



2016 Minerals Yearbook

DIAMOND, INDUSTRIAL [ADVANCE RELEASE]

DIAMOND, INDUSTRIAL

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In 2016, U.S. synthetic diamond production was estimated to be 125 million carats with an estimated value of \$123 million. No natural industrial diamond mining took place in the United States, but an estimated 66.4 million carats of used industrial diamond (natural and synthetic) worth about \$4.08 million (table 1) was recycled (secondary production). U.S. imports of natural and synthetic industrial diamond bort, dust and powder, grit, and stone totaled 218 million carats valued at \$67.9 million, and exports totaled 134 million carats valued at \$63.8 million. The estimated U.S. apparent consumption of industrial diamond bort, dust and powder, grit, and stone totaled 275 million carats with an estimated value of \$131 million. Total industrial diamond output worldwide was estimated by the U.S. Geological Survey (USGS) to be 4.5 billion carats valued at between \$1.7 billion and \$2.5 billion. This was the combination of more than 60.8 million carats of natural industrial diamond and about 4.4 billion carats of synthetic industrial diamond (table 1).

Diamond is best known as a gemstone, but some of its unique properties make it ideal for many industrial and research applications. Current information on gem-grade diamond can be found in the Gemstones chapter of the USGS Minerals Yearbook, volume I, Metals and Minerals. Diamond that does not meet gem-quality standards for clarity, color, shape, or size is used as industrial-grade diamond. Total production and consumption quantities and values in table 1 are estimated based on past and current reported data. Trade data in this chapter are from the U.S. Census Bureau. All percentages in the chapter were calculated using unrounded data.

Production

The USGS conducts an annual survey of domestic synthetic industrial diamond producers and a survey of the U.S. firms that recover diamond wastes. Of the two U.S. synthetic industrial diamond producers, one responded to the USGS survey, and of the three leading U.S. firms that recover diamond wastes, two responded to the USGS survey. Production quantities and values for the nonreporting companies were estimated on the basis of industry production trends, reports from some producers and other industry sources, and discussions with consultants within the industrial diamond industry. The USGS does not conduct surveys of domestic producers of polycrystalline diamond (PCD) or chemical vapor deposition (CVD) diamond for quantity or value of annual production.

During 2016, the United States was one of the world's leading producers of synthetic industrial diamond. The United States accounted for an estimated output of 125 million carats valued at \$123 million. Only two U.S. companies produced synthetic industrial diamond during the year—Mypodiamond Inc. (Smithfield, PA) and Sandvik Hyperion (Worthington, OH). By type, primary production was the combination of 41.6 million

carats of diamond bort, dust and powder, and grit valued at \$21.9 million and 83.2 million carats of diamond stone valued at \$101 million.

In 2016, at least eight U.S. companies also manufactured PCD from synthetic diamond dust and powder and grit. These companies were Dennis Tool Co. (Houston, TX), Novatek Inc. (Provo, UT), Precorp Inc. (Provo), Sandvik Hyperion, Sii MegaDiamond Inc. (Provo), Tempo Technology Corp. (Somerset, NJ), US Synthetic Corp. (Orem, UT), and Western Diamond Products LLC (Salt Lake City, UT).

During 2016, an estimated 66.4 million carats of used industrial diamond (natural and synthetic) worth about \$4.08 million (table 1) was recycled (secondary production) in the United States. By type, secondary production was made up of 66.1 million carats of bort, dust and powder, and grit valued at \$3.53 million and 360,000 carats of diamond stone valued at \$544,000. Recycling firms recovered most of this material from used diamond drill bits, diamond tools, and other diamond-containing wastes. Additional diamond was recovered during the year from residues generated in the manufacture of PCD.

The recovery and sale of industrial diamond was the principal business of three U.S. companies in 2016—Industrial Diamond Laboratory, Inc. (Bronx, NY), International Diamond Services Inc. (Houston, TX), and National Research Co. (Chesterfield, MI). In addition to these companies, other domestic firms may have recovered industrial diamond in smaller secondary operations.

Since the 1950s, when scientists manufactured the first synthetic bits of diamond grit using a high-pressure, high-temperature (HPHT) method, this method of growing diamonds has become relatively commonplace in the world as a technology for synthetic diamond production. Diamonds of 1 carat or more are harder to manufacture because that size high-quality diamond is difficult to consistently produce, even in the controlled environment of a laboratory using the HPHT method. After more than 50 years of development, several synthetic diamond companies were able to produce relatively large high-quality industrial diamonds that equaled those produced from mines.

In the early 2000s, technology was developed for a method for growing single, extremely pure diamond crystals by CVD. The CVD technique transforms carbon into plasma, which is then precipitated onto a substrate as diamond. CVD had been used for more than a decade to cover large surfaces with microscopic diamond crystals, but in developing this process, synthetic diamond producers discovered the temperature, gas composition, and pressure combination that resulted in the growth of a single diamond crystal and were able to produce synthetic stones that ranged from 1 to 2 carats.

