	--	--	798	763	798	763
1094	Uranium and vanadium ores	--	--	2	5	2	5
10	Other ores	--	--	57	109	57	109
26, 261	Pulpmills and paper products	W	84	343	334	343	418
28, 285, 286, 2816	Inorganic pigments, paints and allied products, industrial organic chemicals, other chemical products 4/	67	94	152	234	219	328
281	Other inorganic chemicals	128	30	154	270	282	300
282, 2822	Synthetic rubber and other plastic materials and synthetics	W	W	270	87	270	87
2823	Cellulosic fibers, including rayon	--	--	47	32	47	32
283	Drugs	--	--	4	3	4	3
284	Soaps and detergents	9	W	19	17	28	17
286	Industrial organic chemicals	--	--	48	107	48	107
2873	Nitrogenous fertilizers	--	--	142	161	142	161
2874	Phosphatic fertilizers	--	--	7,380	7,000	7,380	7,000
2879	Pesticides	--	--	10	16	10	16
287	Other agricultural chemicals	809 r/	998	-- r/	--	809 r/	998
2892	Explosives	--	--	5	4	5	5
2899	Water-treating compounds	--	--	91	65	91	65
28	Other chemical products	--	--	41	107	41	107
29, 291	Petroleum refining and other petroleum and coal products	739	1,270	525	616	1,260	1,880
30	Rubber and miscellaneous plastic products	W	W	--	--	W	W
331	Steel pickling	--	--	8	12	8	12
333	Nonferrous metals	--	--	7	78	7	78
33	Other primary metals	--	--	1	12	1	12
3691	Storage batteries (acid)	--	--	33	32	33	32
	Exported sulfuric acid	--	--	6	52	6	52
	Total identified	1,750 r/	2,470	10,100 r/	10,100	11,900 r/	12,600
	Unidentified	807	997	780	559	1,590	1,560
	Grand total	2,560 r/	3,470	10,900 r/	10,700	13,500 r/	14,100

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

1/ Data are rounded to 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	1996	1997
102	Copper ores	2,360	2,250
10	Other ores	W	W
26, 261	Pulp mills and other paper products	47	W
28, 281, 282, 283, 286, 2816	Miscellaneous chemicals	103 r/	392
2873	Nitrogenous fertilizers	58	97
2874	Phosphatic fertilizers	417	625
287, 2879	Pesticides and other agricultural chemicals	86	98
2899	Water-treating compounds	80	117
291	Petroleum refining	W	W
3691	Storage batteries (acid)	W	W
33, 331, 333, 1094	Miscellaneous metal usage	25	196
	Unidentified 3/	1,230 r/	1,110
	Total	4,400 r/	4,880

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Unidentified."
1/ Data are rounded to 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)

	1996		1997	
Country	Quantity	Value	Quantity	Value
Argentina	4	537	20	684
Australia	29	3,450	32	1,130
Brazil	50	2,260	148	4,830
Canada	65	6,010	40	3,790
Colombia	9	668	7	443
India	(3/)	4	79	2,720
Indonesia	(3/)	11	24	986
Korea, Republic of	4	5,690	2	3,380
Mexico	139	7,370	80	4,590
Morocco	--	--	34	1,140
Senegal	194	7,300	145	4,840
South Africa	1	302	1	267
Tunisia	97	3,280	35	1,180
Other	263	14,900	56	6,090
Total	855	51,700	703	36,000

1/ Includes exports from the U.S. Virgin Islands.
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ Less than 1/2 unit.

Source: Bureau of the Census.

