

ABRASIVES, MANUFACTURED

By Donald W. Olson

Domestic survey data and tables were prepared by Christine K. Pisut, statistical assistant.

Abrasives play an important role in the fashioning and finishing of numerous products with a wide range of end-use applications. Abrasives are natural or manufactured substances that are used to abrade, clean, etch, grind, polish, scour, or otherwise remove solid material by rubbing action (as in a grinding wheel) or impact (as in pressure blasting). The most important physical properties for abrasives are hardness ("scratch" hardness), toughness (rigidity), friability, grain shape and size, character of fracture (cleavage), and purity (uniformity). Additional considerations include thermal stability, bonding characteristics, cost, and availability. Manufactured abrasives are made from metals or minerals by heating or chemically treating them to enhance or give them abrasive physical properties. No single property is paramount for any use (Wellborn, 1996, p. 31, 43).

Manufactured abrasives generally dominate high-grade abrasive markets as opposed to natural abrasives because they have superior physical properties and more uniform quality and can be tailored to meet user needs. Consequently, manufactured abrasives typically are characterized by premium prices relative to natural abrasive minerals. Even though manufactured abrasives are more expensive, their durability and efficiency have proven to be more cost-effective. Therefore, they are preferred in many industrial applications, such as metal finishing, cutting, and polishing.

This report includes information on the following abrasives: aluminum-zirconium oxide, boron carbide, fused aluminum

oxide, metallic shot and grit, and silicon carbide. In some cases, United States production data were combined with Canadian output to protect proprietary information. Trade data in this report are from the U.S. Census Bureau. Quantities are reported in metric units unless otherwise noted.

Combined Canadian and United States production of aluminum oxide increased, while production of silicon carbide declined in 2000 from that of 1999. U.S. imports of crude, ground, and refined silicon carbide and of ground and refined aluminum oxide increased. U.S. metallic abrasives production decreased compared with that of 1999.

Fused Aluminum Oxide

Legislation and Government Programs.—As of January 1, 2000, the national defense stockpile (NDS) maintained by the U.S. Department of Defense (DOD) contained about 37,700 metric tons (t) of crude fused aluminum oxide valued at \$7.3 million and about 17,700 t of fused aluminum oxide abrasive grain valued at \$6.7 million. During 2000, the DOD reported sales of all NDS crude fused aluminum oxide for \$8.7 million and sales of about 1,300 t of NDS aluminum oxide abrasive grain for \$627,960. Under Federal legislation authorizing the disposal of all NDS aluminum oxide, the DOD plans to continue such sales until all the stockpiled aluminum oxide is sold (Janet Rollins, Market Analyst, Defense National Stockpile Center, oral commun., 2001). All the stockpiled aluminum

Manufactured Abrasives in the 20th Century

Silicon carbide was the first synthetic abrasive to be produced and the first to be commercialized. In 1891, the electric-furnace method for making silicon carbide was developed, beginning a revolution in the high-grade abrasives industry. Before that time, all abrasives were natural minerals and rocks, except for some minor use of chemically prepared materials. Silicon carbide was initially marketed under the trade name Carborundum. By 1900, U.S. production of Carborundum had already increased to about 1,200 metric tons with an estimated value of \$263,000. Carborundum was mainly used by lapidaries in place of diamond powder, and as an abrasive material, it was made into hones and wheels. The only other manufactured abrasive in 1900 was crushed steel, for which domestic production was about 320 tons valued at \$50,000. The largest part of the crushed steel production was used in the stonecutting trade, particularly for marble and granite. Very fine grades of crushed steel, also known as steel emery and rouge, were used by lens and other glass grinders.

