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2015 Minerals Yearbook

SILICA [ADVANCE RELEASE]

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Silica

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Domestic survey data and tables were prepared by Susan M. Weaver, statistical assistant, and the world production table was prepared by Lisa D. Miller,[1] international data coordinator.

Four silica categories are covered in this report—industrial sand and gravel, quartz crystal (a form of crystalline silica), special silica stone products, and tripoli. Most of the stone covered in the special silica stone products section is novaculite. The section on tripoli includes other fine-grained, porous silica materials, such as rottenstone, that have similar properties and end uses. Certain silica and silicate materials, such as diatomite and pumice, are covered in other chapters of the U.S. Geological Survey (USGS) Minerals Yearbook, volume I, Metals and Minerals. Trade data in this report are from the U.S. Census Bureau. All percentages were computed using unrounded data.

Industrial Sand and Gravel

Total industrial sand and gravel production in the United States decreased to 103 million metric tons (Mt) in 2015 from 110 Mt in 2014 (table 1). Industrial sand production decreased by 7% and industrial gravel production increased by 54% compared with those of 2014. The value of production in 2015 was $4.85 billion—a decrease of 41% compared with the revised $8.2 billion of 2014. Estimated world production of industrial sand and gravel in 2015 was 189 Mt, a 3% decrease compared with 2014 production (table 10).

The most important driving force in the industrial sand and gravel industry remained the production and sale of hydraulic fracturing sand (frac sand). In 2015, despite a decline in demand, frac sand production tonnage was the second highest total ever reported by the USGS.

During the past several years, the consumption of frac sand increased greatly as hydrocarbon exploration in the United States shifted to natural gas and petroleum in shale deposits. In 2015, the fall in global oil and gas prices prompted decreased demand for frac sand in the energy sector and resulted in slowing frac sand production and sales. However, improved hydraulic fracturing techniques, which require more frac sand volume use per well, helped to buoy frac sand production in 2015.

Industrial sand and gravel, often called "silica," "silica sand," and "quartz sand," includes sands and gravels with high silicon dioxide (SiO_2) content. Some examples of end uses for these sands and gravels are in abrasives, filtration, foundry, glassmaking, hydraulic fracturing, and silicon metal applications. The specifications for each use differ, but silica resources for most uses are abundant. In almost all cases, silica mining uses open pit or dredging methods with standard mining equipment. Except for temporarily disturbing the immediate area while operations are active, sand and gravel mining usually has limited environmental impact. Following extraction, the silica sand is processed because it is important that the sand is free of any contaminants and separated by grain size, regardless of the eventual end use.

Legislation and Government Programs.—One of the most important issues affecting the industrial minerals industry has been the potential effect of crystalline silica on human health. The understanding of the regulations, the implementation of the measurements and actions taken to mitigate exposure to crystalline silica, and the appreciation of the effect of such exposure on the future of many industries remain central to an ongoing debate. The Occupational Safety and Health Administration (OSHA) enforces permissible exposure limits that stipulate the maximum amount of crystalline silica to which workers may be safely exposed during an 8-hour work shift (29 CFR §§1926.55 and 1910.1000). OSHA provides guidelines and training tools for the proper handling of crystalline silica (Occupational Safety and Health Administration, 2002).

After many years of study, OSHA issued a Notice of Proposed Rulemaking (NPRM) for Occupational Exposure to Respirable Crystalline Silica in the Federal Register on September 12, 2013. The NPRM was a proposal and not a final rule. OSHA stated that the proposed rule was the result of extensive review of scientific evidence relating to the health risks of exposure to respirable crystalline silica, analysis of the diverse industries where worker exposure to crystalline silica takes place, robust outreach efforts to affected stakeholders, and careful consideration of current industry consensus standards for crystalline silica exposure. OSHA stated that current permissible exposure limits for crystalline silica were inadequate (Occupational Safety and Health Administration, 2013). In December 2015, OSHA submitted its draft final rule on silica for review to the Office of Management and Budget. Following approval, OSHA plans to publish the final rule on silica in early 2016, which would be the first time that silica regulations have been updated since 2002 (Safety and Health Magazine, 2015).

Production.—Domestic production data for industrial sand and gravel were developed by the USGS from a voluntary survey of U.S. producers. The USGS canvassed 211 active producers with 347 operations known to produce industrial sand and gravel. Of the 347 surveyed operations, 304 (88%) were active and 43 were idle or closed. The USGS received responses for 103 operations, and their combined production represented 33% of the U.S. total tonnage. Production data for the nonrespondents were estimated, primarily on the basis of previously reported information, and were supplemented with worker-hour reports from the Mine Safety and Health Administration (MSHA) and information from State agencies.

The Midwest (East North Central and West North Central divisions) led the Nation with 64% of the 103 Mt of industrial sand and gravel produced in the United States, followed by the South (South Atlantic, East South Central, and

[1]Deceased.

West South Central divisions) with 31%, the West (Pacific and Mountain divisions) with 4%, and the Northeast (New England and Middle Atlantic) with 1% (table 2).

The leading producing States were, in descending order, Wisconsin, Texas, Illinois, Missouri, Minnesota, North Carolina, Michigan, Oklahoma, Louisiana, and Arkansas (table 3). Their combined production accounted for 84% of the national total.

Of the total industrial sand and gravel produced, 91% was produced at 122 operations, each with production of 200,000 metric tons per year (t/yr) or more (table 4). The 10 leading producers of industrial sand and gravel were, in descending order, Unimin Corp.; U.S. Silica Holdings, Inc.; Fairmount Minerals, Ltd.; Superior Silica Sands, LLC; Eagle Materials, Inc.; Source Energy Services LP; Hi-Crush Partners LP; Capital Sand Proppants, LLC; Pattison Sand Co., LLC; and Great Lakes Aggregates, LLC. Their combined production represented 58% of the U.S. total.

In 2015, despite the decreased production and demand for frac sand owing to lower global oil and gas prices, frac sand demand was rising on a per well basis, helping to protect the silica sand mining industry from further oil market changes. Additionally, frac sand use per well has risen 80% when comparing old completion wells to new completion wells (Industrial Minerals, 2015a). Increased frac sand use per well notwithstanding, decreased overall demand for frac sand placed downward pressure on frac sand prices in 2015. This caused some silica sand producers to rein in expansion plans and in some cases, resulted in employee layoffs. Additional downstream effects of slackening frac sand demand included decreased need for sand hauling services by both truck and railroad, and oilfield services companies that perform hydraulic fracturing services had to curtail expansion plans along with employee layoffs (Industrial Minerals, 2015b).

