INDUSTRIAL DIAMOND

By Ronald F. Balazik

Industrial diamond is a natural diamond that does not meet the standards of gem-quality diamond because of its color, clarity, or other properties. Industrial diamond also may be a synthetic diamond that is custom-made for industrial applications.

Natural and synthetic diamonds have optical properties and other characteristics that make them ideal for many industrial applications and emerging technologies. As the hardest material known, diamond is a very effective abrasive in a broad range of industrial uses such as grinding, drilling, cutting, and polishing. In fact, industrial diamond is principally used as an abrasive material. However, the optical properties, electrical/thermal conductivity, and durability of diamond also make it the material of choice for special lenses, heat sinks in electrical circuits, wire drawing, and many new research applications.

Although both synthetic and natural diamond are used by industry, synthetic industrial diamond is superior to its natural diamond counterpart in many cases because its properties can be tailored for specific applications. Thus, synthetic diamond accounts for at least 85% of the abrasive diamond market in the United States.

Legislation and Government Programs

The National Defense Stockpile (NDS) held three categories of industrial diamond in 1995: industrial stones, crushing bort, and diamond dies. At yearend, the Stockpile had an inventory of 5.13 million carats of industrial stones, 1.97 million carats of crushing bort, and approximately 25,500 carats of diamond dies. However, stockpile goals authorized by law were only 3 million carats for industrial stones, zero for crushing bort, and zero for diamond dies. Moreover, a stockpile goal of zero for industrial stones was recommended by the Department of Defense in a 1995 report to Congress on stockpile requirements. For fiscal year 1996, which began on October 1, 1995, the Department of Defense planned to sell 1 million carats of industrial bort and 2 million carats of industrial stones.

Production

The United States was one of the world's leading producers of synthetic industrial diamond in 1995, accounting for an estimated record high output of 115 million carats. Three U.S. firms produced synthetic industrial diamond during the year: Du Pont Industrial Diamond Div., Gibbstown, NJ; GE Superabrasives, Worthington, OH; and Tempo Technology Corp., Somerset, NJ. Three additional firms, Megadiamond Industries Inc., Provo, UT; U.S. Synthetics Corp., Orem, UT; and Dennis Tool Co., Houston, TX, manufactured polycrystalline diamond from purchased synthetic diamond grit.

At least six domestic firms recovered and sold industrial diamond as their principal product in 1995. These firms included Amplex Corp., Worcester, MA; American Borts Crushing, Boca Raton, FL; Industrial Diamond Laboratory Inc., Bronx, NY; Industrial Diamond Powders Co., Pittsburgh, PA; International Diamond Services Inc., Houston, TX; and National Research Co., Fraser, MI. These firms reclaimed industrial diamond from used drill bits, diamond tools, and wet and dry diamond-containing waste. In addition to these companies, more than 30 other U.S. companies reportedly recovered industrial diamond in secondary operations.

The U.S. Geological Survey (USGS) conducts a survey of domestic industrial diamond producers and firms that recover and sell industrial diamond as their primary product. Although most of these companies responded to the survey, significant producers did not. Thus, only an estimate of total domestic output can be provided (115 million carats); additional survey data are not published in order to protect proprietary company information.

Consumption

The United States continued to be the largest single consumer of industrial diamond in 1995. Apparent U.S. consumption of industrial diamond during the year was approximately 200 million carats. This consumption reflects the vitality of many U.S. industrial sectors because industrial diamond is used in nearly every major domestic industry. It is estimated that most of domestic consumption in the 1990's primarily was accounted for by the following U.S. industry sectors (in declining order): machinery manufacturing, mineral services, stone and ceramic production, abrasives operations, construction, and transportation equipment manufacturing.

Industrial diamond stones primarily are used in drilling bits and reaming shells, single- or multiple-point diamond tools, diamond saws, diamond wheels, and diamond wire-drawing dies. Miscellaneous uses include: engraving points, glass cutters, bearings, and surgical instruments. Changes in technology have resulted in an increased use of synthetic industrial diamond and polycrystalline diamond shapes (PDS) and compacts (PDC) for many of the applications cited above. In addition, there has been an increased use of PDS, PDC, and matrix set synthetic diamond grit in drilling bits and reaming shells in recent years. Moreover, PDS and PDC are used in the manufacture of single- and multiple-point tools and PDC is used

in a majority of the diamond wire-drawing dies.

