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2017 Minerals Yearbook

SULFUR [ADVANCE RELEASE]

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Sulfur

By Lori E. Apodaca

Domestic survey data and tables were prepared by Sheema Merchant, statistical assistant.

The United States was the world's second-ranked producer of sulfur behind China in 2017 (table 11). Elemental sulfur and byproduct sulfuric acid, produced as a result of efforts to meet environmental requirements that limit atmospheric emissions of sulfur dioxide, were the dominant sources of sulfur around the world.

In 2017, domestic production and shipments of sulfur in all forms were slightly lower than those of 2016 (table 1). Elemental sulfur recovered at petroleum refineries was slightly higher and from natural gas operations was 15% lower than that of 2016 (table 3). Producers' stocks, equivalent to 1% of the shipments, decreased by 14%. Byproduct sulfuric acid production and shipments decreased by 15%. Apparent consumption of sulfur in all forms decreased by 4%. Imports of elemental sulfur and sulfuric acid combined decreased slightly, and exports increased by 15%. The average unit value of recovered sulfur in 2017 was 22% higher than that of 2016, resulting in the value of total elemental sulfur shipments increasing by 23% compared with the value of shipments in 2016. The total value of byproduct sulfuric acid shipments decreased by about 3% (table 1).

Through its major derivative, sulfuric acid, sulfur ranks as one of the most important elements used as an industrial raw material and is of prime importance to every sector of the world's fertilizer and manufacturing industries. 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 inorganic chemical; 32.2 million metric tons (Mt), which is equivalent to about 10.6 Mt of elemental sulfur, was produced in 2017 (Integer Research Ltd., written commun., December 6, 2018).

Worldwide, compliance with environmental regulations has contributed to increased sulfur recovery; for 2017, global sulfur production, in all forms, was slightly higher than that of 2016 (table 11). Recovered elemental sulfur is produced primarily during the processing of natural gas and crude petroleum. Estimated worldwide production of native (naturally occurring elemental) sulfur increased by 5% from that of 2016. In the few countries where pyrites remains an important raw material for sulfuric acid production, sulfur production from pyrites was estimated to have increased slightly from that of 2016.

Since 2005, more than 75% of the world's sulfur production has been byproduct from natural gas and petroleum processing and contained in byproduct sulfuric acid from nonferrous metal smelting. Some sources of sulfur were unspecified, which means that the material could have been, and likely was, recovered elemental sulfur or byproduct sulfuric acid, increasing the percentage of byproduct sulfur production to about 90% annually. The quantity of sulfur produced from recovered sources was dependent on the world demand for fuels, nonferrous metals, and petroleum products rather than for sulfur.

In 2017, global consumption of sulfur was estimated to have increased by 3% compared with that in 2016. Typically, about 50% is used in fertilizer production and the remainder is used in myriad other industrial uses. Increased consumption was a result of sustained demand in sulfur-based fertilizer production and industrial uses (Prud'homme, 2017, p. 38).

Legislation and Government Programs

On January 24, 2017, the President of the United States signed an executive order to move forward with the construction of the Keystone XL and Dakota Access oil pipelines. The Keystone XL pipeline is a proposed 1,900-kilometer (km), 91-centimeter (cm)-diameter crude oil pipeline, beginning in Hardisty, Alberta, Canada, and ending in Steele City, NE. The Dakota Access pipeline is a 1,890-km, 76-cm diameter underground oil pipeline extending from the oil shale fields of the Bakken Formation in northwestern North Dakota to Patoka, IL. Both pipelines would move the crude oil to gulf coast refineries for processing (North America Sulphur Review, 2017).

Production

Recovered Elemental Sulfur.—U.S. production statistics were collected on a monthly basis and published in the U.S. Geological Survey (USGS) monthly sulfur Mineral Industry Surveys. Of the 96 operations to which survey requests were sent, 96 responded, representing 100% of the total production listed in table 1. In 2017, production and shipments were slightly lower than those of 2016. Higher sulfur prices resulted in the value of shipments of recovered material being 23% higher than that of 2016. For 2017, on average, U.S. petroleum refineries operated at 91% of capacity, a slight increase from that of 2016 (U.S. Energy Information Administration, 2018c).

During the 2017 hurricane season, Hurricane Harvey and Hurricane Nate had significant negative impacts on oil, natural gas, and sulfur production in the Gulf of Mexico region. Hurricane Harvey, a Category 4 storm, made landfall on August 28, 2017, causing reduced production by an estimated 3.0 million barrels (Mbbl) of crude oil and 187 million cubic meters of natural gas. This was 6% and 7% of the expected August crude oil and natural gas production, respectively, in the Gulf of Mexico region. Hurricane Nate, a Category 1 storm, made landfall on October 7, 2017, reduced production by an estimated 8.4 Mbbl of crude oil and 334 million cubic meters of natural gas. This was 18% and 15% of the expected October crude oil and natural gas production, respectively, in the Gulf of Mexico region. Although Hurricane Nate was weaker than Hurricane Harvey, the direction and location of Nate's track was more disruptive to the offshore production in the Gulf of Mexico (U.S. Energy Information Administration, 2018b).