Consumption.—Industrial sand and gravel production, reported by producers to the USGS, was material used by the producing companies or sold to their customers. Stockpiled material is not reported until consumed or sold. Of the 103 Mt of industrial sand and gravel sold or used, 72% was consumed as frac sand and sand for well packing and cementing, 8% as other whole-grain silica, and 7% as glassmaking sand (table 6). Other leading uses were foundry sand (4%), chemicals (1%), other ground silica (1%), and whole-grain fillers for building products (1%). Abrasives, ceramics, fillers, filtration, metallurgical flux, recreational sand, roofing granules, silica gravel, and traction sand, combined, accounted for about 6% of industrial sand and gravel end uses. Increased consumption was noted for uses such as abrasive sand, ceramics, foundry sand, sand for flat and specialty glass, recreational sand, sand for well packing and cementing, and traction sand. Consumption of silica sand for the remaining end uses in 2015 declined compared with that of 2014. Silica gravel consumption increased substantially for all end uses, including silicon and ferrosilicon metal production, filtration, and other uses.

Minable deposits of industrial sand and gravel occur throughout the United States, and mining operations are located near markets that have traditionally been in the Eastern United States. In some cases, consuming industries are intentionally located near a silica resource. For example, the automotive industry was originally located in the Midwest near clay, coal, iron, and silica resources. Therefore, foundry sands have been widely produced in Illinois, Indiana, Michigan, Ohio, and other Midwestern States. In 2015, 85% of foundry sand was produced in the Midwest (table 6).

In 2015, 78% of frac sand was produced in the Midwest. The principal sources of "Northern White" or "Ottawa" sand in the upper Midwest are the Middle and Upper Ordovician St. Peter Sandstone and the Lower Ordovician and Upper Cambrian Jordan Formation, along with the Upper Cambrian Wonewoc and Mount Simon Formations, which are gaining in importance. The St. Peter Sandstone in the Midwest is a primary source of "Northern White" or "Ottawa" sand for many end uses, including frac sand. Mined in five States, frac sand from the St. Peter Sandstone is within reasonable transport distance to numerous underground shale formations producing natural gas. Additional frac sand sources to the south include the Upper Cambrian Hickory Sandstone Member of the Riley Formation in Texas, which is referred to informally as "Brown" or "Brady" sand, and the Middle Ordovician Oil Creek Formation in Oklahoma (Benson and Wilson, 2015).

Producers of industrial sand and gravel were asked to provide statistics on the destination of silica produced at their operations. The producers were asked to list only the quantity of shipments (no value data were collected in this section of the questionnaire) and the State or other location to which the material was shipped for consumption. Forty-nine States received industrial sand and gravel. The States that received the most industrial sand and gravel were, in descending order, Texas, Oklahoma, Illinois, Ohio, Pennsylvania, Wisconsin, California, North Carolina, Louisiana, and North Dakota. Producers reported exporting 347,000 metric tons (t) of silica to Mexico (table 7). Because some producers did not provide this information, their data were estimated or assigned to the "Destination unknown" category. In 2015, 76% of industrial sand and gravel shipped by producers was assigned to that category.

The share of silica sold for all types of glassmaking decreased by 7% compared with that of 2014. Sales of sand for container glass production decreased by 5% in 2015 and sales to flat glass and specialty glass manufacturers increased slightly compared with those in 2014. On average, in the container glassmaking industry, silica accounts for 60% of raw materials used (Industrial Minerals, 2004). The amount of unground silica sand consumed for fiberglass production decreased by 47% and ground silica sand consumed for fiberglass production decreased by 31% compared with that of 2014.

The demand for foundry sand is dependent mainly on automobile and light truck production. Production and sales of automobiles and light trucks in the United States set an alltime record in 2015 (Burden and Wayland, 2016). Sales of foundry sand reportedly increased by about 63% compared with those of 2014.

Whole-grain silica is used regularly in filler-type and building applications. In 2015, consumption of whole-grain fillers for building products was 1.5 Mt, a 19% decrease compared with that of 2014.

In 2015, silica sand sales for chemical production were 896,000 t, a decrease of about 10% compared with those in 2014. Total sales of silica gravel for silicon and ferrosilicon production, filtration, and other uses increased by 48% in 2015 compared with those in 2014. The main uses for silicon metal are in the manufacture of silanes and semiconductor-grade silicon and in the production of aluminum alloys.

Transportation.—According to the USGS voluntary survey of U.S. producers, of all industrial sand and gravel produced, 44% was transported by truck from the plant to the site of first sale or use, 25% was transported by rail, 1% was transported by waterway, and 30% was transported by unspecified modes of transport. In any given year, most industrial sand and gravel, including frac sand, was transported by rail and truck to sites of first use, but because some producers did not provide transportation information, some transportation data were assigned to the "unspecified modes of transport" category.

Prices.—The average value, free on board plant, of U.S. industrial sand and gravel decreased to $47.08 per metric ton in 2015, a 37% decrease compared with the average value of $74.78 per metric ton in 2014 (table 6). Average values decreased for most end uses, but substantial decreases for the leading end uses resulted in overall decreased unit values. The average unit values for industrial sand and industrial gravel were $47.42 per ton and $16.78 per ton, respectively. The average unit value for sand ranged from $24.98 per ton for sand for well packing and cementing to $63.93 per ton for sand for swimming pool filtration. For gravel, unit values ranged from $15.09 per ton for other uses to $44.83 per ton for filtration uses. Nationally, sand for swimming pool filtration had the highest value ($63.93 per ton), followed by ground sand used for ceramics ($54.56 per ton); ground sand used as filler for paint, putty, and rubber ($53.42 per ton); frac sand ($53.19 per ton); recreational sand for baseball and softball, volleyball, play sand, and beaches ($52.82 per ton); ground and unground sand for chemicals ($48.63 per ton); and sand for metallurgical flux for metal smelting ($47.83 per ton).