No commercial diamond mines operated in the United States during 2016. The last commercially operated diamond mine

in the United States closed in 2002 and was fully reclaimed. The Arkansas Department of Parks and Tourism operated a diamond mine for hobbyists at Crater of Diamonds State Park in Murfreesboro, AR.

Consumption

Diamond is the hardest known material and has the highest thermal conductivity of any material at room temperature. Diamond is more than twice as hard as its nearest competitors, cubic boron nitride and silicon nitride. Because of its hardness, diamond has been used for centuries as an abrasive in cutting, drilling, grinding, and polishing. Industrial-grade diamond continues to be used as an abrasive for many applications. Even though it has a higher unit cost than alternative abrasive materials, diamond has proven to be more cost effective in many industrial processes because it cuts faster and lasts longer than alternatives. Diamond also has chemical, electrical, optical, and thermal characteristics that make it the best material available to industry for wear- and corrosion-resistant coatings, special lenses, heat sinks in electrical circuits, wire drawing, computing, and other advanced technologies.

Both natural and synthetic diamond have industrial uses. Synthetic industrial diamond is superior to its natural diamond counterpart because its properties can be tailored to specific applications, and it can be produced in large quantities.

The United States remained one of the world's leading markets for industrial diamond in 2016. According to production estimates and trade data, U.S. apparent consumption of industrial diamond during the year decreased by 14% in quantity to an estimated 275 million carats valued at \$131 million compared with 319 million carats valued at \$131 million in 2015 (table 1). Apparent consumption was the combination of 33.2 million carats of natural industrial diamond valued at \$18.2 million and 242 million carats of synthetic industrial diamond valued at \$113 million. By type, apparent consumption was the combination of 190 million carats of diamond bort, dust and powder, and grit valued at \$10.9 million and 84.9 million carats of diamond stone valued at \$120 million.

The major consuming industrial sectors of industrial diamond cutting and drilling tools and abrasives in the United States during 2016 were construction, machinery manufacturing, mining services (exploration drilling for minerals, natural gas, and oil), stone cutting and polishing, and transportation systems (infrastructure and vehicles). Within these sectors, highway building and repair and stone cutting, combined, accounted for most of the consumption of industrial diamond. Research and high-technology uses included close-tolerance machining of ceramic parts for the aerospace industry, heat sinks in electronic circuits, lenses for laser radiation equipment, polishing of silicon wafers and disk drives, and other applications in the computer industry.

Diamond tools have numerous industrial functions. Diamond drilling bits and reaming shells are used principally for extraction of minerals, natural gas, and oil. Other applications of diamond bits and reaming shells include foundation testing, inspecting concrete, and masonry drilling. The primary uses of point diamond tools are for dressing and truing grinding wheels and for boring, cutting, finishing, and machining applications.

Beveling glass for automobile windows is another application. Cutting dimension stone and cutting and grooving concrete in highway reconditioning are the main uses of diamond saws; other applications include cutting composites and forming refractory shapes for furnace linings. Very fine diamond saws are used to slice brittle metals and crystals into thin wafers for electronic and electrical devices. Diamond wire dies are essential for high-speed drawing of fine wire, especially from hard, high-strength metals and alloys. The primary uses of diamond grinding wheels include edging plate glass, grinding dies, grinding parts for optical instruments, and sharpening and shaping carbide machine tool tips.

Two types of natural diamond are used by industry—diamond stone (generally larger than 60 mesh, 250 micrometers) and diamond bort, dust and powder, and grit (smaller, fragmented material). Diamond stone is used mainly in drill bits and reaming shells used by mining companies; it also is incorporated in single- or multiple-point diamond tools, diamond saws, diamond wheels, and diamond wire dies. Diamond bort is used for drill bits and as a loose grain abrasive for polishing. Other tools that incorporate natural diamond include bearings, engraving points, glass cutters, and surgical instruments.

Synthetic diamond dust and powder and grit are used in diamond grinding wheels, saws, impregnated bits and tools, and as a loose abrasive for polishing. Diamond grinding wheels can be as large as 1 meter in diameter.

Loose powders made with synthetic diamond for polishing are used primarily to finish cutting tools, drill bits, gemstones, jewel bearings, optical surfaces, reaming shells, silicon wafers, and wire-drawing dies for computer chips. Hundreds of other products made from ceramics, glass, metals, and plastics also are finished with diamond powders.

Consumption quantity and value data are not available for PCD or for CVD diamond. Two types of PCDs used by industry are polycrystalline diamond compacts (PDCs) and polycrystalline diamond shapes (PDSs). The use of PDCs and PDSs continues to increase for many of the applications cited above, including some of those that employ natural diamond. PDCs and PDSs are used in the manufacture of single- and multiple-point tools, and PDCs are used in a majority of the diamond wire-drawing dies.

Since its introduction in the mid-1980s, CVD diamond has seen strong growth and has been increasingly accepted by multiple industries as an enhanced material of choice owing to its properties of exceptional strength, durability, stiffness, high thermal conductivity, and electrical isolation.