By 2000, manufactured abrasives, with the exceptions of diamond and garnet, dominated the field of high-grade abrasives. Manufactured abrasives became essential to modern

industry because they were more uniform in their properties and in their quality than most natural abrasives. The properties of manufactured abrasives can be varied to meet specialized needs. Most of the manufactured abrasives used in 2000 fell into one of the following categories: boron carbide, boron nitride, calcium and magnesium oxides, cerium oxide, chromium oxide, fused aluminum oxides, glass, iron oxides, magnesia, manufactured diamonds, metallic abrasives, porcelains or ceramics (which primarily used zirconium oxides or silicates), precipitated calcium carbonate, silicon carbide, sintered abrasives, sol-gel abrasives, and tin oxide. Manufactured abrasives included in this report are aluminum-zirconium oxide, boron carbide, fused aluminum oxide, metallic abrasives, and silicon carbide. Many of the other abrasives mentioned above are the subject of other U.S. Geological Survey mineral industry surveys. In 2000, the combined Canadian and United States production of abrasive aluminum oxide was estimated to be 90,000 tons with an estimated value of \$29.4 million. The combined Canadian and United States production of silicon carbide was estimated to be 45,000 tons with an estimated value of \$26.3 million.

oxide will be sold before 2004 if the current disposal and sales schedules continue.

Production.—The production data for fused aluminum oxide in this report were obtained by the U.S. Geological Survey (USGS) from producers in Canada and the United States. The data were collected from three companies that operated six plants and represented the entire Canadian and United States fused aluminum oxide industry (table 1). Two of the companies operated fused aluminum oxide plants in Canada and the United States. Data from the two countries were combined to protect company proprietary information.

Estimated production of regular-grade fused aluminum oxide in 2000 was 90,000 t with an estimated value of \$29.4 million, an increase of about 6% by weight over the 1999 regular-grade fused aluminum oxide production (table 2). Reporting on the output of high-purity fused aluminum oxide has been discontinued to avoid disclosing company proprietary data.

Consumption.—Abrasive-grade fused aluminum oxide has many end uses. Specific applications in 2000 included bonded abrasives (such as abrasive grains that are made to adhere to each other and then are pressed or molded into abrasive tools), coated abrasives (such as abrasive grains glued to a backing of paper or cloth), tumbling media, air or water blasting media, polishing/buffing compounds, and antislip additives. The total value of fused aluminum oxide abrasive grain consumed in the United States was estimated to be \$93 million in 2000.

Prices.—The USGS surveyed fused aluminum oxide producers to determine the total value of their production for the year. The survey indicated that the average unit value of regular fused aluminum oxide produced in the United States and Canada during 2000 was \$331 per metric ton at the point of production; the average value of high-purity fused aluminum oxide output was \$566 per ton at the point of production. Prices of abrasive grain produced from these materials and sold to consumers were significantly higher.

The average price of NDS crude fused aluminum oxide sold by the DOD in 2000 was \$232 per ton. The average price of stockpiled fused aluminum oxide grain sold in 2000 was \$483 per ton.

Average unit values of fused aluminum oxide trade by the United States in 2000 are based on U.S. Census Bureau customs value data. Average unit values of crude fused aluminum oxide imports during the year ranged from \$179 per ton (China) to \$447 per ton (Venezuela). Values of fused aluminum oxide grain imports ranged from \$268 per ton (China) to \$1,371 per ton (Austria). The average value for U.S. exports of fused aluminum oxide during the year was about \$2,600 per ton.

Foreign Trade.—During 2000, imports of crude fused aluminum oxide were received from 8 countries and increased by about 21% to 110,000 t valued at \$35.2 million compared with those of 1999, and imports of ground and refined fused aluminum oxide were received from 20 countries and increased by 57% to 117,000 t valued at \$64.7 million (table 5). Some of the imported crude fused aluminum oxide was refractory-grade material. Canada, China, and Venezuela supplied 44%, 41%, and 15%, respectively, of the crude imports. China, Canada, and Austria provided 37%, 34%, and 9%, respectively, of the ground and refined material.

Compared with 1999 exports of all fused aluminum oxides, 2000 exports remained the same at 9,020 t, but the value of those exports increased to \$23.5 million (table 6). Of the exports shipped to 29 countries, 76% went to Canada, Germany,

Mexico, and the Netherlands.