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

Country	1996 Quantity (metric tons)	1996 Value (thousands)	1997 Quantity (metric tons)	1997 Value (thousands)
Argentina	28	$3	--	--
Canada	70,200	5,280	85,200	$5,600
China	2,160	464	957	369
Costa Rica	361	18	207	7
Dominican Republic	2,550	178	1,510	118
Israel	1,460	433	2,250	502
Japan	462	144	333	158
Korea, Republic of	204	36	10	12
Mexico	6,550	930	7,160	849
Netherlands	4,580	245	--	--
Netherlands Antilles	12	4	2,910	212
Panama	1,180	57	176	20
Saudi Arabia	143	18	1,140	684
Singapore	734	437	697	591
Taiwan	497	293	2,000	635
Trinidad and Tobago	7,270	430	2,620	181
United Kingdom	237	39	296	34
Venezuela	1,520	173	1,060	126
Other	17,300	3,170	9,280	2,560
Total	117,000	12,400	118,000	12,700

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

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

(Thousand metric tons and thousand dollars)

Country	1996 Quantity	1996 Value 2/	1997 Quantity	1997 Value 2/
Canada	1,400 r/	40,000 r/	1,470	31,000
Mexico	448	21,200	480	24,400
Other	112	8,970	110	9,460
Total	1,960 r/	70,200 r/	2,060	64,900

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Declared customs valuation.

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

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

Country	1996 Quantity (metric tons)	1996 Value 2/ (thousands)	1997 Quantity (metric tons)	1997 Value 2/ (thousands)
Argentina	2,840	$373	--	--
Canada	1,600,000	59,600	1,600,000	$60,500
Germany	167,000	5,630	32,900	872
Japan	127,000	5,220	80,600	5,760
Mexico	138,000	5,760	215,000	6,420
Netherlands	16,800	400	--	--
Spain	25,800	889	7,330	186
United Kingdom	78	23	--	--
Other	673	123	79,200	10,300
Total	2,070,000	78,000	2,010,000	84,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Declared c.i.f. (cost, insurance, and freight paid by shipper) valuation.

Source: Bureau of the Census.

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

(Thousand metric tons)

Country and source 3/	1993	1994	1995	1996	1997 e/
Canada: Byproduct:					
Metallurgy	900	870	860	789 r/	801
Natural gas	6,600	7,000	7,100	8,327 r/	8,280
Petroleum	340	350	380	400 r/	410
Tar sands	590	630	670	670 r/ e/	680
Total	8,430	8,850	9,010	10,186 r/	10,200
China: e/					
Native	330	330	160	170	170
Pyrites	5,330	5,870	5,930 r/	5,990 r/	5,880
Byproduct, all sources	700	700	700	700	700
Total	6,360	6,900	6,790 r/	6,860 r/	6,750
France: Byproduct:					
Natural gas	829	865	825	755 r/ e/	797
Petroleum	278	219	240	235 r/ e/	210
Unspecified e/	150	100	100	99 r/	100
Total e/	1,260	1,180	1,170	1,090 r/	1,110
Germany: Byproduct:					
Metallurgy	33	35 e/	20	20 e/	25
Natural gas and petroleum	1,137	880	1,000	1,000 e/	1,000
Unspecified e/	90 4/	90	90	90	100
Total e/	1,260	1,005 4/	1,110	1,110	1,130
Iran: Byproduct: e/					
Metallurgy	50	50	50	50	50
Natural gas and petroleum	750	830	840	840	850
Total	800	880 4/	890	890	900
Iraq: e/					
Frasch	250	250	250	250	250
Byproduct, natural gas and petroleum	200	225	225	225	200
Total	450	475	475	475	450
Japan:					
Pyrites	29	4	2 e/	2 e/	2
Byproduct:					
Metallurgy	1,383	1,269	1,312 r/	1,285 r/	1,300
Petroleum e/	1,510 4/	1,550	1,500	1,500	1,500
Total e/	2,922 4/	2,820	2,810 r/	2,790 r/	2,800
Kazakstan: e/					
Native	--	--	--	--	--
Pyrites	219	200	71	71	--
Byproduct:					
Metallurgy	276	261	131	139	139
Natural gas and petroleum	182	219	255	515	806
Total	677	680	457	725	945
Mexico:					
Frasch	102	--	--	--	--
Byproduct:					
Metallurgy e/	(5/) r/	(5/) r/	(5/) r/	(5/) r/	(5/)
Natural gas and petroleum	804	877	882	921 r/	923 4/
Total e/	906 r/	877 r/	883 r/	922 r/	924
Poland: 6/					
Frasch	1,861	2,163	2,425	1,530 e/	1,710
Byproduct: e/					
Metallurgy	220 4/	200	200	200	100
Petroleum	29 4/	25	25	25	10
Gypsum e/	10	10	10	10	4
Total	2,120	2,398	2,660 e/	1,769	1,820
Russia: e/ 7/					
Native	100	80	80	70	50
Pyrites	640	700	450	400	400
Byproduct, natural gas	2,680	2,550	2,970	3,000	2,950
Other	300 r/	320 r/	335 r/	325 r/	350
Total	3,720 r/	3,650 r/	3,840 r/	3,800 r/	3,750