Early applications for CVD diamond focused largely around thin- and thick-film PCD for cutting tools and dressing applications because of the mechanical properties of diamond. Newer applications that take advantage of CVD diamond's mechanical properties include wear parts, such as watch gears and chemical mechanical polishing pad conditioners. Diamond has tremendous potential for electronics applications because it significantly improves upon current strategies for thermal management while remaining highly cost competitive with other approaches. CVD diamond is used in microelectronic components, such as high-speed processors, medical devices, wide bandgap radio frequency (RF) devices, power conversion

devices, and opto-electronic devices (light-emitting diodes, laser diodes) that generate exceptionally high heat densities requiring innovative approaches to thermal management. Diamond coatings are increasingly being used in these applications because the thermal conductivity of diamond is 10 times that of silicon. In the manufacture of semiconductors, wafer-scale diamond offers enhanced mechanical properties, such as significantly higher stiffness, strength, hardness, thermal conductivity, and chemical inertness, compared with silicon and most other commonly used thin-film materials. Micro-electro-mechanical systems (MEMS), such as RF MEMS resonators, have design needs that can be met by the use of diamond as a base material because of its very high resistance to being deformed elastically when a force is applied and because of its durability in harsh environments. Researchers are investigating the use of boron-doped diamond (BDD) electrodes for water treatment owing to diamond's potential as an environmentally friendly, high-performance electrode material. BDD electrodes have many characteristics that make them ideal for eliminating organic contaminants from water (Zimmer, 2011).

Historically, diamond has been perceived as an expensive material. Advances in CVD diamond manufacturing, such as the development of microwave carbon plasma technology and the development of higher throughput hot filament CVD diamond reactors, have significantly reduced diamond costs. This led many industries to revisit development activities and actively pursue the use of CVD diamond for an increasing number of applications (Zimmer, 2011).

In addition to the existing opportunities for their synthetic diamond for use as gemstones, Scio Diamond Technology Corp. was developing the use of single-crystal CVD diamond materials in high-voltage power switches, lasers, quantum communications and computing, and water treatment and purification. Scio Diamond reported that these projects could translate into high-value market opportunities and high-volume technology applications (Scio Diamond Technology Corp., 2012).

Prices

Natural and synthetic industrial diamonds differ significantly in price. Natural industrial diamond normally had a more limited range of values, from about \$0.50 per carat for bort-size material to about \$2.50 to \$10 per carat for most stones, with some larger stones having sold for several hundred dollars per carat. Prices of synthetic diamond vary according to size, shape, crystallinity, and the absence or presence of metal coatings. In general, prices for synthetic diamond for grinding and polishing ranged from as low as \$0.24 per carat to \$2.66 per carat. Strong and blocky material for sawing and drilling sold for \$2.35 to \$4.00 per carat. Large, synthetic crystals with excellent structure for specific applications sold for several hundred dollars per carat. During 2016, U.S. imports of all types of industrial diamond had an average unit value of \$0.31 per carat. These imports were a combination of natural diamond that had an average value of \$4.12 per carat and synthetic diamond that had an average value of \$0.22 per carat. By type, diamond imports were the combination of diamond bort, dust and powder, and grit (natural and synthetic) that had an average value of \$0.23 per carat and diamond stone (natural and synthetic) that had an average value

of \$13.63 per carat. These average unit values for imported diamond bort, dust and powder, and grit (natural and synthetic) were lower than the average reported prices for the same size fractions of domestically produced diamond listed above.

Foreign Trade

The United States continued to lead the world in industrial diamond trade in 2016; imports were received from 32 countries or localities and exports and reexports were sent to 28 countries or localities (tables 2–5). Although the United States has been a major producer of synthetic diamond for decades, expanding domestic markets have become more reliant on foreign sources of industrial diamond in recent years. U.S. markets for natural industrial diamond have always been dependent on imports and secondary recovery operations because natural diamond has not been produced domestically.

During 2016, U.S. imports of industrial-quality diamond stones (natural and synthetic) increased by 4% from those of 2015 to 1.37 million carats valued at \$18.7 million (table 2). Imports of natural diamond bort, dust and powder, and grit decreased by 32% from those of 2015 to 3.59 million carats valued at \$2.02 million owing to an 86% decrease of imports from China. Imports of synthetic diamond bort, dust and powder, and grit decreased by 21% from those of 2015 to 213 million carats valued at \$47.2 million owing to a 21% decrease of imports from China (table 3).

Reexports accounted for a significant portion of total exports; therefore, exports and reexports are listed separately in tables 4 and 5 so that U.S. trade and consumption can be calculated more accurately. During 2016, the United States did not export industrial diamond stones, unchanged from 2015. U.S. reexports of industrial diamond stone decreased by 8% from those of 2015 to 526,000 carats valued at \$15.4 million and an average value of \$29.30 per carat (table 4). U.S. exports of industrial diamond bort, dust and powder, and grit (natural and synthetic) decreased by 4% from those of 2015 to 134 million carats valued at \$63.8 million and an average value of \$0.48 per carat. Reexports of industrial diamond bort, dust and powder, and grit (natural and synthetic) increased slightly from those of 2015 to 17.7 million carats valued at \$7.75 million and an average value of \$0.44 per carat (table 5). Trade quantity and value data are not available for PCD or for CVD diamond.