In any given year, producer prices reported to the USGS for silica commonly ranged from several dollars per ton to hundreds of dollars per ton. Prices for certain high-purity quartz products for specialized end uses, not covered in this chapter, can reach the $5,000 per ton level. These specialized end uses include fused quartz crucibles (for the manufacture of silicon metal ingots that are later processed into silicon wafers for the photovoltaic cell and semiconductor markets), solar power cells, high-temperature lamp tubing, and telecommunications uses (Industrial Minerals, 2013).

By geographic region, the average value of industrial sand and gravel was highest in the Midwest ($51.26 per ton), followed by the Northeast ($46.30 per ton), the South ($40.22 per ton), and the West ($35.78 per ton) (table 6). Prices can vary greatly for similar grades of silica at various locations in the United States, owing to tighter supplies and higher production costs in certain regions of the country. For example, the average value of container glass sand varied from $25.50 per ton in the West to $55.63 per ton in the Northeast.

Foreign Trade.—Exports of industrial sand and gravel in 2015 decreased by 13% compared with the amount exported in 2014 and the associated value decreased by about 17% (table 8). Canada was the leading recipient of U.S. exports, receiving 78% of total industrial sand and gravel exports; Mexico received 10%, and Japan, 6%. The remainder went to many other countries. The average unit value of exports decreased to $98.61 per ton in 2015 from $103.70 per ton in 2014. In 2015, export unit values varied widely by region; exports of silica to Africa averaged $684.50 per ton, and exports to the rest of the world averaged $98.31 per ton.

Imports for consumption of industrial sand and gravel increased by 19% to 290,000 t, compared with those of 2014 (table 9). Canada supplied about 89% of the silica imports, and imports from Canada averaged $13.43 per ton; this included cost, insurance, and freight costs to the port of entry in the United States. The total value of imports was $20.2 million, with an average unit value of $69.79 per ton. Higher priced imports came from Australia, Chile, China, Germany, Japan, Mexico, and the Netherlands.

World Review.—Based on information provided mainly by foreign governments, world production of industrial sand and gravel was estimated to be 189 Mt (table 10). Of the countries listed, the United States was the leading producer followed, in descending order, by Italy, France, Turkey, Germany, Australia, the United Kingdom, Moldova, Mexico, India, and Spain. Most countries had some production and consumption of industrial sand and gravel, which are essential to the glass and foundry industries. Because of the great variation in reporting standards, however, obtaining reliable information was sometimes difficult. In addition to the countries listed, many other countries were thought to have had some type of silica production and consumption.

Outlook.—The United States is the leading producer and a major consumer of silica sand and is self-sufficient in this mined mineral commodity. Domestic production is expected to continue to satisfy 97% to 98% of U.S. consumption well beyond 2015. Declining to flat global oil and gas prices in 2015 and continuing into 2016 will result in decreased oilfield activity and concomitant declining consumption of frac sand and sand for well packing and cementing.

Because the unit price of silica sand is relatively low, except for a few end uses that require a high degree of processing, the location of a silica sand deposit in relation to market location will continue to be an important factor in determining the economic feasibility of developing a deposit. Consequently, a significant number of relatively small operations supply local markets with a limited number of products.

Increased efforts to reduce waste and to increase recycling also would be likely to lower the demand for mined glass sand. Glass cullet is an industry term for furnace-ready scrap glass and is an important material used in the manufacturing of glass. Recycling of glass cullet has been increasing in most industrialized nations, and recycling has accounted for anywhere from 25% to 70% of the raw material needed for the glass container industry in many countries. It has been estimated that for every 10% of recycled glass cullet used in the melting process for glass container manufacture, energy use decreases by approximately 2% to 3%. In 2013, 41% of beer and soft drink glass bottles were recovered for

recycling in the United States. An additional 34% of wine and liquor glass bottles and 15% of food and other glass jars were recycled. In total, about 34% of all glass containers were recycled (Glass Packaging Institute, 2016). Based on these factors, production of silica sand for glassmaking in 2016 is expected to be 7.5 to 8 Mt.

Health concerns about the use of silica sand and stricter legislative and regulatory measures concerning crystalline silica exposure could reduce the demand in some silica markets. The use of silica sand in the abrasive blast industry was being evaluated as a health hazard, and marketers of competing materials, which include garnet, olivine, and slags, encouraged the use of their "safer" abrasive media.

Quartz Crystal

Natural quartz crystal was used in most electronic and optical applications until 1971, when it was surpassed by cultured quartz crystal. Cultured quartz is not a mined mineral commodity. Historically, it is synthetically produced from natural feedstock quartz, termed "lascas," which is mined. However, cultured quartz crystal that has been rejected owing to crystallographic imperfections is used by certain companies as feedstock for growing cultured quartz crystal. Mining of lascas in the United States ceased in 1997 owing to competition from less expensive imported lascas, predominantly from mines in Brazil and Madagascar.

The use of natural quartz crystal for carvings and other gemstone applications has continued; more information can be found in the "Gemstones" chapter of the USGS Minerals Yearbook, volume I, Metals and Minerals.

Legislation and Government Programs.—The strategic value of quartz crystal was demonstrated during World War II when it gained widespread use as an essential component of military communication systems. After the war, natural electronic-grade quartz crystal was officially designated as a strategic and critical material for stockpiling by the Federal Government. Cultured quartz crystal, which eventually supplanted natural crystal in nearly all applications, was not commercially available when acquisition of natural quartz crystal for a national stockpile began.

As of December 31, 2015, the National Defense Stockpile (NDS) contained 7,148 kilograms (kg) of natural quartz crystal. The stockpile has 11 weight classes for natural quartz crystal that range from 0.2 kg to more than 10 kg. The stockpiled crystals, however, are primarily in the larger weight classes. The larger pieces are individual crystals in the NDS inventory that weigh 10 kg or more and are suitable as seed crystals, which are very thin crystals cut to exact dimensions, to produce cultured quartz crystal. In addition, many of the stockpiled crystals could be of interest to the specimen and gemstone industry. Little, if any, of the stockpiled material is likely to be used in the same applications as cultured quartz crystal. Brazil traditionally has been the source of such large natural crystals, but changes in mining operations have reduced output.