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/	1993	1994	1995	1996	1997 e/
Saudi Arabia: Byproduct, all sources	2,400	2,300	2,400 r/	2,300 r/	2,000
South Africa:					
Pyrites	323	252	159	184 r/	167
Byproduct:					
Metallurgy	81 e/	118	67	91 r/	110
Petroleum 8/	171	209	233	200 r/	293
Total	575	579	459	475 r/	570
Spain:					
Pyrites	408	436	404	479 r/	425
Byproduct: e/					
Coal (lignite) gasification	2	2	2	2	2
Metallurgy	258	250	250	250	225
Petroleum	100	100	100	100	109
Total e/	768	788	756	831 r/	761
United States:					
Frasch e/	1,900 4/ 9/	2,930	3,150	2,900	2,820
Pyrites	W	(10/)	(10/)	(10/)	(10/)
Byproduct:					
Metallurgy	1,430	1,380	1,400	1,430	1,550
Natural gas	2,910 11/	2,240	2,210	2,100	2,420
Petroleum	4,820	4,920	5,040	5,370	5,230
Unspecified	3	(10/)	(10/)	(10/)	(10/)
Total e/	11,100 4/	11,500	11,800	11,800 r/	12,000
Other countries:	7,870 r/	7,943 r/	7,624 r/	7,407 r/	7,510
Of which:					
Frasch	22	21	22	25 r/	25
Native	649 r/	528 r/	413 r/	248 r/	167
Pyrites	1,298 r/	1,256 r/	1,173 r/	1,100 r/	1,100
Byproduct:					
Metallurgy	2,296 r/	2,194 r/	2,144 r/	2,079 r/	2,210
Natural gas	402 r/	349 r/	386 r/	383 r/	332
Natural gas and petroleum, undifferentiated	855 r/	1,214 r/	1,208 r/	1,223 r/	1,410
Petroleum	1,530 r/	1,543 r/	1,406 r/	1,437 r/	1,390
Unspecified sources	819 r/	839 r/	872 r/	911 r/	881
Grand total	51,600 r/	52,800 r/	53,100 r/	53,400 r/	53,600
Of which:					
Frasch	4,140	5,360	5,850	4,710	4,810
Native	1,080 r/	938 r/	653 r/	488 r/	387
Pyrites	8,250 r/	8,720 r/	8,190 r/	8,230 r/	7,970
Byproduct:					
Coal (lignite) gasification e/	2	2	2	2	2
Metallurgy	6,930 r/	6,630 r/	6,430 r/	6,330 r/	6,510
Natural gas	13,400 r/	13,000 r/	13,500 r/	14,600 r/	14,800
Natural gas and petroleum, undifferentiated	3,930 r/	4,250 r/	4,410 r/	4,720 r/	5,190
Petroleum	8,780 r/	8,920 r/	8,920 r/	9,270 r/	9,150
Tar sands	590	630	670	670 r/	680
Unspecified sources	4,460 r/	4,350 r/	4,500 r/	4,420 r/	4,130
Gysum e/	10	10	10	10	4

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Byproduct: Unspecified sources."