World Industry Structure

Global natural diamond production increased by 5% during 2016 to 134 million carats from 127 million carats in 2015. The world's rough diamond producers were as follows: Russia, producing 40.3 million carats or 30% of total world production; Congo (Kinshasa), with 23.2 million carats (17%); Botswana, with 20.5 million carats (15%); Australia, with 14.0 million carats (10%); Canada, with 13.0 million carats (9.7%); Angola, with 9.02 million carats (6.7%); South Africa, with 8.31 million carats (6.2%); and other countries, with 5.8 million carats (4.3%). Of the 134 million carats of total natural diamond production, 73.2 million carats (55% of total diamond production) was gemstone diamond and 60.8 million carats (45% of total diamond production) was industrial diamond

(table 6). During 2016, the value of worldwide rough diamond production decreased by 12% to \$15.4 billion from the 2015 value of \$17.5 billion (De Beers Group UK Ltd., 2017, p. 7). Total combined natural and synthetic industrial diamond output worldwide was estimated by the USGS to be about 4.47 billion carats (table 1).

During 2016, OJSC ALROSA and De Beers Group remained the two leading diamond producers by quantity and value. ALROSA's production was about 26% of total global quantity and 25% of total global value; De Beers' production was about 18% of total global quantity and 30% of total global value. The third-ranked company was Rio Tinto Ltd., which produced about 12% of total global production quantity and approximately 4% of global production value (De Beers Group UK Ltd., 2017, p. 7).

In 2002, the international rough diamond certification system, the Kimberley Process Certification Scheme (KPCS), was agreed upon by United Nations (UN) member nations, the diamond industry, and involved nongovernmental organizations to prevent the shipment and sale of conflict diamonds. Conflict diamonds are diamonds that originate from areas controlled by forces or factions opposed to legitimate and internationally recognized Governments and are used to fund military action in opposition to those Governments or in contravention of the objectives of the UN Security Council. The KPCS monitors rough diamond trade in both gemstone and industrial diamond. The KPCS includes the following key elements: the use of forgery-resistant certificates and tamper-proof containers for shipments of rough diamonds; internal controls and procedures that provide credible assurance that conflict diamonds do not enter the legitimate diamond market; a certification process for all exports of rough diamonds; the gathering, organizing, and sharing of import and export data on rough diamonds with other participants of relevant production; credible monitoring and oversight of the international certification scheme for rough diamonds; effective enforcement of the provisions of the certification scheme through dissuasive and proportional penalties for violations; self-regulation by the diamond industry that fulfills minimum requirements; and sharing information with all other participants on relevant rules, procedures, and legislation as well as examples of national certificates used to accompany shipments of rough diamonds. The United Arab Emirates assumed the chair of KPCS from January 1 through December 31, 2016. As of December 31, 2016, the 54 participants represented 81 nations (including the 28 member nations of the European Union counted as a single participant) plus the rough diamond trading entity of Taipei (Taiwan). The participating nations in the KPCS account for approximately 99.8% of the global production and trade of rough diamonds (Kimberley Process, 2018).

In 2016, natural industrial diamond production was reported from 13 countries (table 6). Natural industrial diamond production worldwide was estimated to be about 60.8 million carats, an 8% increase compared with 56.5 million carats in 2015. Congo (Kinshasa) was the leading country in the production of natural industrial diamond with 18.6 million carats or 30% of total world production; followed by Russia, with 17.7 million carats (29%); Australia, with 13.7 million carats

(22%); Botswana, with 6.15 million carats (10%); Zimbabwe, with 2.00 million carats (3%); and South Africa, with 1.66 million carats (3%). These six countries produced 98% of the world's natural industrial diamond (table 6). Synthetic industrial diamond production worldwide was estimated to be more than 4.41 billion carats, a slight increase compared with that of 2015. China was the leading producing country, followed by the United States, Russia, Ireland, and South Africa, in descending order of quantity. These five countries produced about 98% of the world's synthetic industrial diamond.

In 2016, 97% of the total global combined output of natural and synthetic industrial diamond was produced in China, Ireland, Russia, South Africa, and the United States. Synthetic diamond accounted for more than 99% of global diamond production and consumption.

Worldwide diamond exploration spending decreased by 21% in 2016 with 45 companies allocating \$290 million, compared with 52 companies allocating \$367 million during 2015. The diamond share of overall worldwide mineral exploration spending remained at 4.2% (SNL Metals & Mining, 2016, p. 1, 12–13).

World Review

Botswana.—Diamond production in Botswana was 20.5 million carats during 2016, a slight decrease compared with that of 2015, accounting for 15% of total global production.

The Jwaneng diamond mine in the Kalahari Desert of south-central Botswana was wholly owned by Debswana Diamond Co. (Pty.) Ltd. The company began the Cut 8 project at Jwaneng in 2016, and production was expected to begin in 2017 (De Beers Group UK Ltd., 2017, p. 7).