Recovered elemental sulfur, which is 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 of sulfur dioxide 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 39 companies at 96 plants in 27 States. The size of the sulfur recovery operations varied greatly from plants producing more than 500,000 metric tons per year (t/yr) to others producing less than 500 t/yr. Of all the sulfur operations that responded to the canvass, 36 plants produced more than 100,000 metric tons (t) of elemental sulfur in 2017; 19 produced between 50,000 and 100,000 t; 26 produced between 10,000 and 50,000 t; and 15 produced less than 10,000 t. By source, 93% of recovered elemental sulfur production came from petroleum refineries or satellite plants that treated refinery gases and coking plants; the remainder was produced at natural-gas-treatment plants (table 3).

The leading producers of recovered sulfur, all with more than 500,000 t of sulfur production, were, in descending order of production, Exxon Mobil Corp., Valero Energy Corp., Marathon Petroleum Corp., ConocoPhillips Co. (including its joint venture with Encana Corp.), Motiva Enterprises LLC, BP p.l.c., CITGO Petroleum Corp., and Chevron Corp. The 50 plants owned by these companies accounted for 79% of recovered sulfur output during the year. Texas, Louisiana, and California, in descending order of production, were the leading States accounting for 66% of recovered sulfur output. Recovered sulfur production by State and district is listed in tables 2 and 3.

In 2017, 5 of the 20 largest oil refineries in the world, in terms of crude-petroleum-processing capacity, were in the United States. In descending order of capacity, they were Motiva's Port Arthur, TX, refinery; Marathon's Galveston Bay, TX, refinery; Marathon's Garyville, LA, refinery; ExxonMobil's Baytown, TX, refinery; and ExxonMobil's Baton Rouge, LA, refinery (Oil & Gas Journal, 2017a). The capacity to process large quantities of crude petroleum does not necessarily mean that refineries recover large quantities of sulfur, but all these refineries were major producers of recovered sulfur. Sulfur production depends on installed sulfur recovery capacity as well as the types of crude petroleum that were refined at the specific refineries. Major refineries that process low-sulfur crude petroleum may have relatively low sulfur production. The United States operated 20% of world refining capacity but had almost 33% of world sulfur recovery capacity at these refineries (Oil & Gas Journal, 2017b).

U.S. refining capacity rose by 4% from 2013 through 2017 and by about 13% from 2000 through 2017, mostly from upgrades at existing refineries. In 2017, U.S. refinery capacity was 18.6 million barrels per day, slightly higher than that of 2016. Overall U.S. refinery capacity increased by about 163,000 barrels per day (bbl/d) in 2017 (U.S. Energy Information Administration, 2018c). Although sulfur capacity expansion was not specifically mentioned, any such expansions would likely include increased sulfur recovery facilities, probably proportionally higher than the increases in throughput capacity.

Byproduct Sulfuric Acid.—Sulfuric acid production at copper, lead, molybdenum, and zinc roasters and smelters accounted for about 6% of total domestic production of sulfur in all forms and totaled the equivalent of 575,000 t of elemental sulfur. Byproduct sulfuric acid production decreased by 15% compared with that of 2016 (tables 1, 4). Three sulfuric acid plants operated in conjunction with copper smelters, and two were byproduct operations of lead, molybdenum, and zinc smelting and roasting operations. The three largest byproduct sulfuric acid plants, in terms of size and capacity, were associated with copper smelters and accounted for 85% of byproduct sulfuric acid output. The copper producers—ASARCO LLC, Rio Tinto Kennecott Corp., and Freeport-McMoRan Copper & Gold Inc.—each operated a sulfuric acid plant at its primary copper smelter.

Consumption

Apparent domestic consumption of sulfur in all forms was 4% less than that of 2016 (table 5). Of the sulfur consumed, 72% was obtained from domestic sources as elemental sulfur (67%) and byproduct acid (5%) compared with 73% in 2016, 69% in 2015, 69% in 2014, an 65% in 2013. The remaining 28% was supplied by imports of recovered elemental sulfur (18%) and sulfuric acid (10%). The USGS collected end-use data on sulfur and sulfuric acid according to the Standard Industrial Classification of industrial activities (table 6).

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 leading sulfur end use, sulfuric acid, represented 68% of reported consumption with an identified end use. Although reported as elemental sulfur consumption in table 6, it is reasonable to assume that nearly all the sulfur consumption reportedly used in petroleum refining was first converted to sulfuric acid, bringing sulfur used to produce sulfuric acid to 91% of the total sulfur consumption. Some identified sulfur end uses were included in the "Unidentified" category (table 6) because these data were proprietary. 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 assumptions 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. Data based on USGS surveys of sulfur and sulfuric acid producers showed that reported U.S. consumption of sulfur in sulfuric acid (100% basis) decreased by 12%, and total reported sulfur consumption decreased by 11%. The reported decrease in sulfuric acid consumption can primarily be attributed to a 14% decrease in sulfuric acid use in the production of phosphatic fertilizers. Reported consumption figures do not correlate with calculated apparent consumption owing to reporting errors and possible double counting in some data categories. These data are considered independently from apparent consumption as an indication of market shares rather than actual consumption totals (table 6).

Agriculture was the leading sulfur-consuming industry; 2017 consumption in this end use was about 6.2 Mt, which was about 14% less than that of 2016. On the basis of export data reported by the U.S. Census Bureau, the estimated quantity of sulfur needed to manufacture exported phosphatic fertilizers decreased by 11% to 2.9 Mt. In 2017, approximately 50% of the wet-process phosphoric acid produced was exported in the form of upgraded granular diammonium and monoammonium phosphate fertilizer and merchant-grade phosphoric acid.