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through August 7, 1998.

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.

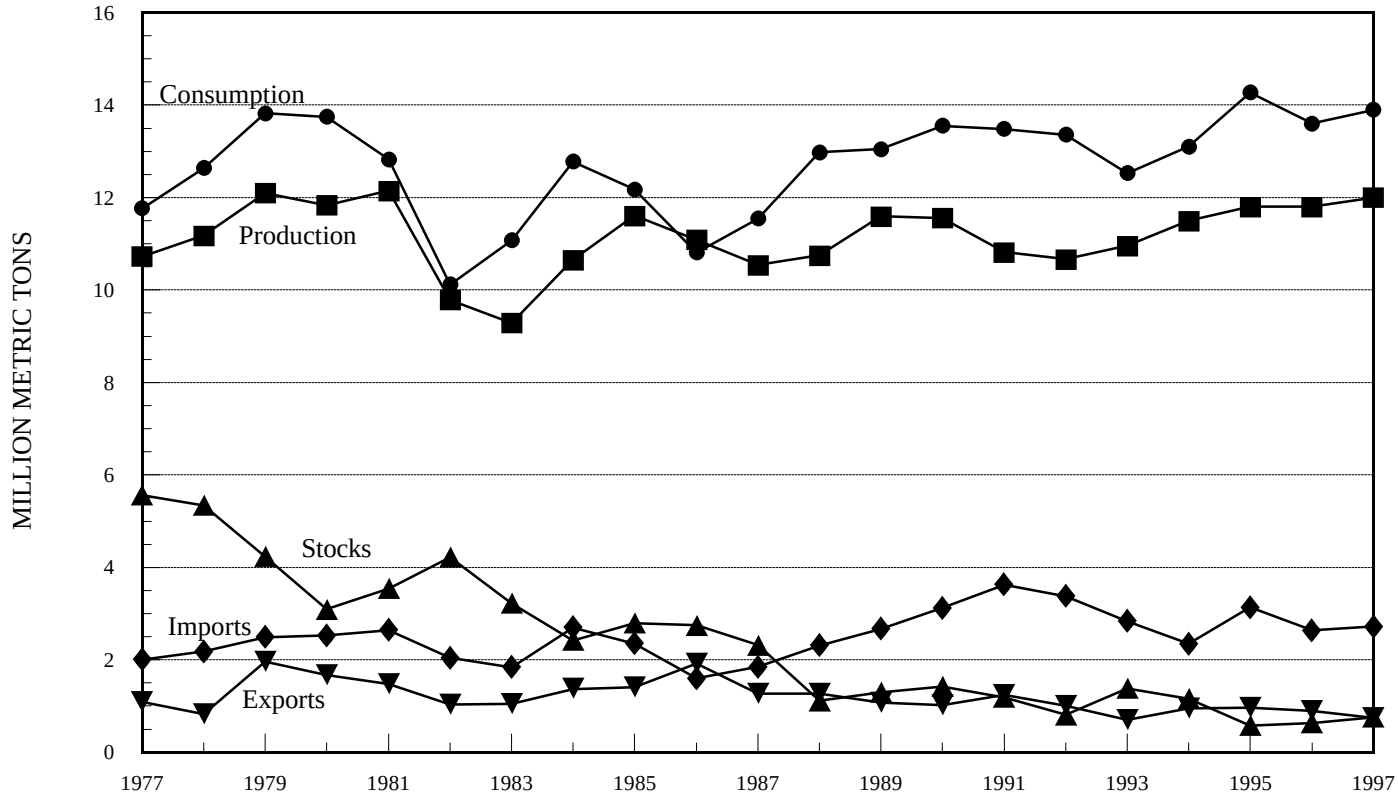
5/ Less than 1/2 unit.