Canada.—Diamond production in Canada was 13.0 million carats during 2016, a 12% increase compared with that of 2015, accounting for 9.7% of total global production.

The Diavik Diamond Mine in the Northwest Territories began an extension project of the A21 kimberlite pipe pit during 2016 with production expected to begin in 2018. Diavik was jointly owned by Rio Tinto Group (60%) and Dominion Diamond Corp. (40%) (De Beers Group UK Ltd., 2017, p. 7).

The Gahcho Kué Mine in the Northwest Territories began production in 2016. The mine was jointly owned by De Beers Canada, Inc. (51%) and Mountain Province Diamonds Inc. (49%). The mine owners anticipated average annual diamond production of 4.5 million carats (De Beers Group UK Ltd., 2017, p. 7).

The Renard Mine in Quebec also began production in 2016. The mine was wholly owned by Stornoway Diamond Corp. Stornoway anticipated average annual diamond production of 1.6 million carats (De Beers Group UK Ltd., 2017, p. 7).

Lesotho.—Diamond production in Lesotho was 342,000 carats during 2016, a 13% increase compared with that of 2015, accounting for 0.3% of total global production.

The Lihobong Diamond Mine in the Maluti Mountains of northern Lesotho began production in 2016. The mine was owned by Firestone Diamonds plc (75%) and the Government of Lesotho (25%). The mine owners anticipated average annual diamond production of 1.0 million carats (De Beers Group UK Ltd., 2017, p. 7).

Russia.—Diamond production in Russia was 40.3 million carats during 2016, a 4% decrease compared with that of 2015, accounting for 30% of total global production.

ALROSA started the Verkhne-Munskoe project in Yakutia, Russia, during 2016. Project completion and mine startup were expected in 2018 (De Beers Group UK Ltd., 2017, p. 7).

Outlook

China is expected to remain the world's leading producer of synthetic industrial diamond, with annual production exceeding 4 billion carats. The United States is likely to continue to be one of the world's leading markets for industrial diamond into the next decade and likely will remain a significant producer and exporter of synthetic industrial diamond as well. U.S. industrial diamond production and apparent consumption are expected to continue increasing as manufacturing sectors that use industrial diamond continue experiencing economic growth. U.S. demand for industrial diamond is likely to continue in the construction sector as the United States continues building and repairing the Nation's highway system.

Diamond offers many advantages for precision machining and longer tool life. In fact, even the use of wear-resistant diamond coatings to increase the life of materials that compete with diamond is a rapidly growing application. Increased tool life not only leads to lower costs per unit of output but also means fewer tool changes and longer production runs. In view of the many advantages that come from increased tool life and reports that diamond film surfaces can increase durability, much wider use of diamond as an engineering material is expected.

PCD for abrasive tools and wear parts is likely to continue to replace competing materials in many industrial applications by providing closer tolerances as well as extending tool life. For example, PDCs and PDSs will continue to displace natural diamond stone and tungsten carbide products used in the drilling and tooling industries.

CVD technology can produce extremely pure diamond crystals that have great potential in computer technology in the production of diamond computer chips when their cost becomes competitive. These diamond computer chips work at a much higher frequency or faster speed and can be placed in higher temperature environments than the silicon chips currently used in computers. Eventually, they may replace silicon chips in computers. CVD diamonds annealed using the low-pressure, high-temperature microwave plasma process may have applications in high-pressure research, optical applications that take advantage of the outstanding transparency of diamond, and in quantum computing to store quantum information in vacancy centers in the diamond's crystal lattice.

CVD diamond is likely to be used to provide a better and more efficient alternative process to existing water purification processes. This technology will use single-crystal diamond electrodes for electrochemical water purification.

Truing and dressing applications will remain a major domestic end use for natural industrial diamond stone. Stones for these applications have not yet been manufactured economically. No shortage of the stone is anticipated, however, because new mines and more producers selling in the rough diamond market will maintain ample supplies. More competition introduced by the additional sources also may temper price increases.

Demand for synthetic diamond bort, dust and powder, and grit is expected to remain greater than for natural diamond material. Constant-dollar prices of synthetic diamond products are likely to continue to decline as production technology becomes more cost-effective. The decline is even more likely if competition from low-cost producers in China and Russia continues to increase.