The second-ranked end use for sulfur was in petroleum refining and other petroleum and coal products. Producers of sulfur and sulfuric acid reported that the consumption of sulfur in that end use decreased by 3% from that of 2016. Consumption of sulfuric acid in copper ore leaching, which was the third-ranked end use, decreased by 21%.

Two types of companies recycle spent and contaminated acid from petroleum alkylation—companies that produce acid for consumption in their own operations and also recycle their own spent acid, and companies that provide acid regeneration services to sulfuric acid users. The petroleum-refining industry was thought to be the leading source and consumer of recycled acid for use in its alkylation process, but insufficient data were available to make reasonable estimates.

In October 2017, The Mosaic Company announced that it would idle its Plant City, FL, plant which produced phosphoric acid and phosphate fertilizers. When operating at capacity, the plant was estimated to consume 800,000 t/yr of sulfur (Acuity Commodities, 2017).

Stocks

Yearend inventories held by domestic producers of recovered elemental sulfur decreased to 124,000 t, 14% lower than those of 2016 (table 1). On the basis of apparent consumption of all forms of sulfur, combined yearend stocks amounted to about a 4-day supply, which was slightly less than that in 2016. Final stocks in 2017 represented about 2% 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, 1980, p. 877). When the United States mined large quantities of sulfur, as in 1976, mining companies had the capacity to store large quantities. When mining ceased in 2000, storage capacity declined significantly. Since that time, stocks have been relatively low because recovered sulfur producers have minimal storage capacity.

Prices

The unit value of sulfur produced in the United States was higher in 2017 than in 2016, as a result of increased international sulfur prices from September through the end of November. International sulfur prices increased owing to a tight sulfur supply in the Middle East and China's sulfur inventory stocks declining to 1 Mt in August, after which China increased imports from September through November (Sulphur, 2018b). On the basis of value data reported to the USGS, the average unit value of shipments for all elemental sulfur was estimated to be $46.40 per metric ton, which was 22% more than that of 2016 (table 1). The increased unit value reported by producers was higher than the trends in prices recorded in trade publications, which indicated a 3% increase in prices.

Contract prices for elemental sulfur at terminals in Tampa, FL, which were reported weekly in Green Markets, began the year at $70 per long ton. By early November, prices increased to $110 per ton and remained at this price through yearend.

Prices vary greatly on a regional basis. Tampa, FL, prices usually were the highest reported in the United States because of the large demand for sulfur in the central Florida area; however, U.S. west coast average prices were higher in 2017. At yearend, U.S. west coast prices ranged from $140 per long ton to $145 per ton. Nearly all the sulfur produced in some regions, such as the west coast, was processed at forming plants, incurring substantial costs to make solid sulfur in acceptable forms to be shipped overseas. The majority of west coast sulfur was shipped overseas. World sulfur prices generally were higher than domestic prices in 2017.

Although prices vary by location, provider, and type, the Abu Dhabi National Oil Co.'s (ADNOC's) price is recognized as an indicator of world sulfur price trends. In 2017, the ADNOC contract price averaged about $111 per metric ton, with the lowest price of $82 per ton in May and the highest price of $195 per ton in December (Fertilizer Week, 2017). Price increases in November and December 2017 were influenced mainly by the increased imports into China to rebuild its sulfur stocks, which decreased from 1.8 Mt in August 2016 to just over 1.0 Mt in August 2017, and the tight supply of sulfur from the Middle East, owing to delayed refining operations as well as startup of a phosphate fertilizer project (Sulphur, 2018a).

Foreign Trade

Elemental sulfur exports from the United States were 2.3 Mt. The average unit value of exported elemental sulfur was $107 per ton, a 3% increase from $104 per ton in 2016 (tables 1, 7). The leading destination for this material was Brazil followed by, in descending order of quantity, Mexico, Morocco, China, Canada, and New Caledonia. Export facilities on the gulf coast that began shipping in 2006 have become significant outlets for exported sulfur. Exports from the gulf coast were 1.22 Mt, or 52% of the U.S. total. Exports from the west coast were 884,000 t, or 38% of total U.S. exports.

In 2017, the United States imported 1.9 Mt of sulfur. Recovered elemental sulfur from Canada delivered to United States terminals and consumers in the liquid phase furnished 74% of United States sulfur import requirements. Total elemental sulfur imports in 2017 were slightly more than those of 2016, and higher prices for imported material resulted in the value increasing by 34% compared with that of 2016. Imports from Canada, mostly by rail, were estimated to be 7% lower than those of 2016 (table 9).

In addition to elemental sulfur, the United States trades in sulfuric acid. Sulfuric acid exports of 254,000 t were 41% higher than those of 2016 (table 8). Acid imports were about 11.5 times greater than exports at about 2.9 Mt (tables 1, 10). Canada and Mexico were the leading sources of

83% of sulfuric acid imported into the United States, most of which was thought to be byproduct acid from nonferrous metal smelters. Shipments from Canada and some from Mexico came by rail, and the remainder of imports came by ship, primarily from Asia and Europe. The tonnage of sulfuric acid imports was about 9% less than that of 2016, and the value of imported sulfuric acid decreased by about 60%.

World Review

The world 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 either sulfur or pyrites (mostly naturally occurring iron sulfide) 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 is subject to demand for the primary product and environmental regulations that limit atmospheric emissions of sulfur compounds irrespective of sulfur demand. Discretionary sources, once the primary sources of sulfur in all forms, represented only 8% of the sulfur in all forms produced worldwide in 2017 (table 11).