Diamond drilling bits and shells primarily are used for mineral, oil, and gas exploration. Other applications for diamond bits and shells include foundation testing, masonry drilling, and the testing of concrete in various structures. The primary uses of point diamond tools are for dressing and trueing grinding wheels and for cutting, machining, boring, and finishing; the beveling of glass automobile windows also is an application. Cutting dimension stone, ceramics, and concrete in highway reconditioning are the major uses of diamond saws; another application is the forming of refractory shapes for furnace linings. Diamond wire dies are essential for high-speed drawing of fine wire, especially from hard, high-strength metals and alloys.

Diamond grit, powders, and fragmented bort are used in diamond grinding wheels, saws, impregnated bits and tools, and loose abrasives compounds for lapping and polishing. Three major types of grinding wheels are made: resinoid, metal, and vitrified bonds. These tools are made in many shapes and sizes designed for specific applications. Grinding wheel sizes range up to 1 meter in diameter for very large industrial wheels. The primary uses of diamond grinding wheels include the sharpening and shaping of carbide machine tool tips, die grinding, plate glass edging, and optical grinding. Saws made with diamond grit are used to cut concrete, stone, ceramics, and composite materials. Very fine saws are used to slice brittle metals and crystals into thin wafers for electronic and electric devices.

Polishing and lapping powder and compounds primarily are used to finish optical surfaces, jewel bearings, gemstones, wiredrawing dies, cutting tools, and metallographic specimens. However, hundreds of other important items made from metals, ceramics, plastics, and glass also are finished with diamond compounds.

Prices

The USGS does not collect price data on industrial diamonds. However, the USGS monitors the average import value of certain industrial diamonds. The average per-carat value of U.S. imports of natural grit and powder, synthetic grit and powder, and industrial stones was $0.39, $0.44, and $6.62, respectively.

In addition, the average market value of crushing bort, industrial stones, and small diamond dies in the NDS was appraised by the Department of Defense to be $4.48, $10.12, and $36.00 per carat at yearend 1995. In some cases, however, evaluations of industrial diamond in the stockpile may reflect assessments that such materials contain gem quality stones.

Foreign Trade

The United States is one of the world's largest traders of industrial diamond grit and powder. In 1995, the United States exported and reexported 101 million carats ($98 million) of natural and synthetic grit and powder. Additionally, the United States exported and reexported approximately 5.2 million carats of industrial stones, valued at $30 million.

Imports of dust, grit, and powder in 1995 reached a record high of 188 million carats ($81 million). Imports of industrial quality stones were 4.1 million carats ($27 million). Major U.S. import sources for synthetic industrial diamonds were Ireland, the United Kingdom, and Zaire.

As a top producer, the United States generally has been independent of foreign sources for crushing bort or similar diamond except for grit sizes larger than about 850 micrometers. However, the United States is dependent on imports of natural diamond for industrial purposes because it has no production of natural stones for industry use. (Plans to open a gem-quality diamond mine in Colorado were reported in 1995; industrial stones normally would be a byproduct.)

World Review

The worldwide market for industrial diamond grew to about $600 million in 1995 as the majority of consuming countries continued to emerge from recession. More than 75% of this market is supplied by a few top producers, namely the United States, Ireland, Russia, Ukraine, China, Japan, and South Africa. The United States continues to be the world's largest single market for industrial diamond. Tables 3 and 4 show world production of natural and synthetic industrial diamond by country.

As in the United States, world industrial diamond markets are dominated by synthetic diamond. It is estimated that synthetic diamond accounts for approximately 90% of global production and consumption.

Outlook

The United States will continue to be the largest market for industrial diamond through the remainder of this decade. Domestic producers should be able to satisfy U.S. demand for synthetic grit and powder during this period and will continue to be major exporters as well.

Both domestic and world demand for diamond grit and powder will experience substantial increases through the next 5 years. The increases for synthetic grit and powder are expected to be greater than for natural diamond material. Constant-dollar prices of synthetic diamond products probably will continue to decline as production increases make them more cost-effective. However, the consolidation of major synthetic diamond producers could stabilize prices.

During the next several years, the use of diamond tools made from synthetic grit and powder probably will increase most dramatically in the construction industry. Large quantities of saw-grade diamond may be required for highway and bridge repair and replacement. Significant increases in demand for diamond as cutting and polishing media also are expected in the dimension stone industry. The stone, clay, and glass industries will increase their use of diamond tools for cutting, shaping, and polishing. Additionally, polycrystalline synthetic diamond compacts and shapes will continue to displace natural diamond

stone and tungsten carbide drill bits in the mineral services sector.

The major domestic end use for industrial stones in the next several years will continue to be in the oil, gas, and mineral industries. These stones are natural and cannot be manufactured commercially yet. However, polycrystalline synthetic diamond compacts and shapes already have displaced natural industrial diamond stone in some markets and will limit future U.S. demand for stone. Domestic consumption of natural stone should average between 6 and 7 million carats annually to the year 2000. Approximately one-half of the natural stone used in its remaining applications will be replaced by synthetic compacts and shapes in this decade.