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TABLE 1
SALIENT NATURAL AND SYNTHETIC INDUSTRIAL DIAMOND STATISTICS¹

(Thousand carats and thousand dollars)

	2012	2013	2014	2015	2016
United States:					
Natural:					
Secondary production: ^c					
Quantity	18,300	19,000	21,900	31,700	33,000
Value	8,920	9,240	10,600	1,710	1,770
Exports:					
Quantity	9,570	6,420	8,990	6,050	4,710
Value	7,340	5,010	5,670	4,710	3,790
Imports for consumption:					
Quantity	6,400	6,810	5,560	6,570	4,900
Value	37,000	30,400	32,500	24,800	20,200
Synthetic:					
Primary production: ^c					
Quantity	103,000	108,000	124,000	119,000	125,000
Value	70,600	73,200	84,200	117,000	123,000
Secondary production: ^c					
Quantity	18,600	19,400	22,400	31,900	33,400
Value	9,750	10,100	11,900	2,170	2,310
Exports:					
Quantity	165,000	143,000	154,000	133,000	129,000
Value	80,500	72,600	74,900	62,800	60,000
Imports for consumption:					
Quantity	591,000	724,000	679,000	270,000	213,000
Value	78,600	79,400	75,400	52,800	47,700
Apparent consumption, natural and synthetic: ^{c,2}					
Quantity	563,000	728,000	690,000	319,000	275,000
Value	117,000	125,000	134,000	131,000	131,000
World: ^c					
Production, natural	61,200 ^r	59,800	52,800	56,500	60,800
Production, synthetic	4,390,000	4,390,000	4,410,000	4,400,000 ^r	4,410,000
Production, natural and synthetic	4,450,000	4,440,000 ^r	4,460,000	4,460,000 ^r	4,470,000

^cEstimated. ^rRevised.

¹Table includes data available through September 11, 2018. Data are rounded to no more than three significant digits; may not add to totals shown.

²Domestic primary and secondary production plus imports minus exports.

TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF INDUSTRIAL DIAMOND STONES BY COUNTRY OR LOCALITY¹

(Thousand carats and thousand dollars)

Country or locality	Natural industrial diamond stones ²				Miners' diamond, natural and synthetic ³			
	2015		2016		2015		2016	
	Quantity	Value ⁴	Quantity	Value ⁴	Quantity	Value ⁴	Quantity	Value ⁴
Angola	(5)	6	(5)	18	--	--	--	--
Australia	58	808	181	1,140	3	77	9	73
Austria	1	6	--	--	--	--	--	--
Belgium	--	--	1	21	--	--	--	--
Botswana	266	12,500	304	11,500	4	240	1	101
Brazil	(5)	12	--	--	--	--	--	--
Canada	(5)	1	(5)	2	--	--	--	--
Congo (Kinshasa)	56	355	58	478	--	--	(5)	1
India	392	503	461	359	--	--	45	71
Liberia	--	--	--	--	3	119	--	--
Namibia	26	122	20	70	--	--	--	--
Russia	79	106	4	14	--	--	--	--
Sierra Leone	1	48	--	--	--	--	2	48
South Africa	420	7,750	277	4,470	3	151	4	186
United Kingdom	1	66	(5)	53	--	--	(5)	7
Other	1 ^r	9 ^r	1	35	--	--	--	--
Total	1,300	22,300	1,310	18,200	13	586	60	487

^rRevised. -- Zero.

¹Table includes data available through September 11, 2018. Data are rounded to no more than three significant digits; may not add to totals shown.

²Includes glazers' and engravers' diamond unset, Harmonized Tariff Schedule of the United States (HTS) codes 7102.21.3000 and 7102.21.4000 for natural industrial diamond stone.

³HTS codes 7102.21.1010 and 7102.21.1020 for miners' diamond, natural and synthetic.

⁴Customs value.

⁵Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 3
U.S. IMPORTS FOR CONSUMPTION OF DIAMOND BORT, DUST AND POWDER, AND GRIT BY COUNTRY OR LOCALITY¹

(Thousand carats and thousand dollars)

Country or locality	Natural ²				Synthetic ³			
	2015		2016		2015		2016	
	Quantity	Value ⁴	Quantity	Value ⁴	Quantity	Value ⁴	Quantity	Value ⁴
Australia	8	3	30	21	273	194	192	138
Austria	--	--	1	4	37	36	--	--
Belgium	10	6	60	38	449	158	331	154
China	1,450	455	207	135	185,000	25,500	146,000	23,700
France	--	--	--	--	65	54	--	--
Germany	130	39	275	77	32	22	76	20
Hong Kong	--	--	--	--	127	89	119	28
India	2,940	1,500	2,180	1,310	71	43	221	134
Ireland	130	60	85	25	29,300	12,800	28,700	11,200
Israel	--	--	--	--	170	75	14	10
Italy	--	--	--	--	--	--	13	9
Japan	2	3	38	21	957	1,230	582	650
Korea, Republic of	--	--	--	--	21,900	6,690	22,200	6,650
Luxembourg	--	--	--	--	139	109	10	7
Romania	37	63	7	12	10,600	948 ^r	3,010	1,280
Russia	50	11	--	--	15,600	2,470	9,180	1,630
South Africa	87	64	101	70	5	6	7	5
Switzerland	64	38	203	92	2,730	1,440	1,440	1,330
Taiwan	20	5	20	5	68	18	28	11
Thailand	--	--	--	--	369	39	--	--
United Kingdom	337	162	308	137	1,320	252	592	130
Vietnam	--	--	23	38	280	26	--	--
Other	5	16	58	37	21	12	106	65
Total	5,270	2,430	3,590	2,020	270,000	52,200	213,000	47,200

^rRevised. -- Zero.