Poland, with 663,000 t, was the only country that produced more than 300,000 t of native sulfur by using either the Frasch process or conventional mining methods (table 11). The Frasch process is the term for hot-water mining of native sulfur associated with the caprock of salt domes and in sedimentary deposits; in this mining method, the native sulfur is melted underground with superheated water and brought to the surface by compressed air. The United States, where the Frasch process was developed early in the 20th century, was the leading producer of Frasch sulfur until 2000. 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 and Finland were the top producers of sulfur from pyrites with China accounting for 86% of the world pyrite production.

Of the 14 countries listed in table 11 that produced more than 1 Mt of sulfur, 12 obtained the majority of their production as recovered elemental sulfur. These 14 countries produced 87% of the total sulfur produced worldwide.

In 2017, sulfur consumption was estimated to have increased globally by 3%, and exceeded global production. Prices were lowest at the beginning of 2017 and increased through November. International prices for 2017 averaged about 41% higher than those in the United States. Higher prices in the fourth quarter of 2017 were a result of China's increased sulfur imports and increased sulfur consumption supported by higher phosphate and copper prices (Prud'homme, 2018, p. 39).

Native sulfur production, including production of Frasch sulfur at Poland's last operating mine, was estimated to be 5% higher than that of 2016. Recovered elemental sulfur production and byproduct from metallurgy was about the same or slightly less than that in 2016. Globally, production of sulfur from pyrites was estimated to have increased slightly from that of 2016. Pyrites is a less attractive alternative to elemental sulfur for sulfuric acid production. The environmental remediation costs of mining pyrites are onerous, and additional costs are incurred when using this less environmentally friendly raw material to produce sulfuric acid.

Canada.—Ranked fifth in the world in sulfur production, Canada was one of the leading sulfur and sulfuric acid exporters. In 2017, sulfur production, in all forms, in Canada was slightly higher than it was in 2016. About three-fourths of Canada's sulfur was recovered at natural gas and oil sands operations in Alberta, with some sulfur recovered from oil sands in Saskatchewan and from oil refineries in other parts of the country, as well as byproduct sulfuric acid from metallurgy.

Canada's sulfur production was expected to remain stable over the medium term and may increase during the long term as a result of expanded oil sands production. Sulfur production from natural gas was expected to decline as natural gas production decreased. Exploration for conventional natural gas came to a halt in 2012. Sulfur production from oil sands operations was expected to overtake that from natural gas processing, and sulfur recovered from petroleum refineries was expected to remain relatively stable. Canada was likely to remain a leader in world sulfur production and export of sulfur. Byproduct sulfuric acid production was expected to remain relatively stable.

Environment and Climate Change Canada (2018) published information on Canada's sulfur emissions in 2016, which indicated a slight decrease from those of 2015 and a 65% decrease from those of 1990. Sulfur emissions in Canada have declined as the result of improved sulfur recovery technology at nonferrous metal smelters but also as a result of reduced emissions from coal-fired, electric-power-generating utilities and plant closures, as well as a reduction in emissions from the petroleum-refining sector. Further decreases in sulfur emissions were achieved through the implementation of low-sulfur fuel standards.

China.—China was the leading global producer of sulfur in all forms and the leading producer of pyrites, with about 25% of its sulfur in all forms coming from that source. The country was the leading sulfur importer with a total of 11.2 Mt, which was about one-third of global imports. Imports represented about 55% to 60% of elemental sulfur consumption in China, the bulk of which was used to manufacture sulfuric acid (Sulphur, 2018a). Fertilizer production consumed about 60% of the sulfuric acid used in China, of which 84% was used in the production of phosphoric-acid-based fertilizers (Prud'homme, 2016).

The Government of China removed the export tariffs from phosphate fertilizers in 2017. No tariffs were imposed on diammonium phosphate and monoammonium phosphate through 2017 and into 2018 (CRU Group, 2018).

Oman.—Duqm Refinery and Petrochemical Industries LLC contracted with Técnicas Ruenidas to build the new refinery in Oman. The contract included the engineering, supply, construction, and commissioning of the refinery. In addition, to the 230,000-bbl/d crude distillation unit, the refinery would have three 355-metric-ton-per-day sulfur recovery units. The plant was expected to cost $2.75 billion and was scheduled to be completed by 2021 (Sulphur, 2017b).

Outlook

Worldwide recovered sulfur output is expected to increase as a result of higher sulfur recovery in the oil and gas sector. New sulfur supply would mostly come from Kazakhstan, India, and Qatar. Through 2015, worldwide production of sulfur was nearly equal to consumption; however, in 2016 sulfur was in surplus. In 2017, sulfur production was not enough to meet demand because of project delays and production declines at existing facilities (Prud'homme, 2018).

Since 2000, recovered sulfur production in the United States has been relatively stable, averaging about 8.6 million metric tons per year. Production from natural gas operations is expected to increase from that of 2017 as more natural gas is recovered from shale formations, horizontal drilling, and hydraulic fracturing (U.S. Energy Information Administration, 2018a, p. 66).

Domestic byproduct sulfuric acid production may fluctuate somewhat as the copper industry reacts to market conditions and varying prices by adjusting output at operating smelters. Worldwide, the outlook for byproduct acid is more predictable. Because copper production costs in some countries are lower than those in the United States, acid production from those countries has increased, and continued increases are likely. Many copper producers have installed more efficient sulfuric acid plants to limit sulfur dioxide emissions at new and existing smelters. Worldwide, sulfur emissions at nonferrous smelters declined as a result of improved sulfur recovery; increased byproduct acid production is likely to become more a function of metal demand than a function of improved recovery technology. Smelter acid production in the United States has decreased by 44% since 2000. China's smelter acid production has nearly doubled in the past 10 years; however, the rate of increase has begun to slow. China and Indonesia are the main locations for new smelter acid capacity (Sulphur, 2017a).