Silicon Carbide

Legislation and Government Programs.—As of January 1, 2000, the NDS contained no more silicon carbide. Under congressional authority to dispose all NDS silicon carbide, the DOD sold the last portion of its stockpiled silicon carbide during the first quarter of 1999 (Janet Rollins, Market Analyst, Defense National Stockpile Center, oral commun., 2001). The DOD was not expected to replenish the silicon carbide stockpile.

Production.—Two companies produced abrasive-grade silicon carbide in Canada and the United States during 2000 (table 1). These companies also produced similar amounts of metallurgical-grade silicon carbide. Another company in Hopkinsville, KY, produced a small quantity of silicon carbide, primarily intended for use in heat-resistant products rather than abrasives. Table 2 lists estimated production rounded to avoid disclosing company proprietary information.

Consumption.—Abrasive-grade silicon carbide has many end uses. Specific applications in 2000 included antislip abrasives, blasting abrasives, bonded abrasives, coated abrasives, polishing/buffing compounds, tumbling media, and wiresawing abrasives. The total value of silicon carbide consumed in the United States was estimated to be about \$111 million in 2000.

Prices.—The USGS does not collect price data on the various grades of silicon carbide. Based on information from industry sources and publications, however, the average value of abrasive-grade silicon carbide at the point of manufacture was estimated to be about \$585 per ton in 2000.

During 2000, imports from China accounted for 82% of total U.S. crude silicon carbide imports and had an average value of \$311 per ton; the average value of the remaining 18% of U.S. crude silicon carbide imports was \$536 per ton. The average value of silicon carbide grain imports was \$1,330 per ton; China accounted for 48% of such imports. The average value of total silicon carbide exports in 2000 was approximately \$1,150 per ton.

Foreign Trade.—In 2000, the United States imported crude silicon carbide from 11 countries and imported ground or refined silicon carbide from 22 countries. Imports of crude silicon carbide increased by about 5% during the year to 162,000 t valued at \$56.7 million (table 5). Imports of silicon carbide in ground or refined form increased by about 98% to 28,300 t valued at \$37.6 million. China accounted for 82% of the crude silicon carbide imports and 48% of the ground or refined silicon carbide. A large part of the Chinese imports, however, reportedly included metallurgical-grade material.

During 2000, the United States exported crude silicon carbide to 15 countries and exported refined or ground silicon carbide to 26 countries. The total value of crude silicon carbide exports for 2000 increased by 13% to \$2.78 million from the total value for 1999 (table 6). Compared with 1999 exports of refined or ground silicon carbide, 2000 exports increased by about 7% to 8,810 t valued at \$8.71 million. Approximately 72% of the crude exports went to Mexico, and about 82% of the refined or ground material was shipped to Canada.

Aluminum-Zirconium Oxide

During 2000, fused aluminum-zirconium oxide for abrasive

applications (such as resin-bonded grinding wheels) was produced at two plants in Canada, one belonging to Norton Company (James Chenard, Senior Staff Accountant, Norton Company, oral commun., 2001) and one belonging to Washington Mills Electro Minerals Corp. (Martin Wozniak, Quality Assurance/Manufacturing Services Manager, Washington Mills Electro Minerals Corp., oral commun., 2001). The USGS does not publish aluminum-zirconium oxide production data received from the producers to avoid disclosing company proprietary information.

Boron Carbide

Only one firm, Washington Mills Electro Minerals Corp., was a commercial producer of boron carbide in the United States during 2000 (Martin Wozniak, Quality Assurance/Manufacturing Services Manager, Washington Mills Electro Minerals Corp., oral commun., 2001). Boron carbide was used for grinding and lapping operations previously possible only with diamond dust; it also was molded to form highly wear-resistant products, such as pressure blast nozzle liners and extrusion dies.

Domestic production data for boron carbide are not reported here to avoid disclosing company proprietary information. The following trade information on boron carbide, however, was available: the United States imported 277 t of boron carbide valued at \$6.97 million from 5 countries, primarily Germany, China, and Japan, and exported 28.6 t valued at \$481,000 to 12 nations in 2000 (U.S. International Trade Commission, [undated], HTS-2849901000—Customs value by customs value for all countries, accessed July 9, 2001, via URL http://dataweb.usitc.gov/scripts/user_set.asp).