No natural quartz crystal was sold from the NDS in 2015, and the Federal Government did not intend to dispose of or sell any of the remaining material.

Quartz crystal is also affected by the regulation of crystalline silica as discussed in the "Legislation and Government Programs" portion of the "Industrial Sand and Gravel" section of this chapter.

Production.—The USGS collects production data for quartz crystal through a survey of the domestic industry. In 2015, no domestic companies reported the production of cultured quartz crystal. However, cultured quartz crystal production was thought to take place in the United States, but production statistics were not available. Anecdotal evidence indicated that two companies produced cultured quartz crystal in the United States. At least one of these companies used cultured quartz crystal that had been rejected owing to crystallographic imperfections as feedstock for growing cultured quartz crystal. Larger quantities of cultured quartz crystal were produced overseas, primarily in Asia and Europe.

Consumption.—In 2015, the USGS collected domestic consumption data for quartz crystal through a survey of 10 U.S. operations that fabricate quartz crystal devices in seven States. Of the 10 operations, 3 responded to the survey. Total U.S. consumption of quartz crystal in 2015, including nonrespondents, was estimated to be 2,500 kg.

Electronic-grade quartz crystal, also known as cultured quartz crystal, is single-crystal silica with properties that make it uniquely suited for accurate filters, frequency controls, and timers used in electronic circuits. These devices are used for a variety of electronic applications in aerospace hardware, commercial and military navigational instruments, communications equipment, computers, and consumer goods (for example, clocks, games, television receivers, and toys). Such uses generate practically all of the demand for electronic-grade quartz crystal. A smaller amount of optical-grade quartz crystal is used for lenses and windows in specialized devices, which include some lasers.

Prices.—The price of as-grown cultured quartz was estimated to be $280 per kilogram in 2015. Lumbered quartz, which is as-grown cultured quartz that has been processed by sawing and grinding, was estimated to be $160 per kilogram in 2015, but the price can range from $20 per kilogram to more than $1,000 per kilogram, depending on the application.

Foreign Trade.—The U.S. Census Bureau, which is the major Government source of U.S. trade data, does not provide specific import or export statistics on lascas. The U.S. Census Bureau collects export and import statistics on electronic- and optical-grade quartz crystal; however, the quartz crystal export and import quantities and values reported were thought to include large quantities of fused mullite and fused zirconia, which were inadvertently reported as quartz crystal, not including mounted piezoelectric crystals. Although no definitive data exist listing import sources for cultured quartz crystal, imported material was thought to be mostly from China, Japan, Romania, and the United Kingdom.

World Review.—Cultured quartz crystal production was concentrated in China, Japan, and Russia; several companies produced crystal in each country. Other producing countries were Belgium, Brazil, Bulgaria, France, Germany, Romania, South Africa, and the United Kingdom. Details concerning quartz operations in China, Eastern Europe, and most nations

of the Commonwealth of Independent States were unavailable. Operations in Russia, however, have significant capacity to produce synthetic quartz.

Outlook.—Demand for cultured quartz crystal for frequency-control oscillators and frequency filters in a variety of electronic devices should remain stable. However, during the past several years, silicon has gradually replaced cultured quartz in two very important markets—cellular telephones and automotive stability control applications. Future capacity increases to grow cultured quartz crystal may be negatively affected by this development. Growth of the consumer electronics market (for example, personal computers, electronic games, and tablet computers) is likely to sustain global production of cultured quartz crystal.

Special Silica Stone Products

It was estimated that in 2015, crude production of special silica stone increased 40% when compared to that of 2014 (table 1). The value of crude production in 2015 was $49,000—an increase of 36% compared to that of 2014. Silica stone (another type of crystalline silica) products are materials for abrasive tools, such as deburring media, grinding pebbles, grindstones, hones, oilstones, stone files, tube-mill liners, and whetstones. These products are manufactured from novaculite, quartzite, and other microcrystalline quartz rock. This chapter, however, excludes products that are fabricated from such materials by artificial bonding of the abrasive grains (information on other manufactured and natural abrasives may be found in other chapters of the USGS Minerals Yearbook, volume I, Metals and Minerals).

Special silica stone is also affected by the regulation of crystalline silica as discussed in the "Legislation and Government Programs" part of the "Industrial Sand and Gravel" section of this chapter.

Production.—In response to a USGS production survey, one of the five domestic firms thought to produce special silica stone responded in 2015. In recent years, Arkansas accounted for most of the value and quantity of production that was reported. Plants in Arkansas manufactured files, deburring-tumbling media, oilstones, and whetstones.

The industry produced and marketed four main grades of Arkansas whetstone in recent years. The grades range from the high-quality black hard Arkansas stone to Washita stone, a soft coarse stone. In general, the black hard Arkansas stone has a porosity of 0.07% and a waxy luster, and Washita stone has a porosity of 16% and resembles unglazed porcelain.

Consumption.—The domestic consumption of special silica stone products consists of a combination of craft, household, industrial, and leisure uses. The leading household use is for sharpening knives and other cutlery, lawn and garden tools, scissors, and shears. Major industrial uses include deburring metal and plastic castings, polishing metal surfaces, and sharpening and honing cutting surfaces. The major recreational use is in sharpening arrowheads, fishhooks, spear points, and sports knives. The leading craft application is sharpening tools for engraving, jewelry making, and woodcarving. Silica stone files also are used in the manufacture, modification, and repair of firearms.

Prices.—In 2015, the average value of crude material suitable for cutting into finished products was estimated to be $239 per metric ton.

Foreign Trade.—In 2015, silica stone product exports had a value of $14.3 million, up by 11% from that in 2014. These exports were categorized as "hand sharpening or polishing stones" by the U.S. Census Bureau. This category accounted for most of or all the silica stone products exported in 2015.

In 2015, the value of imported silica stone products was $14.8 million, up by 20% from that in 2014. These imports were hand sharpening or polishing stones, which accounted for most or all of the imported silica stone products in 2015. A portion of the finished products that were imported may have been made from crude novaculite originally produced from mines in the United States and exported for processing.

Outlook.—Consumption patterns for special silica stone are not expected to change significantly during the next several years. Most of the existing markets are well defined, and the probability of new uses being created is low.