Frasch sulfur and pyrites production are unlikely to have significant long-term increases, although Frasch sulfur production was 5% higher in 2017. Because of the continued increases in elemental sulfur recovery and byproduct sulfuric acid production for environmental reasons, discretionary sulfur has become increasingly less important as demonstrated by the lack of expansion in the Frasch sulfur industry. The Frasch process has become the high-cost process for elemental sulfur production, and any new projects would require sulfur prices to increase enough to justify the initial investment. Pyrites, with significant direct production costs, are an even higher cost raw material for sulfuric acid production when the environmental aspects are considered. Discretionary sulfur output is likely to decline. The decrease likely will be pronounced when large operations are closed for economic reasons, as was the case in 2000 and 2001.

For the long term, sulfur and sulfuric acid likely will continue to be important in agricultural and industrial applications. Phosphate processing, mainly for agricultural uses, continues to be the dominant use of sulfuric acid (about 60%). Phosphate fertilizer is expected to remain a leading end use as the global demand for fertilizer remains strong. Ore leaching (about 10%) likely will be the largest area of sulfur consumption growth. Copper and nickel leaching are major consumers of sulfuric acid; however, high costs and technical difficulties in the high-pressure acid leach process for nickel may result in the use of a less expensive option. In addition, other industrial applications such as caprolactam and titanium dioxide production are expanding. Industrial demand for sulfur is increasing, especially in China and Russia (Sulphur, 2016).

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TABLE 1
SALIENT SULFUR STATISTICS[1]

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

		2013	2014	2015	2016	2017
United States:						
Quantity:						
Production:						
Recovered		8,590 r	9,050	8,890	9,070	9,070
Other		616	587	646	673	575
Total		9,210	9,630	9,540	9,740	9,640
Shipments:						
Recovered		8,590	9,080	8,910	9,080	9,120
Other		616	587	646	673	575
Total		9,200	9,670	9,560	9,750	9,700
Exports:						
Elemental		1,770	2,010 r	1,840	2,060 r	2,340
Sulfuric acid		54	53	58	59 r	83
Imports:						
Elemental[e]		2,990	2,370	2,240	1,820	1,850
Sulfuric acid		972	1,000	1,160	1,050	954
Consumption, all forms[2]		11,300	11,000	11,100	10,500	10,100
Stocks, December 31, producer, recovered		160	141	138	144	124
Value:						
Shipments, free on board (f.o.b.) mine or plant:						
Recovered[e]		590,000	734,000	781,000	344,000	423,000
Other		101,000	92,100	75,500	64,800	62,500
Total		691,000	826,000	857,000	409,000	486,000
Exports, elemental		235,000	315,000	284,000	214,000 r	252,000
Imports, elemental		202,000	134,000	136,000	79,800	107,000
Price, elemental, f.o.b. mine or plant[e]	dollars per metric ton	68.71	80.07	87.62	37.88	46.40
World, production, all forms (including pyrites)		77,000 r	78,300 r	78,100 r	79,000 r	80,200

[e]Estimated. [r]Revised.
[1]Table includes data available through May 7, 2019. Data are rounded to no more than three significant digits except prices; may not add to totals shown.
[2]Calculated as shipments minus exports plus imports.

TABLE 2
RECOVERED SULFUR PRODUCED AND SHIPPED IN THE UNITED STATES, BY STATE[1]

(Thousand metric tons and thousand dollars)

	2016			2017		
		Shipments			Shipments	
State	Production	Quantity	Value[e]	Production	Quantity	Value[e]
Alabama	157	157	4,620	139	140	9,510
California	1,070	1,070	36,500	1,160	1,160	51,600
Illinois	614	613	17,700	557	555	18,500
Louisiana	1,650	1,650	66,500	1,590	1,590	83,400
Ohio	131	132	2,420	154	154	6,500
Texas	3,310	3,300	171,000	3,380	3,380	186,000
Washington	161	161	3,500	156	156	4,760
Wyoming	582	582	13,100	543	548	12,700
Other[2]	1,410 r	1,420	28,900 r	1,390	1,440	50,000
Total	9,070	9,080	344,000	9,070	9,120	423,000

[e]Estimated. [r]Revised.
[1]Table includes data available through May 7, 2019. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes Colorado, Delaware, Florida, Indiana, Kansas, Kentucky, Michigan, Minnesota, Mississippi, Montana, New Jersey, North Dakota, Oklahoma, Pennsylvania, Tennessee, Utah, Virginia, and Wisconsin.