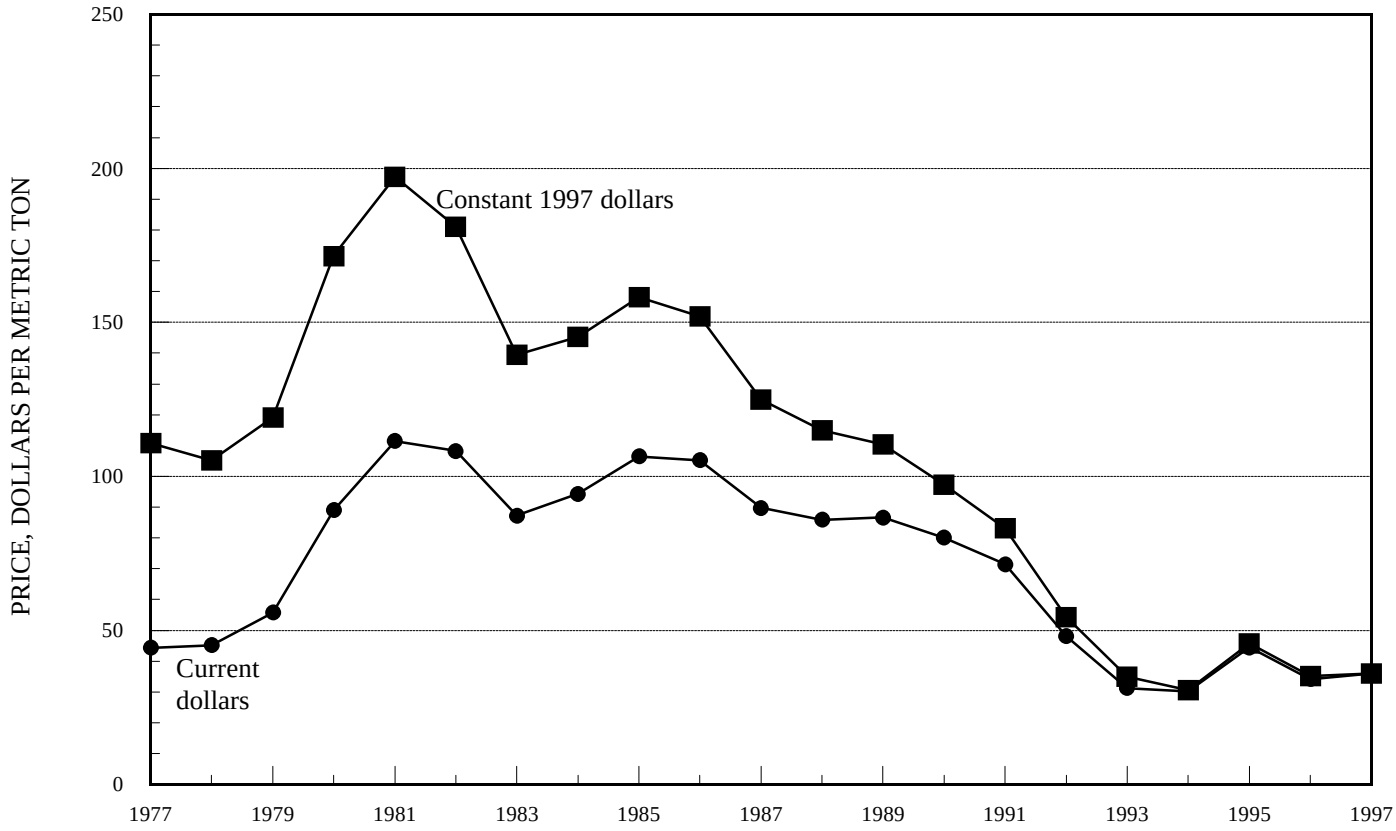
TABLE 12--Continued
SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE 1/ 2/

6/ 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.
7/ Sulfur is believed to be produced from Frasch and pyrite and as a petroleum byproduct; however, information is inadequate to formulate estimates.
8/ Includes byproduct production from synthetic fuels.
9/ Includes 10 months of Frasch sulfur production data. Two remaining months of Frasch data included with byproduct natural gas data to conform with proprietary data requirements.
10/ Survey discontinued in 1994; data not available.
11/ Includes Frasch sulfur production data for November and December.