Tripoli

Tripoli, broadly defined, includes extremely fine-grained crystalline silica in various stages of aggregation. Grain sizes usually range from 1 to 10 micrometers (μm), but particles as small as 0.1 to 0.2 μm are common. Commercial tripoli contains 98% to 99% silica and minor amounts of alumina (as clay) and iron oxide. Tripoli may be white or some shade of brown, red, or yellow, depending on the percentage of iron oxide.

Tripoli also is affected by the regulation of crystalline silica as discussed in the "Legislation and Government Programs" part of the "Industrial Sand and Gravel" section of this chapter.

Production.—In 2015, three U.S. firms were known to produce and process tripoli. American Tripoli, Inc. operated a mine and produced finished material in Newton County, MO. Malvern Minerals Co. in Garland County, AR, produced crude and finished material from novaculite. Unimin Specialty Minerals Inc. in Alexander County, IL, produced crude and finished material. Of the three U.S. firms, one responded to the USGS survey. Production for the nonrespondents was estimated based on reports from previous years and supplemented with worker-hour reports from MSHA.

Consumption.—It was estimated that sales of processed tripoli in 2015 decreased by 24% in quantity to 70,500 t with a value of $19.4 million (table 1). The decrease in tripoli sales was owing to lessened demand for its use as an abrasive and as a functional filler and extender in adhesives, plastics, rubber, and sealants. Tripoli was mostly used as a filler and extender in caulking compounds, concrete admixture, enamel, linings, paint, plastic, rubber, and other products. Most of the filler-grade tripoli was used in the relatively low-cost concrete admixture end use. In 2015, the primary use of tripoli (92%) was used as a filler and extender. Less than 1% of the tripoli was used in brake friction products and refractories. The end-use pattern for tripoli has changed significantly in the past 45 years. In 1970, nearly 70% of the processed tripoli was used as an abrasive. In 2015, about 8% of tripoli output was used as an abrasive.

Prices.—The average unit value as reported by domestic producers of all tripoli sold or used in the United States was estimated to be $276 per metric ton in 2015. The average unit value of abrasive-grade tripoli sold or used in the United States during 2015 was estimated to be $304 per metric ton, and the average unit value of filler-grade tripoli sold or used domestically was estimated to be $277 per metric ton.

Outlook.—Consumption patterns for tripoli are not expected to change significantly during the next several years. Most of the existing markets are well defined, and the probability of new uses being created is low.

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GENERAL SOURCES OF INFORMATION

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TABLE 1
SALIENT U.S. SILICA STATISTICS[1]

(Thousand metric tons and thousand dollars unless otherwise specified)

		2011	2012	2013	2014	2015
Industrial sand and gravel:[2]						
Sold or used:						
Quantity:						
Sand		43,400	50,300	61,900	109,000 r	102,000
Gravel		348	345	276	744 r	1,150
Total		43,800	50,600	62,100	110,000	103,000
Value:						
Sand		1,990,000	2,670,000	3,460,000	8,230,000 r	4,830,000
Gravel		14,400	8,880	9,350	7,540 r	19,200
Total		2,000,000	2,670,000	3,470,000	8,240,000 r	4,850,000
Exports:						
Quantity		4,330	4,360	2,960	4,450	3,890
Value		371,000	327,000	352,000	461,000	384,000
Imports for consumption:						
Quantity		316	306	160	244	290
Value		87,900	36,600	11,700	20,400	20,200
Processed tripoli:[3]						
Quantity	metric tons	73,700	120,000	110,000	93,100	70,500
Value		16,500	18,900	17,600	19,500	19,400
Special silica stone:						
Crude production:						
Quantity	metric tons	W	156	146	146 e	205
Value		W	39	36	36 e	49
Sold or used:						
Quantity	metric tons	W	500	465	465 e	465 e
Value		W	823	765	765 e	765 e

eEstimated. rRevised. W Withheld to avoid disclosing company proprietary data.

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

[2]Excludes Puerto Rico.

[3]Includes amorphous silica and Pennsylvania rottenstone.

TABLE 2

INDUSTRIAL SAND AND GRAVEL SOLD OR USED IN THE UNITED STATES, BY GEOGRAPHIC DIVISION[1]

Geographic region[2]	2014				2015			
	Quantity (thousand metric tons)	Percent of total	Value (thousands)	Percent of total	Quantity (thousand metric tons)	Percent of total	Value (thousands)	Percent of total
Northeast:								
New England	163	(3)	$9,000	(3)	184	(3)	$6,090	(3)
Middle Atlantic	1,690 r	2	77,100 r	1	1,540	1	73,500	2
Midwest:								
East North Central	56,300	51	4,770,000	58	51,200	50	2,420,000	50
West North Central	14,700	13	1,140,000	14	14,600	14	952,000	20
South:								
South Atlantic	5,410 r	5	154,000	2	7,070	7	186,000	4
East South Central	3,140 r	3	106,000 r	1	3,100	3	85,500	2
West South Central	25,100 r	23	1,820,000	22	21,500	21	1,000,000	21
West:								
Mountain	1,690	2	99,800	1	1,780	2	48,600	1
Pacific	1,890	2	66,800	1	2,130	2	79,200	2
Total	110,000	100	8,240,000 r	100	103,000	100	4,850,000	100

rRevised.

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

[2]Sales region equivalent to U.S. Census Bureau Geographic Division as follows: New England (CT, MA, ME, NH, RI, VT); Middle Atlantic (NJ, NY, PA); East North Central (IL, IN, MI, OH, WI); West North Central (IA, KS, MN, MO, ND, NE, SD); South Atlantic (DC, DE, FL, GA, MD, NC, SC, VA, WV); East South Central (AL, KY, MS, TN); West South Central (AR, LA, OK, TX); Mountain (AZ, CO, ID, MT, NM, NV, UT, WY); Pacific (AK, CA, HI, OR, WA).

[3]Less than ½ unit.