OTHER SOURCES OF INFORMATION

U.S. Geological Survey Publications

Diamonds (Industrial), Mineral Commodity Summaries, 1996.
U.S. Geological Survey Professional Paper 820, pp. 27-33.

Other Sources

Annual Report—1995, De Beers Consolidated Mines Limited, Kimberley, South Africa.
Minerals Yearbook, U.S. Bureau of Mines.
Mineral Facts and Problems, U.S. Bureau of Mines.

TABLE 1
U.S. IMPORTS FOR CONSUMPTION OF INDUSTRIAL DIAMOND STONES, BY COUNTRY 1/

(Thousand carats and thousand dollars)

	Natural industrial diamond stones (including glazers' and engraver's diamond unset) (7102.21.3000 and .4000)				Miners' diamond, natural and synthetic (7102.21.1010 and .1020)			
	1994		1995		1994		1995	
Country	Quantity	Value 2/	Quantity	Value 2/	Quantity	Value 2/	Quantity	Value 2/
Belgium	84	683	224	798	453	3,830	571	3,630
China	2	2	91	176	(3/)	3	2	2
Ghana	101	1,990	103	445	39	159	36	300
India	9	19	5	4	--	--	--	--
Ireland	90	120	88	168	30	194	1	17
Japan	(3/)	3	1	4	1	36	(3/)	19
Netherlands	2	1,810	18	956	118	1,270	2	67
South Africa	37	118	90	150	--	--	4	54
Switzerland	(3/)	2	1	3	272	885	140	341
United Kingdom	843	6,780	858	6,880	291	3,620	654	8,810
Zaire	80	838	663	954	238	3,410	37	1,910
Other	68	310	468	1,160	47 r/	309 r/	47	322
Total	1,320	12,700	2,610	11,700	1,490	13,700	1,490	15,500

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Customs value.
3/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF DIAMOND POWDER, DUST AND GRIT, BY COUNTRY 1/

(Thousand carats and thousand dollars)

	Diamond powder and dust, synthetic (7105.10.0020; 0030 and .0050)				Diamond powder and dust, natural (7105.1011 and .0015)			
	1994		1995		1994		1995	
Country	Quantity	Value 2/	Quantity	Value 2/	Quantity	Value 2/	Quantity	Value 2/
Belgium	1,050	1,920	2,050	3,040	772	1,860	2,180	1,930
China	4,920	735	7,240	1,740	1,630	272	11,200	1,440
Germany	22,200	4,630	11,400	4,300	522	574	69	86
Hong Kong	3,390	1,080	489	88	60	13	844	176
India	38	19	163	160	18	8	48	33
Ireland	95,400	60,000	116,000	48,200	3,310	4,100	2,440	2,040
Japan	3,170	2,220	3,800	2,350	2	4	--	--
Korea, Republic of	5,290	3,940	6,750	6,650	841	270	1,250	899
Russia	17,700	2,010	9,860	1,690	217	227	35	53
South Africa	56	31	104	52	--	--	--	--
Switzerland	509	282	985	673	450	155	293	341
Ukraine	5,370	468	2,710	521	--	--	--	--
United Kingdom	3,190	1,370	3,420	1,750	1,760	943	1,300	674
Zaire	30	22	28	44	997	551	10	4
Other	1,090	1,070	2,410	2,140	400	521	808	378
Total	163,000	79,800	167,000	73,400	11,000	9,510	20,500	8,050

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

Source: Bureau of the Census.

TABLE 3
NATURAL DIAMOND: WORLD PRODUCTION, BY TYPE AND COUNTRY 1/ 2/

(Thousand carats)

Country	1991			1992		
	Gem e/ 3/	Industrial e/	Total 4/	Gem e/ 3/	Industrial e/	Total 4/
Angola 5/	899	62	961	1,100	80	1,180
Australia	17,978	17,978	35,956	18,078	22,095	40,173
Botswana	11,550	4,950	16,500	11,160	4,790	15,950
Brazil	600	900	1,500 e/	653	665	1,318
Central African Republic	296	82	378	307	107	414
China	200	800	1,000 e/	200	800	1,000 e/
Gabon	400	100	500 e/	400	100	500 e/
Ghana	560	140	700 e/	570	140	710 e/
Namibia	1,170	20	1,190	1,520	30	1,550
Russia	XX	XX	XX	9,000	9,000	18,000
Sierra Leone 6/	160	83	243	180	116	296
South Africa	3,800	4,600	8,400 r/	4,600	5,600	10,200
U.S.S.R. 7/	10,000	10,000	20,000 e/	XX	XX	XX
Venezuela	102 8/	112 8/	214	302 8/	176 8/	478
Zaire	3,000	14,814	17,814	8,934	4,567	13,501
Other	275 r/	166 r/	441 r/	305 r/	218 r/	524 r/
Total	51,000	54,800	106,000	57,300	48,500	106,000