TABLE 3
RECOVERED SULFUR PRODUCED AND SHIPPED IN THE UNITED STATES,
BY PETROLEUM ADMINISTRATION FOR DEFENSE (PAD) DISTRICT[1]

(Thousand metric tons)

	2016		2017	
District and source	Production	Shipments	Production	Shipments
PAD 1:				
Petroleum and coke	186	185	216	217
Natural gas	13	13	13	13
Total	199	198	230	231
PAD 2:				
Petroleum and coke	1,420	1,420	1,400	1,400
Natural gas	10	10	7	6
Total	1,430	1,430	1,410	1,400
PAD 3:				
Petroleum and coke	5,290	5,280	5,300	5,320
Natural gas	224	228	146	146
Total	5,510	5,500	5,450	5,460
PAD 4 and PAD 5:				
Petroleum and coke	1,390	1,420	1,490	1,520
Natural gas	534	535	496	501
Total	1,930	1,950	1,990	2,020
Grand total	9,070	9,080	9,070	9,120
Of which:				
Petroleum and coke	8,290	8,290	8,410	8,450
Natural gas	781	786	662	666

[1]Table includes data available through May 7, 2019. Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 4
BYPRODUCT SULFURIC ACID PRODUCED IN THE UNITED STATES[1]

(Thousand metric tons of sulfur content and thousand dollars)

Type of plant	2016	2017
Copper[2]	590	489
Zinc, lead, and molybdenum	83	86
Total:		
Quantity	673	575
Value	64,800	62,500

[1]Table includes data available through May 7, 2019. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Excludes acid made from pyrites concentrates.

TABLE 5
CONSUMPTION OF SULFUR IN THE UNITED STATES BY TYPE[1]

(Thousand metric tons of sulfur content)

Type	2016	2017
Elemental sulfur:		
Shipments	9,080	9,120
Exports	2,060 r	2,340
Imports	1,820 e	1,850
Total	8,840 r	8,630
Byproduct sulfuric acid:		
Shipments	673	575
Exports[2]	59 r	83
Imports[2]	1,050	954
Total	1,670	1,450
Grand total	10,500	10,100

eEstimated. rRevised.
[1]Table includes data available through May 7, 2019. Crude sulfur or sulfur content. Data are rounded to no more than three significant digits; may not add to totals shown. Consumption is calculated as shipments minus exports plus imports.
[2]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 of sulfur content)

SIC[2] code	End use	Elemental sulfur[3] 2016	Elemental sulfur[3] 2017	Sulfuric acid (sulfur equivalent) 2016	Sulfuric acid (sulfur equivalent) 2017	Total 2016	Total 2017
102	Copper ores	--	--	301	239	301	239
1094	Uranium and vanadium ores	--	--	5	2	5	2
10	Other ores	--	--	63	66	63	66
26, 261	Pulp mills and paper products	W	W	119	125	119 r	125
28, 285, 286, 2816	Inorganic pigments, paints, and allied products; industrial organic chemicals; other chemical products[4]	W	W	79	90	79 r	90
281	Other inorganic chemicals	W	W	62	61	62 r	61
282, 2822	Synthetic rubber and other plastic materials and synthetics	W	W	6	7	6	7
284	Soaps and detergents	--	--	5	5	5	5
286	Industrial organic chemicals	--	--	22	14	22	14
2873	Nitrogenous fertilizers	--	--	305	305	305	305
2874	Phosphatic fertilizers	--	--	5,820	5,010	5,820	5,010
2879	Pesticides	--	--	7	11	7	11
287	Other agricultural chemicals	1,100	911	29	22	1,130	933
2892	Explosives	--	--	8	8	8	8
2899	Water-treating compounds	--	--	34	31	34	31
28	Other chemical products	--	--	56	76	56	76
29, 291	Petroleum refining and other petroleum and coal products	2,210	2,180	387	347	2,590	2,520
331	Steel pickling	--	--	11	11	11	11
3691	Storage batteries (acid)	--	--	21	21	21	21
	Exported sulfuric acid	--	--	72	72	72	72
	Total identified	3,300	3,090	7,420	6,520	10,700 r	9,610
	Unidentified	2,690 r	2,350	133	126	2,830 r	2,470
	Grand total	6,000 r	5,440	7,550	6,650	13,500 r	12,100

rRevised. W Withheld to avoid disclosing company proprietary data; included with "Unidentified." -- Zero.
[1]Table includes data available through May 7, 2019. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Standard Industrial Classification.
[3]Does not include elemental sulfur used for production of sulfuric acid.
[4]No elemental sulfur was used in inorganic pigments, paints, and allied products.

TABLE 7
U.S. EXPORTS OF ELEMENTAL SULFUR, BY COUNTRY OR LOCALITY[1]

(Thousand metric tons and thousand dollars)

Country or locality	2016 Quantity	2016 Value	2017 Quantity	2017 Value
Brazil	721 r	61,000 r	710	72,900
Canada	13	9,260	211	9,490
China	167	30,700	328	50,800
Mexico	448	39,000	464	45,000
Morocco	387 r	32,900 r	346	32,000
New Caledonia	202	16,100	106	8,730
Other	119	24,800	178	32,700
Total	2,060 r	214,000 r	2,340	252,000

rRevised.
[1]Table includes data available through May 7, 2019. Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 8
U.S. EXPORTS OF SULFURIC ACID (100% H_2SO_4), BY COUNTRY OR LOCALITY[1]

Country or locality	2016 Quantity (metric tons)	2016 Value (thousands)	2017 Quantity (metric tons)	2017 Value (thousands)
Canada	114,000 r	$12,400	133,000	$11,800
Chile	--	--	19,100	1,750
Ireland	7,320	9,650	7,100	9,360
Israel	5,360	2,590	3,010	4,110
Jamaica	2,220	174	4,320	276
Korea, Republic of	5,310	159	4,670	310
Mexico	5,440	1,210	54,300	1,170
Saudi Arabia	16	13	3,320	49
Suriname	16,100	758	15,900	575
Taiwan	1,130	175	125	157
Venezuela	20,200	1,760	8,500	822
Other	3,000 r	1,140 r	1,280	1,030
Total	180,000 r	30,000	254,000	31,400