TABLE 3
INDUSTRIAL SAND AND GRAVEL SOLD OR USED IN
THE UNITED STATES, BY STATE[1]

(Thousand metric tons and thousand dollars)

State	2014		2015	
	Quantity	Value	Quantity	Value
Alabama	1,150 r	33,800 r	972	23,700
Arizona	W	W	W	W
Arkansas	3,180	248,000	1,990	146,000
California	1,520	52,500	1,860	66,100
Colorado	W	W	W	W
Florida	219	12,100	485	32,100
Georgia	520	18,000	W	W
Illinois	13,500	1,290,000	14,100	867,000
Indiana	W	W	W	W
Iowa	W	W	1,790	133,000
Kentucky	W	W	W	W
Louisiana	2,120 r	147,000	2,280	76,700
Michigan	1,590	112,000	3,370	77,300
Minnesota	7,220	574,000	5,170	335,000
Mississippi	373	5,520	451	5,260
Missouri	4,290	289,000	6,290	385,000
Nebraska	W	W	W	W
Nevada	W	W	W	W
New Jersey	961	37,200	950	35,500
New York	W	W	W	W
North Carolina	2,640 r	41,500 r	4,050	55,100
North Dakota	W	W	W	W
Ohio	2,850	211,000	1,440	79,400
Oklahoma	3,340	122,000	3,100	73,100
Oregon	W	W	W	W
Pennsylvania	W	W	W	W
Rhode Island	W	W	W	W
South Carolina	589	26,800	551	24,400
South Dakota	W	W	W	W
Tennessee	1,490	60,500	1,540	49,100
Texas	16,500	1,300,000	14,200	706,000
Virginia	W	W	W	W
Washington	W	W	W	W
West Virginia	536	29,500	681	37,500
Wisconsin	38,300	3,150,000	32,200	1,390,000
Other	7,230 r	476,000 r	5,650	252,000
Total	110,000	8,240,000 r	103,000	4,850,000

rRevised. W Withheld to avoid disclosing company proprietary data; included in "Other."

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

TABLE 4
INDUSTRIAL SAND AND GRAVEL PRODUCTION IN THE UNITED STATES IN 2015, BY SIZE OF OPERATION[1]

Capacity (metric tons per year)	Number of operations	Percent of total	Quantity (thousand metric tons)	Percent of total
Less than 25,000	66	22	628	(2)
25,000 to 49,999	28	9	876	1
50,000 to 99,999	49	16	3,230	3
100,000 to 199,999	39	13	4,890	5
200,000 to 299,999	27	9	6,020	6
300,000 to 399,999	9	3	2,700	3
400,000 to 499,999	16	5	6,470	6
500,000 to 599,999	8	3	3,900	4
600,000 to 699,999	8	3	4,520	4
700,000 and more	54	17	69,900	68
Total	304	100	103,000	100

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Less than ½ unit.

TABLE 5
NUMBER OF INDUSTRIAL SAND AND GRAVEL OPERATIONS AND PROCESSING PLANTS IN THE UNITED STATES IN 2015, BY GEOGRAPHIC DIVISION

Geographic region[1]	Mining operations on land		Dredging operations	Total active operations
	Stationary	Stationary and portable		
Northeast:				
New England	1	--	--	1
Middle Atlantic	5	1	3	9
Midwest:				
East North Central	79	7	6	92
West North Central	20	8	8	36
South:				
South Atlantic	33	7	4	44
East South Central	14	--	4	18
West South Central	63	3	11	77
West:				
Mountain	5	1	--	6
Pacific	19	2	--	21
Total	239	29	36	304

-- Zero.
[1]Sales region equivalent to U.S. Census Bureau Geographic Division as follows: New England (CT, MA, ME, NH, RI, VT); Middle Atlantic (NJ, NY, PA); East North Central (IL, IN, MI, OH, WI); West North Central (IA, KS, MN, MO, ND, NE, SD); South Atlantic (DC, DE, FL, GA, MD, NC, SC, VA, WV); East South Central (AL, KY, MS, TN); West South Central (AR, LA, OK, TX); Mountain (AZ, CO, ID, MT, NM, NV, UT, WY); Pacific (AK, CA, HI,OR, WA).

TABLE 6
INDUSTRIAL SAND AND GRAVEL SOLD OR USED BY U.S. PRODUCERS IN 2015, BY MAJOR END USE[1]