	1993			1994 e/		
	Gem e/ 3/	Industrial e/	Total 4/	Gem 3/	Industrial	Total
Angola 5/	130	15	145	270	30	300
Australia	18,844	23,032	41,876	19,485	23,815	43,300
Botswana	10,310	4,420	14,730	10,550 r/ 8/	5,000	15,550 r/ 8/
Brazil	600	900	1,500 e/	600	900	1,500
Central African Republic	370	125	495	400 r/	131 r/	531 r/
China	230	850	1,080 e/	230	850	1,080
Gabon	400	100	500 e/	400	100	500
Ghana	570	140	710 e/	580	145	725
Namibia	1,120	20	1,140	1,312 r/ 8/	-- r/	1,312 r/ 8/
Russia	8,000	8,000	16,000	8,500	8,500	17,000
Sierra Leone 6/	90	68	158	155	100	255
South Africa	4,600	5,700	10,300	4,340 r/	5,343 r/	9,683 r/
U.S.S.R. 7/	XX	XX	XX	XX	XX	XX
Venezuela	146 r/ 8/	155 8/	301	203 r/ 8/	214 r/ 8/	417 r/ 8/
Zaire	2,006	13,620	15,626	4,000	13,000	17,000
Other	296 r/	218 r/	513 r/	333 r/	221 r/	554 r/
Total	47,700	57,400 r/	105,000	51,400 r/	58,300 r/	110,000 r/

	1995 e/		
	Gem 3/	Industrial	Total
Angola 5/	450	50	500
Australia	18,312	22,381	40,693
Botswana	11,502	5,300	16,802 8/
Brazil	600	900	1,500
Central African Republic	400	130	530
China	230	900	1,130
Gabon	400	100	500
Ghana	580	145	725
Namibia	1,382 8/	--	1,382 8/
Russia	9,000	9,000	18,000
Sierra Leone 6/	113 8/	100	213 8/
South Africa	4,300	5,383	9,683 8/
U.S.S.R. 7/	XX	XX	XX
Venezuela	229 8/	64 8/	293 8/
Zaire	4,000	13,000	17,000
Other	363	246	609
Total	51,900	57,700	110,000

e/ Estimated. r/ Revised. XX Not applicable.

1/ Table includes data available through June 21, 1996.

2/ World totals are rounded to three significant digits; may not add to totals shown.

3/ Includes near-gem and cheap-gem qualities.

4/ Total natural diamond output (gem plus industrial) for each country actually is reported, except where indicated to be an estimate.

5/ Figures do not include smuggled artisanal production.

6/ Figures are estimates based on reported exports and do not include smuggled diamonds.

7/ Dissolved in Dec. 1991.

8/ Reported figure.

TABLE 4
SYNTHETIC DIAMOND: ESTIMATED WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand carats)

Country	1991	1992	1993	1994	1995
Belarus	XX	30,000	30,000	25,000	25,000
China	15,000	15,000	15,500	15,500	15,500
Czech Republic	XX	XX	5,000	5,000	5,000
Czechoslovakia 3/	10,000	10,000	XX	XX	XX
France	4,000	3,500	3,500	3,500	3,000
Greece	1,000	750	1,000	1,000 r/	1,000
Ireland	60,000	60,000	65,000 r/	65,000	60,000
Japan	30,000	30,000	32,000	32,000	32,000
Romania	3,000	3,000 r/	5,000	5,000	5,000
Russia	XX	80,000	80,000	80,000	80,000
Serbia and Montenegro	XX	5,000	5,000 4/	5,000	5,000
Slovakia	XX	XX	5,000	5,000	5,000
South Africa	60,000	60,000	60,000	60,000	60,000
Sweden	25,000	25,000	25,000	25,000	25,000
U.S.S.R. 5/	120,000	XX	XX	XX	XX
Ukraine	XX	10,000	10,000	8,000	8,000
United States	90,000	90,000	103,000	104,000	115,000
Yugoslavia 6/	5,000	XX	XX	XX	XX
Total	423,000	422,000 r/	445,000 r/	439,000	445,000

r/ Revised. XX Not applicable.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Table includes data available through July 12, 1996.
3/ Dissolved Dec. 31, 1992.
4/ Reported figure.
5/ Dissolved in Dec. 1991.
6/ Dissolved in Apr. 1992.