¹Table includes data available through September 11, 2018. Data are rounded to no more than three significant digits; may not add to totals shown.

²Harmonized Tariff Schedule of the United States (HTS) codes 7105.10.0011 and 7105.10.0015 for natural diamond.

³HTS codes 7105.10.0020, 7105.10.0030, and 7105.10.0050 for synthetic diamond.

⁴Customs value.

Source: U.S. Census Bureau.

TABLE 4
U.S. REEXPORTS OF INDUSTRIAL DIAMOND STONES BY COUNTRY OR LOCALITY¹

(Thousand carats and thousand dollars)

Country or locality	Industrial unworked diamonds ²			
	2015		2016	
	Quantity	Value ³	Quantity	Value ³
Belgium	200	6,770	173	3,460
Brazil	2	32	(4)	11
Canada	54	650	89	714
Germany	4	213	4	168
Hong Kong	15	818	34	1,360
India	10	192	(4)	8
Ireland	(4)	4	20	80
Israel	30	40	--	--
Japan	98	7,330	81	5,150
Korea, Republic of	23	1,360	17	954
Mexico	14	594	8	334
Taiwan	16	167	13	119
Thailand	1	59	6	52
United Arab Emirates	(4)	5	6	48
United Kingdom	96	3,250	74	2,930
Other	7 ^r	23 ^r	2	7
Total	569	21,500	526	15,400

^rRevised. -- Zero.

¹Table includes data available through September 11, 2018. Data are rounded to no more than three significant digits; may not add to totals shown.

²Harmonized Tariff Schedule of the United States code 7102.21.0000.

³Values are free alongside ship.

⁴Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 5
U.S. EXPORTS AND REEXPORTS OF INDUSTRIAL DIAMOND BORT, DUST AND POWDER, AND GRIT BY COUNTRY OR LOCALITY^{1,2}

(Thousand carats and thousand dollars)

Country or locality	Natural				Synthetic			
	2015		2016		2015		2016	
	Quantity	Value ³	Quantity	Value ³	Quantity	Value ³	Quantity	Value ³
Exports:								
Austria	157	49	--	--	4,100	1,120	3,330	783
Brazil	60	65	45	74	2,010	617	1,300	462
Canada	3,290	2,630	3,130	2,420	3,650	2,200	4,650	2,630
China	26	7	7	3	17,300	7,670	9,820	3,870
Czechia	--	--	--	--	4	20	--	--
Germany	218	104	97	28	1,900	873	3,640	849
Hong Kong	30	94	7	19	90	101	167	122
India	3	7	--	--	3,090	1,080	2,760	889
Indonesia	4	9	--	--	145	76	147	53
Israel	145	40	384	50	3,240	1,150	1,770	677
Italy	11	28	--	--	1,160	316	1,110	249
Japan	163	257	153	203	35,100	14,600	33,200	14,100
Korea, Republic of	464	151	124	40	19,700	9,030	21,000	9,370
Mexico	586	460	164	157	1,450	475	1,150	337
Netherlands	--	--	1	3	17,600	6,200	22,500	8,250
Portugal	4	3	--	--	13	5	11	17
Singapore	--	--	--	--	1,080	2,450	2,530	4,050
Switzerland	317	192	20	11	7,780	6,930	6,830	6,290
Taiwan	--	--	9	5	5,150	3,540	5,100	3,380
Thailand	--	--	2	4	1,930	917	2,170	868
Turkey	--	--	--	--	2,820	1,200	2,490	1,010
United Kingdom	329	257	354	449	1,340	531	1,150	336
Other	237 ^r	355 ^r	219	326	2,930 ^r	1,670 ^r	2,350	1,390
Total	6,050	4,710	4,710	3,790	133,000	62,800	129,000	60,000
Reexports:								
Austria	157	49	--	--	--	--	--	--
Brazil	31	8	--	--	82	46	16	21
Canada	2,420	1,940	2,290	1,820	1,370	628	2,470	981
China	18	4	7	3	857	220	1,270	286
Germany	170	60	68	20	101	31	249	60
Hong Kong	7	9	2	6	8	10	--	--
Italy	4	11	--	--	--	--	--	--
Japan	163	257	100	188	9,120	2,160	8,320	2,310
Korea, Republic of	--	--	--	--	946	416	1,140	527
Mexico	58	78	79	102	443	138	446	126
Netherlands	--	--	--	--	237	87	252	165
Portugal	4	3	--	--	--	--	11	17
Singapore	--	--	--	--	4	19	7	32
Switzerland	9	3	--	--	125	150	166	280
Taiwan	--	--	--	--	11	3	--	--
Thailand	--	--	--	--	131	232	111	189
United Kingdom	6	20	143	311	47	22	33	9
Other	137 ^r	162 ^r	49	71	652 ^r	260 ^r	488	231
Total	3,180	2,600	2,740	2,520	14,100	4,420	15,000	5,230
Grand total	9,230	7,310	7,450	6,310	148,000	67,200	144,000	65,200

^rRevised. -- Zero.