Major use	Geographic region[2]														
	Northeast			Midwest			South			West			U.S. total		
	Quantity (thousand metric tons)	Value (thousands)	Unit value[3] (dollars per ton)	Quantity (thousand metric tons)	Value (thousands)	Unit value[3] (dollars per ton)	Quantity (thousand metric tons)	Value (thousands)	Unit value[3] (dollars per ton)	Quantity (thousand metric tons)	Value (thousands)	Unit value[3] (dollars per ton)	Quantity (thousand metric tons)	Value (thousands)	Unit value[3] (dollars per ton)
Sand:															
Glassmaking:															
Containers	W	W	$55.63	W	W	$32.08	2,110	$63,800	$30.17	371	$9,460	$25.50	3,880	$133,000	$34.26
Flat, plate and window	--	--	--	W	W	37.91	1,310	36,700	27.90	619	13,700	22.08	2,660	78,000	29.29
Specialty	--	--	--	W	W	51.15	184	5,900	32.05	W	W	61.25	579	26,100	45.15
Fiberglass, unground	W	W	33.75	59	$2,270	38.39	W	W	42.02	W	W	37.67	292	11,900	40.76
Fiberglass, ground	--	--	--	(4)	1	--	288	12,200	42.20	W	W	61.25	296	12,600	42.72
Foundry:															
Molding and core, unground	W	W	47.71	3,670	169,000	46.10	308	12,200	39.71	36	391	10.86	4,040	183,000	45.31
Molding and core, ground	--	--	--	W	W	44.24	12	647	53.92	--	--	--	194	8,700	44.84
Refractory	(4)	$7	--	35	1,340	38.40	82	2,710	32.99	--	--	--	117	4,060	34.67
Metallurgical, flux for metal smelting	--	--	--	W	W	--	W	W	53.70	W	W	13.00	W	W	47.83
Abrasives, blasting	W	W	65.17	22	1,520	68.95	409	15,100	36.83	W	W	69.75	441	17,300	39.12
Chemicals, ground and unground	(4)	(4)	--	302	13,900	46.06	588	29,400	50.01	W	W	43.00	896	43,600	48.63
Fillers, ground, rubber, paints, putty, etc.	3	152	50.67	W	W	54.97	W	W	51.02	W	W	52.67	84	4,490	53.42
Whole-grain fillers/building products	199	8,920	44.84	273	6,390	23.42	356	13,300	37.29	672	12,800	19.12	1,500	41,400	27.63
Ceramic, ground, pottery, brick, tile, etc.	(4)	1	--	3	172	57.33	105	5,660	53.93	(4)	W	--	108	5,890	54.56
Filtration:															
Water, municipal, county, local	W	W	30.46	157	6,860	43.67	395	14,000	35.54	213	7,290	34.24	778	28,600	36.74
Swimming pool, other	W	W	70.50	11	741	67.36	W	W	48.19	W	W	96.64	56	3,580	63.93
Petroleum industry:															
Hydraulic fracturing	W	W	66.00	57,300	3,030,000	52.86	15,800	855,000	54.15	W	W	57.51	73,800	3,920,000	53.19
Well packing and cementing	382	11,500	30.13	97	3,330	34.31	442	7,000	15.85	10	1,420	141.50	931	23,300	24.98
Recreational:															
Golf course, greens and traps	W	W	60.27	65	2,600	40.05	475	14,300	30.03	W	W	31.53	625	20,300	32.48
Baseball, volleyball, play sand, beaches	W	W	59.55	74	4,050	54.66	479	25,600	53.39	W	W	35.25	602	31,800	52.82
Traction, engine	1	32	32.00	14	754	53.86	56	1,870	33.36	W	W	56.33	86	3,500	40.69
Roofing granules and fillers	10	574	57.40	21	470	22.38	233	9,020	38.70	W	W	41.33	297	11,400	38.46
Other, ground silica	--	--	--	242	11,000	38.91	989	34,700	34.38	291	11,900	39.90	1,250	44,600	35.70
Other, whole grain	1,120	58,000	49.04	3,390	118,000	45.35	6,120	101,000	31.74	1,570	68,300	46.31	8,470	173,000	39.46
Total or average	1,720	79,200	46.15	65,700	3,370,000	51.29	30,700	1,260,000	40.98	3,790	125,000	33.08	102,000	4,830,000	47.42
Gravel:															
Silicon, ferrosilicon	--	--	--	--	--	--	W	W	18.41	--	--	--	W	W	18.41
Filtration	W	W	135.00	6	487	81.17	W	W	21.52	--	--	--	W	W	44.83
Other uses, specified	--	--	--	68	996	14.65	470	6,420	13.66	127	2,620	20.62	665	10,000	15.09
Total or average	W	W	135.00	74	1,480	20.04	942	14,700	15.63	127	2,620	20.62	1,150	19,200	16.78
Grand total or average	1,720	79,600	46.30	65,800	3,370,000	51.26	31,700	1,270,000	40.22	3,570	128,000	35.78	103,000	4,850,000	47.08

W Withheld to avoid disclosing company proprietary data; for sand, included in "Other, whole grain"; for gravel, included in "Total or average." -- Zero.

[1]Data are rounded to no more than three significant digits except for unit values; may not add to totals shown.

[2]Sales region equivalent to U.S. Census Bureau Geographic Division as follows: New England (CT, MA, ME, NH, RI, VT); Middle Atlantic (NJ, NY, PA); East North Central (IL, IN, MI, OH, WI); South Atlantic (DC, DE, FL, GA, MD, NC, SC, VA, WV); East South Central (AL, KY, MS, TN); West South Central (AR, LA, OK, TX); Mountain (AZ, CO, ID, MT, NM, NV, UT, WY); Pacific (AK, CA, HI, OR, WA).

[3]Calculated using unrounded data.

[4]Less than ½ unit.

TABLE 7
INDUSTRIAL SAND AND GRAVEL SOLD OR USED, BY DESTINATION[1]

(Thousand metric tons)

Destination	2014	2015	Destination	2014	2015
State:			State—Continued:		
Alabama	228	222	New Jersey	367	24
Alaska	W	W	New Mexico	W	W
Arizona	21	24	New York	W	W
Arkansas	218	206	North Carolina	1,680 r	858
California	1,120	954	North Dakota	2,020	780
Colorado	W	W	Ohio	1,550	1,240
Connecticut	W	W	Oklahoma	2,860	2,000
Delaware	W	W	Oregon	W	W
Florida	98	336	Pennsylvania	1,620	1,130
Georgia	W	W	Rhode Island	W	--
Hawaii	W	W	South Carolina	195	59
Idaho	W	W	South Dakota	71	69
Illinois	1,890	1,350	Tennessee	913	544
Indiana	W	W	Texas	14,800	6,390
Iowa	W	W	Utah	W	W
Kansas	217	62	Vermont	W	W
Kentucky	W	W	Virginia	W	W
Louisiana	1,210	853	Washington	W	W
Maine	W	W	West Virginia	W	W
Maryland	W	W	Wisconsin	5,680	1,120
Massachusetts	W	W	Wyoming	W	W
Michigan	180	19	Country:		
Minnesota	315	77	Canada	W	W
Mississippi	W	W	Mexico	650	347
Missouri	600	501	Other	W	W
Montana	102	74	Other:		
Nebraska	W	W	Puerto Rico	W	W
Nevada	W	W	U.S. possessions and territories	W	--
New Hampshire	W	W	Destination unknown	61,000 r	78,700
			Total	110,000	103,000

rRevised. W Withheld to avoid disclosing company proprietary data; included in "Total." -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 8
U.S. EXPORTS OF INDUSTRIAL SAND AND GRAVEL, BY REGION AND COUNTRY[1]

(Thousand metric tons and thousand dollars)