[r]Revised. -- Zero.
[1]Table includes data available through May 7, 2019. Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 9
U.S. IMPORTS OF ELEMENTAL SULFUR, BY COUNTRY OR LOCALITY[1]

(Thousand metric tons and thousand dollars)

Country or locality	2016 Quantity	2016 Value[2]	2017 Quantity	2017 Value[2]
Canada	1,480 e	45,700	1,380	49,600
Mexico	74 r	1,830	15	753
Venezuela	9	808	--	--
Other	252 r	31,400	461	56,900
Total	1,820 e	79,800	1,850	107,000

[e]Estimated. [r]Revised. -- Zero.
[1]Table includes data available through May 7, 2019. 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 and ICIS PentaSul North American Sulphur Service; data adjusted by the U.S. Geological Survey.

TABLE 10
U.S. IMPORTS OF SULFURIC ACID (100% H_2SO_4), BY COUNTRY OR LOCALITY[1]

Country or locality	2016 Quantity (metric tons)	2016 Value[2] (thousands)	2017 Quantity (metric tons)	2017 Value[2] (thousands)
Belgium	13	$2	19,000	$286
Brazil	1,270	228	--	--
Bulgaria	21,000	175,000	--	--
Canada	2,100,000	92,200 r	1,890,000	80,700
Colombia	--	--	1,050	341
Finland	109,000	3,760	106,000	3,780
Germany	145,000	3,920	169,000	2,870
Iraq	3,790	790	11,800	4,080
Libya	--	--	759	300
Mexico	640,000	26,100	518,000	14,100
Saudi Arabia	9,510	2,560	24,200	8,430
Spain	151,000	5,090	113,000	2,660
Sweden	29,900	1,040	55,100	2,110
Taiwan	3,170	2,620	3,810	2,960
Other	2,590 r	1,050 r	3,490	2,070
Total	3,220,000	315,000 r	2,920,000	125,000

[r]Revised. -- Zero.
[1]Table includes data available through May 7, 2019. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Declared cost, insurance, and freight paid by shipper valuation.

Source: U.S. Census Bureau.

TABLE 11

SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY OR LOCALITY AND SOURCE[1, 2]

(Thousand metric tons, sulfur content)

Country or locality and source	2013	2014	2015	2016	2017
Australia, byproduct:[e]					
Metallurgy	810	810	810	810	810
Petroleum	90	90	90	90	90
Total	900	900	900	900	900
Belgium, byproduct, all forms and sources, unspecified	397	400 [e]	400 [e]	455 [r]	453
Brazil, byproduct:					
Metallurgy	324	287	290 [e]	290 [e]	290 [e]
Petroleum	218	240	240 [e]	240 [e]	240 [e]
Total	542	527	530 [e]	530 [e]	530 [e]
Canada, byproduct:					
Metallurgy	677	590	558	635 [r]	534
Natural gas and petroleum, including oil sands	5,624	5,252	5,187	4,746 [r]	4,930
Total	6,300	5,840	5,750	5,380 [r]	5,460
Chile, byproduct, metallurgy	1,771	1,849	1,800 [e]	1,800 [e]	1,800 [e]
China:					
Byproduct:					
Metallurgy	7,520 [r]	7,500 [r, e]	7,400 [r, e]	7,100 [r, e]	7,100 [e]
Natural gas and petroleum	5,560 [r]	5,800 [r]	5,530 [r]	5,500 [r]	5,940
Pyrites	4,580 [r]	5,150 [r]	4,360 [r]	4,400 [r, e]	4,400 [e]
Total	17,700 [r]	18,500 [r]	17,300 [r]	17,000 [r]	17,400
Finland:					
Byproduct:					
Metallurgy	316	336	336	340	340 [e]
Petroleum	130 [e]	130 [e]	130 [e]	130	130 [e]
Pyrites	347 [e]	353 [e]	556 [r]	384 [r]	470
Total	793	819	1,020 [r]	854 [r]	940
France, byproduct:[e]					
Natural gas and petroleum	400	400	400	400	400
All forms and sources, unspecified	78	78	78	78	78
Total	478	478	478	478	478
Germany, byproduct:					
Metallurgy	465 [r]	438 [r]	384 [r]	352 [r]	350 [e]
Natural gas and petroleum	755 [r]	708 [r]	628 [r]	578 [r]	538 [e]
Total	1,220 [r]	1,150 [r]	1,010 [r]	930 [r]	888 [e]
India, byproduct:					
Metallurgy	1,200 [e]	1,200 [e]	1,200 [e]	1,200	1,200
Petroleum	1,990 [r]	1,900 [r]	1,930 [r]	2,010 [r]	2,230
Total	3,190	3,100	3,130	3,210 [r]	3,430
Iran, byproduct, natural gas and petroleum[e]	2,100	2,000	2,200	2,200	2,200
Italy, byproduct:					
Metallurgy	1 [r]	1 [r]	1 [r]	1 [r, e]	1 [e]
Petroleum[e]	510	510	510	510	510
Total	511 [r]	511 [r]	511 [r]	511 [r]	511
Japan, byproduct:					
Metallurgy	1,686	1,752	1,688	1,690	1,700 [e]
Petroleum	1,779	1,751	1,733	1,818 [r]	1,789
Total	3,470 [r]	3,500 [r]	3,420 [r]	3,510 [r]	3,490
Kazakhstan, byproduct:					
Metallurgy	605	604 [e]	604 [e]	604 [e]	604 [e]
Natural gas and petroleum	2,443	2,465	2,520 [e]	2,547 [r]	2,914
Total	3,050	3,070	3,120 [e]	3,150 [r]	3,520
Korea, Republic of, byproduct:					
Metallurgy	1,080 [e]	1,080 [e]	1,080 [e]	1,078	1,080 [e]
Natural gas and petroleum	1,601 [r]	1,200 [r]	1,450 [r]	2,000 [r]	2,000
Total	2,680 [r]	2,280 [r]	2,530 [r]	3,080 [r]	3,080
Kuwait, byproduct, petroleum	850 [e]	850	850	850	850 [e]

See footnotes at end of table.