FIGURE 1

TRENDS IN THE SULFUR INDUSTRY IN THE UNITED STATES

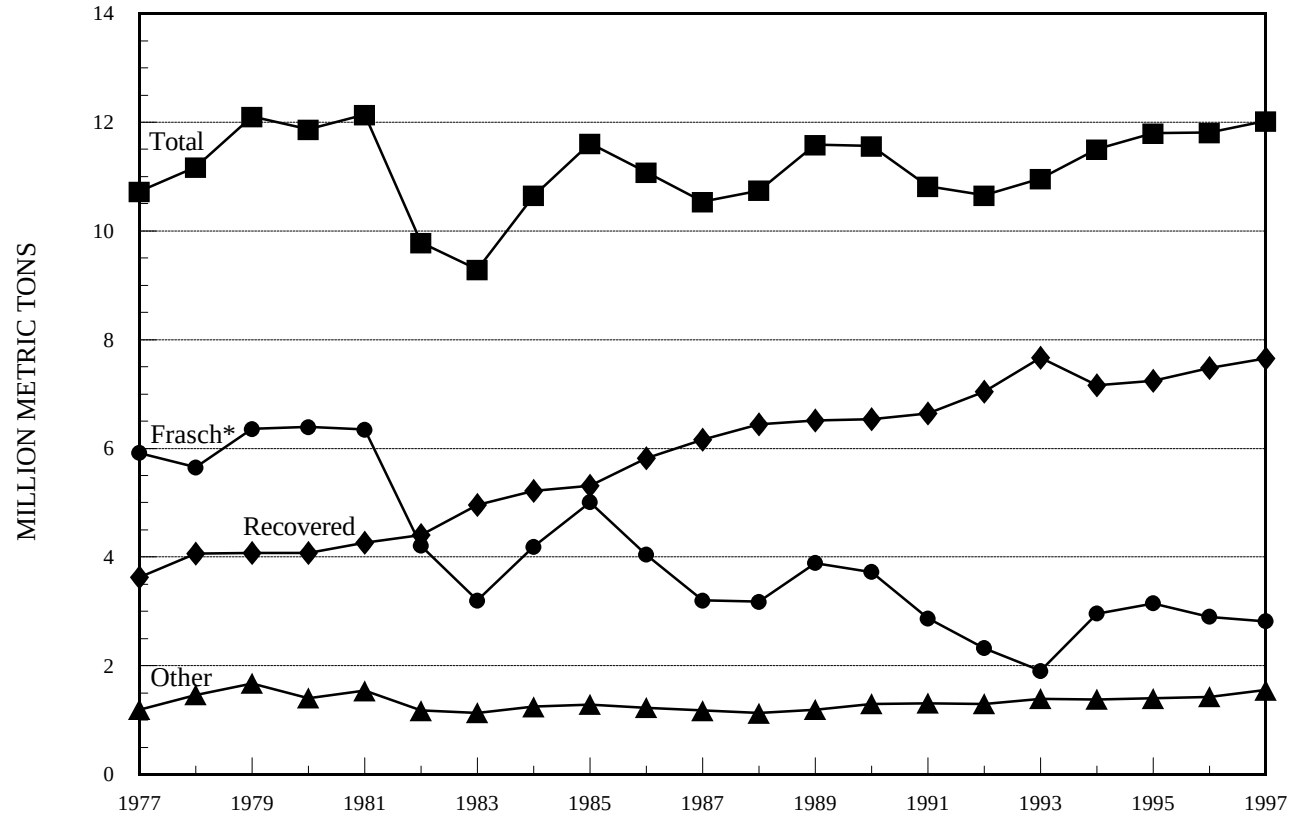


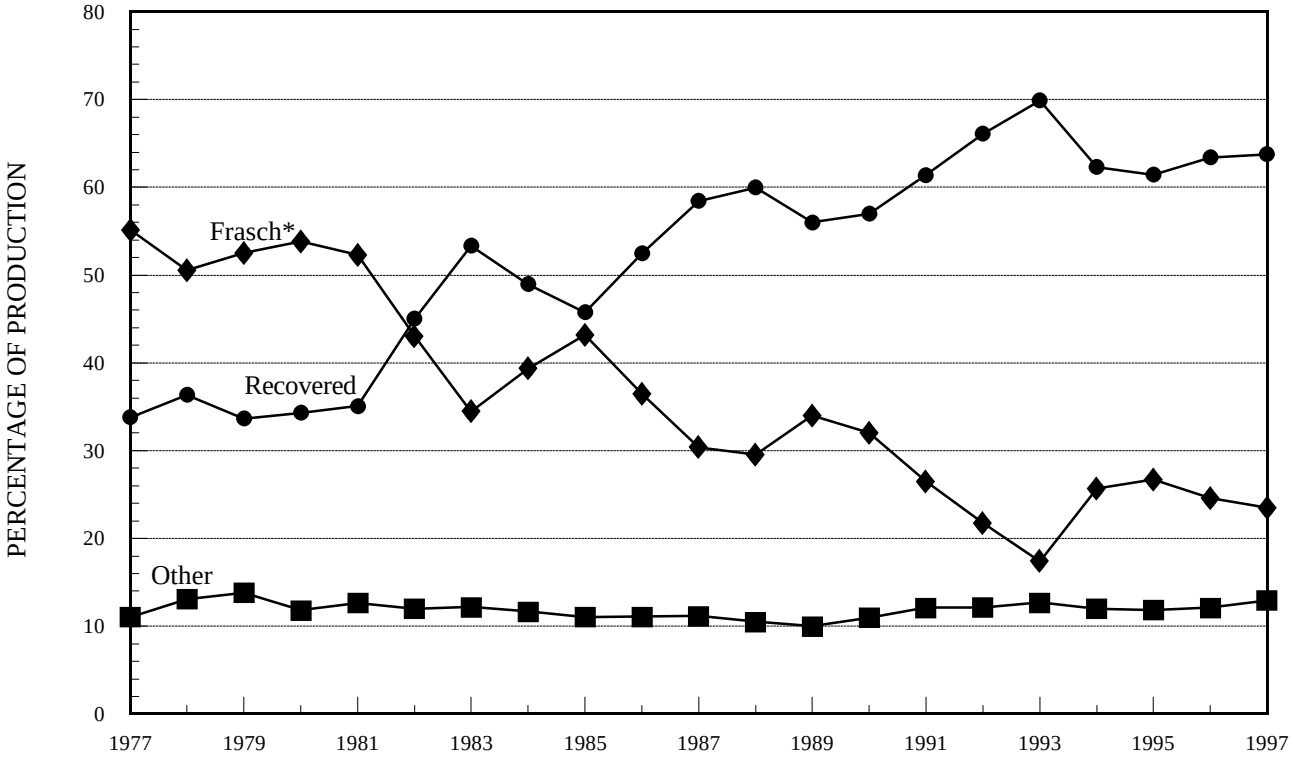


Based on the average reported values for elemental sulfur (Frasch and recovered), f.o.b. mine and/or plant, these prices reflect about 90% of the shipments of sulfur in all forms from 1977 through 1997.

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 recovered sulfur data to conform with proprietary data requirements. Data for 1994-96 are estimates.