Destination	2014		2015	
	Quantity	Value[2]	Quantity	Value[2]
Africa and the Middle East:				
Israel	(3)	274	(3)	180
Other	4	1,120	2	1,190
Total	4	1,390	2	1,370
Asia:				
China	23	39,700	9	24,100
Hong Kong	(3)	118	(3)	69
Japan	277	45,200	225	39,100
Korea, Republic of	3	3,400	4	4,990
Singapore	1	722	1	533
Taiwan	2	1,470	1	750
Other	2	2,240	2	2,560
Total	308	92,800	242	72,100
Europe:				
Belgium	5	2,380	6	2,440
Germany	18	26,500	17	23,100
Italy	(3)	125	(3)	213
Netherlands	15	7,820	14	6,930
Russia	1	1,310	(3)	692
United Kingdom	2	975	1	569
Other	49	10,400	44	13,600
Total	90	49,500	82	47,500
North America:				
Bahamas, The	1	351	3	161
Canada	3,240	226,000	3,040	196,000
Mexico	664	52,200	390	25,000
Trinidad and Tobago	1	653	2	955
Other	6	2,220	10	2,890
Total	3,910	281,000	3,440	225,000
Oceania:				
Australia	1	409	1	389
New Zealand	1	159	(3)	121
Total	2	568	1	510
South America:				
Argentina	120	32,300	81	28,300
Brazil	1	695	1	379
Colombia	2	849	2	874
Peru	4	845	7	1,560
Venezuela	(3)	41	(3)	41
Other	3	943	27	6,240
Total	130	35,700	118	37,400
Grand total	4,450	461,000	3,890	384,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Free alongside ship value of material at U.S. port of export. Based on transaction price; includes all charges incurred in placing material alongside ship.
[3]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 9
U.S. IMPORTS FOR CONSUMPTION OF INDUSTRIAL SAND, BY COUNTRY[1]

(Thousand metric tons and thousand dollars)

Country	2014		2015	
	Quantity	Value[2]	Quantity	Value[2]
Australia	8	8,250	7	6,480
Canada	215	3,630	258	3,460
Chile	(3)	51	(3)	10
China	1	370	2	516
Germany	(3)	106	(3)	32
Japan	(3)	8	(3)	15
Mexico	9	2,380	2	362
Netherlands	--	--	(3)	9
Other	11	5,590	21	9,360
Total	244	20,400	290	20,200

-- Zero.

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

[2]Cost, insurance, and freight value of material at U.S. port of entry. Based on purchase price; includes all charges (except U.S. import duties) in bringing material from foreign country to alongside carrier.

[3]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 10
INDUSTRIAL SAND AND GRAVEL (SILICA): WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country[3]	2011	2012	2013	2014[e]	2015[e]
Algeria[e]	95 [4]	95	100	100	106
Argentina	517	615	500	500	500
Australia[e]	3,500	3,500	5,500	5,500	6,000
Austria	898	820	808	808	808
Bosnia and Herzegovina	119	121	114	114 [4]	114
Bulgaria[e]	660	660	660	660	660
Canada, quartz	1,431	1,593	1,690	1,690	1,700
Chile	1,237	1,267	1,358	1,360 [4]	1,250
Croatia	227	106	102	102 [4]	102
Cuba	20	25	26	26	26
Czech Republic, foundry and glass sand	1,371	1,340	1,274 [e]	1,270 [4]	1,270
Ecuador	27	30	30 [e]	30	30
Egypt[e, 5]	400 [4]	400	400	400	400
Estonia, industrial sand	14	21	20	20	20
Ethiopia[e, 6]	7 [4]	7	33	33	33
Finland[e]	312	257	2,400	2,400	2,400
France	6,286	8,880	8,752	8,750	8,750
Gambia[e]	-- [4]	--	--	--	--
Germany	7,770	7,498	7,500	7,500	7,500
Greece	2 [e]	NA	NA	NA	NA
Guatemala	60	49 [e]	53	53 [4]	53
Hungary, foundry and glass sand	287	124	145	145	145
India	4,496	3,985	3,432	3,430 [4]	3,400
Indonesia[e]	37	38	35	35	35
Iraq	(7)	(7)	(7)	2	2
Israel	233	180	200 [e]	200	200
Italy	16,369	13,946	13,870	13,900 [4]	13,900
Jamaica	14	14	16	16 [4]	16
Japan	3,003	2,877	3,000	3,000	3,000
Jordan	88	88	90 [e]	90	90
Kenya[e]	17	18	19	19	19
Korea, Republic of, quartzite	4	4	4	4 [4]	4
Lithuania	53	54	57	57 [4]	57
Malaysia	1,340	932	1,244	1,240 [4]	1,199
Mexico	2,542	3,593	3,590	3,590	3,600
Moldova	2,547	3,042	3,502	3,500	3,800
New Zealand	109	73	102	102	102
Nigeria[e]	30	30	30	30	30
Norway, quartz and quartzite	1,162	1,083	1,000	1,000	1,000
Peru, quartz and quartzite (crushed)[e]	124	87	88 [4]	88	88
Philippines	352	260	429 [e]	429	429
Poland	2,290	2,149	2,112	2,300	2,300
Portugal, quartz and quartzite	84	80	37 [e]	37	37
Saudi Arabia	1,303	1,368	1,300	1,400	1,260
Slovakia[e]	600	600	600	600	600
Slovenia	231	219	224	224	224
South Africa, industrial or glass sand	2,863	2,150	2,107	2,110	2,300
Spain, industrial sand	5,073	3,416	3,400	3,400	3,400
Sri Lanka[e]	36 [4]	37	38	38	38
Sweden, quartz and quartzite[e]	163 [4]	101	102	102	102
Taiwan	173	58	62	132	132
Thailand[e]	500	500	500	500	500
Turkey	7,021	7,085	7,969	7,970	8,000
United Kingdom	3,969	3,888	4,000	4,000	4,000
United States, sold or used by producers	43,800	50,600	62,100	110,000 [4]	103,000 [4]
Venezuela	500	118 [e]	8	8	8
World total	126,000	130,000	147,000	195,000	189,000

See footnotes at end of table.

TABLE 10—Continued
INDUSTRIAL SAND AND GRAVEL (SILICA): WORLD PRODUCTION, BY COUNTRY[1, 2]

[e]Estimated. NA Not available. -- Zero.
[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes data available through August 31, 2016.
[3]In addition to the countries listed, Angola, Antigua and Barbuda, The Bahamas, Belgium, Brazil (silex), Denmark, Iran, Ireland, Latvia, the Netherlands, Paraguay, and Romania produce industrial sand, but available information is inadequate to make reliable estimates output. Based on estimates of glass end use consumption, China is thought to be the world's leading producer of industrial sand; however, available information is inadequate to make reliable estimates of output.
[4]Reported figure.
[5]Data for fiscal year beginning July 1 of that stated. Silica sand only; no gravel.
[6]Ethiopian calendar year ending July 7 of that stated.
[7]Less than ½ unit.