TABLE 11—Continued
SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY OR LOCALITY AND SOURCE[1, 2]

(Thousand metric tons, sulfur content)

Country or locality and source	2013	2014	2015	2016	2017
Mexico, byproduct, all forms and sources, unspecified	1,030	993	858 r	673	551
Netherlands, byproduct:					
Metallurgy[e]	121	120	120	120	120
Petroleum	430	410 e	400 r, e	400 r, e	400 e
Total	551	530	520 r	520 r	520
Poland:					
Byproduct:					
Metallurgy	260	260 e	280 e	280 e	280 e
Natural gas	24	24	24	25 r	25 e
Petroleum	269	269 e	269 e	269 r, e	269 e
Native, frasch	526	605	628 r	621 r	663
Other, unspecified	1	1 e	1 e	1	1 e
Total	1,080	1,160	1,200	1,200 r	1,240
Qatar, byproduct, natural gas	2,000 r	2,136 r	2,300 r	2,068 r	2,100 e
Russia:					
Byproduct:					
Metallurgy[e]	300	200	200	200	200
Natural gas	5,977	5,859	5,961	6,097 r	6,100 e
Petroleum[e]	700	500	500	500	500
Native	123	119 e	110 r	94 r	96
Pyrites[e]	200	180	180	180	180
Total	7,300	6,860	6,950 r	7,070 r	7,080
Saudi Arabia, byproduct, all forms and sources, unspecified	3,900	4,400	4,900	6,000 r	6,000 e
Turkmenistan, byproduct, all forms and sources, unspecified	400	506	600	600	610 e
United Arab Emirates, byproduct, natural gas and petroleum[e]	2,510	3,300	3,300 r	3,300 r	3,300
United States, byproduct:					
Metallurgy	616	587	646	673	575
Natural gas	1,020 r	1,000 r	982	781	662
Petroleum	7,570 r	8,040 r	7,910 r	8,290	8,410
Total	9,210	9,630	9,540	9,740	9,640
Uzbekistan, byproduct:[e]					
Metallurgy	131	131	131	130	130
Natural gas and petroleum	330	340	340	340	340
Total	461	471	471	470	470
Venezuela, byproduct, natural gas and petroleum	800	700	700	700 e	700 e
Other (total):[3]					
Byproduct:					
Metallurgy	418 r	399 r	231 r	359 r	503
Natural gas and petroleum	392 r	415 r	430 r	429 r	437
Petroleum	444	541 r	536 r	552 r	561
All forms and sources, unspecified	320	321 r	317 r	226 r	222
Frasch, native	237 r	218 r	238 r	256 r	259
Pyrites	45	40	40	40	40
Total	1,860 r	1,930 r	1,790 r	1,860 r	2,020
Grand total	77,000 r	78,300 r	78,100 r	79,000 r	80,200
Of which:					
Byproduct:					
Metallurgy	18,300 r	18,100 r	17,800 r	17,700 r	17,600
Natural gas	9,020 r	9,020 r	9,270 r	8,970 r	8,890
Natural gas and petroleum	22,500 r	22,600 r	22,700 r	22,700 r	23,700
Petroleum	15,000 r	15,200 r	15,100 r	15,700 r	16,000
All forms and sources, unspecified	6,120 r	6,700 r	7,150 r	8,030 r	7,910
Frasch, native	886	942	976 r	971 r	1,020
Pyrites	5,170	5,720 r	5,140 r	5,000 r	5,090

See footnotes at end of table.

TABLE 11—Continued

SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY OR LOCALITY AND SOURCE[1, 2]

(Thousand metric tons, sulfur content)

[e]Estimated. [r]Revised.

[1]Table includes data available through November 5, 2018. All data are reported unless otherwise noted. Grand totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

[2]The term "source" reflects the means of collecting sulfur and the type of raw material. Sources listed include the following: Frasch recovery; native, comprising all production of elemental sulfur by traditional mining methods (thereby excluding Frasch); pyrites (whether or not the sulfur is recovered in the elemental form or as acid); 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, oil sand cleaning, and processing of spent oxide from stack-gas scrubbers; and recovery from processing mined gypsum. Recovery of sulfur in the form of sulfuric acid from synthetic gypsum produced as a byproduct of phosphatic fertilizer production is excluded, because to include it would result in double counting. 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 oil 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 of the crude product from which the sulfur is

[3]Includes Algeria, Austria, Bahrain, Colombia, Croatia, Denmark, Egypt, Greece, Hungary, Iraq, Israel, Libya, Lithuania, Morocco, Nigeria, Norway, Oman, Pakistan, South Africa, Taiwan, Trinidad and Tobago, Turkey, and Ukraine.