¹Table includes data available through September 11, 2018. Data are rounded to no more than three significant digits; may not add to totals shown.

²Harmonized Tariff Schedule of the United States codes 7105.10.0010 for natural and 7105.10.0025 for synthetic.

³Values are free alongside ship.

Source: U.S. Census Bureau.

TABLE 6
NATURAL DIAMOND: WORLD PRODUCTION, BY TYPE AND COUNTRY OR LOCALITY¹

(Thousand carats)

Type and country or locality ²	2012	2013	2014	2015	2016
Gemstones:					
Angola ^{e, 3}	7,500	7,740	7,910	8,120	8,120
Australia ^{e, 4}	184	235	186	271	279
Botswana ^{e, 5}	14,400	16,200	17,300	14,500	14,400
Brazil, gem, unspecified ⁶	46 ^r	49	57	32	184
Cameroon, gem, unspecified ⁷	1	3	4	2	--
Canada, gem, unspecified	10,451	10,600	12,012	11,677	13,036
Central African Republic ^{e, 8}	293	65 ⁹	-- ⁹	-- ⁹	9 ⁹
China, gem, unspecified	2	1	--	--	(10)
Congo (Brazzaville), gem, unspecified	52	56	53	40	12
Congo (Kinshasa) ^{e, 11}	4,310 ^r	3,140	3,130	3,200	4,640
Côte d'Ivoire, gem, unspecified	-- ¹²	-- ¹²	1	15	20
Ghana, gem, unspecified	233	169	242	174	142
Guinea, gemstones ^{e, 8}	213	162	131	134	90
Guyana, gem, unspecified	44	60	100	118	140
India ^{e, 13}	7	10	10	9	9
Lesotho, gem, unspecified	479	414	346	304	342
Liberia ^{e, 14}	25	32	39	41	63
Namibia, gem, unspecified	1,629	1,689	1,918	2,053	1,718
Russia ^{e, 15}	19,600	21,200	21,500	23,500	22,600
Sierra Leone ^{e, 8}	433	487	496	400	439
South Africa ^{e, 8}	5,660	6,520	5,950	5,780	6,650
Tanzania ^{e, 16}	108	153	215	184	205
Togo, gem, unspecified	(10)	(10)	(10)	(10)	(10)
Zimbabwe ^{e, 17}	1,210	1,040	477	349	210
Total^c	66,800	70,100	72,000	70,900	73,200
Industrial:^c					
Angola ³	833	860	879	902	902
Australia ⁴	9,000	11,500	9,100	13,300	13,700
Botswana ⁵	6,170	6,960	7,400	6,230	6,150
Central African Republic ⁸	73	16 ⁹	-- ⁹	-- ⁹	2 ⁹
Congo (Kinshasa) ¹¹	17,200	12,500	12,500	12,800	18,600
Guinea ⁸	53	40	33	33	23
India ¹³	20	27	27	24	24
Liberia ¹⁴	17	21	26	27	42
Russia ¹⁵	15,400	16,700	16,900	18,400	17,700
Sierra Leone ⁸	108	122	124	100	110
South Africa ⁸	1,420	1,630	1,490	1,440	1,660
Tanzania ¹⁶	19	27	38	33	37
Zimbabwe ¹⁷	10,900	9,370	4,290	3,140	2,000
Total	61,200^r	59,800	52,800	56,500	60,800
Grand total	128,000^r	130,000^r	125,000^r	127,000^r	134,000

^cEstimated. ^rRevised. -- Zero.

¹Table includes data available through November 22, 2017. All data are reported unless otherwise noted. Totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown. Estimated gem and industrial diamond quantities are calculated from reported country or locality totals using percentages noted.

²In addition to the countries and (or) localities listed, Nigeria produced natural diamond, but information was inadequate to make reliable estimates of output levels.

³About 90% gem quality and 10% industrial quality.

⁴About 2% gem quality and 98% industrial quality.

⁵About 70% gem and near-gem quality and 30% industrial quality.

⁶Private sector and artisanal mining. Includes near-gem and cheap-gem qualities.

⁷From artisanal mining.

⁸About 80% gem quality and 20% industrial quality.

⁹From May 2013–15, the Central African Republic was under a temporary suspension from the Kimberley Process Certification Scheme and was not trading in rough diamond.

¹⁰Less than ½ unit.

¹¹About 20% gem quality and 80% industrial quality; the majority of production was from artisanal mining.

TABLE 6—Continued
NATURAL DIAMOND: WORLD PRODUCTION, BY TYPE AND COUNTRY OR LOCALITY¹

(Thousand carats)

¹²From 2011–13, Côte d’Ivoire was under United Nations sanctions and was not trading in rough diamond.

¹³About 27% gem quality and 73% industrial quality.

¹⁴About 60% gem quality and 40% industrial quality.

¹⁵About 56% gem quality and 44% industrial quality.

¹⁶About 85% gem quality and 15% industrial quality.

¹⁷About 10% gem quality and 90% industrial quality.

Source: Kimberley Process Certification Scheme.