Metallic Abrasives

Production.—Data on U.S. production and shipments of metallic abrasives were based on a survey of domestic producers conducted by the USGS. Survey data were collected from 12 companies operating 14 plants in the United States and accounted for all the domestic industry (table 3).

Steel shot and grit account for almost all metallic abrasives produced domestically (table 4). U.S. production of steel shot and grit in 2000 decreased slightly compared with that of 1999; the average value per ton was \$444. Six companies reported production of cut wire shot in 2000, and most of that was cut from carbon steel wire and stainless steel wire. Other products reported included shot cut from aluminum, copper, and zinc wire.

Consumption.—Metal abrasives are used primarily as loose particles propelled at high velocities for blast cleaning or to improve the properties of metal surfaces; approximately 75% of the abrasives are employed in cleaning operations. Principal consumers include foundries, steel manufacturers, machine tool industries, and metalworking plants, particularly those supporting the automotive and aircraft industries.

During 2000, total sales of all steel shot and grit by U.S. producers decreased slightly compared with shipments in the preceding year, and the average value per ton sold or used decreased slightly to \$449.

Prices.—The USGS compiles survey data on the value of production and shipments, but it does not collect price data. Values of production and shipments reported by metallic

abrasive producers in 2000 are listed in table 4. Values of steel shot and grit were estimated to be from \$0.35 to \$0.50 per kilogram in 2000. Estimated average values of cut wire shot in 2000 were \$3.65 to \$5.15 per kilogram for aluminum wire shot and \$2.65 to \$5.15 per kilogram for stainless steel wire shot.

Average unit values for metallic abrasives traded by the United States during 1999 were as follows: exports averaged \$0.64 per kilogram, and imports averaged \$0.52 per kilogram.

Foreign Trade.—During 2000, the United States imported metallic abrasives from 18 countries and exported metallic abrasives to 38 countries. Domestic imports increased by about 11% in 2000 to 33,500 t valued at \$17.6 million (table 5). About 68% of the imports came from Canada; most of the remaining imports were shipped from the United Kingdom, France, and Germany.

U.S. exports of metallic abrasives increased by about 9% during the year to 28,900 t valued at \$18.6 million (table 6). Most of the exports went to Canada; most of the remainder was shipped to Mexico, the United Kingdom, Japan, and Belgium.

Outlook

Economic and technological trends will most likely continue to influence the manufacturing of abrasive materials in the United States. Cheaper imports and higher domestic costs will challenge U.S. producers of fused aluminum oxide and silicon carbide. Competition from developing nations, such as China, will continue to lead to decreases in domestic output. The traditional suppliers among the Western industrialized nations are expected to continue consolidating and contracting.

Metal abrasives markets will continue to be influenced by improved technology in industries that use metallic abrasives. For example, better metal casting methods that achieve near-finish surfaces will reduce demand for some abrasives. Lesser quantities of metallic abrasives will be needed in foundries where new chemical cleaning and finishing techniques are employed.

Emerging suppliers of fused aluminum oxide and silicon carbide in China, Eastern Europe, India, the Republic of Korea, and South America will continue to increase their prominence in world markets. Further success for these suppliers, particularly in such major markets as Japan, the United States, and Western Europe, will depend on their ability to provide higher grades of material and the level of supply reliability while maintaining lower prices. Energy costs, furnace size, quality-control systems, and the availability of essential mineral inputs will be the dominant factors influencing the competitive stance of these suppliers (O'Driscoll, 1997; Zhilun, 1997; Lunghofer and Wolfe, 1998).

Motor vehicle manufacturing will remain a significant indirect influence on demand for manufactured abrasives used by metalworking operations supporting the industry. Curbs on metals consumption by the industry, such as substitution by plastics and newer lighter weight designs of automobiles, are important factors to be considered in long-range demand forecasts for manufactured abrasives.

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TABLE 1
CRUDE ARTIFICIAL ABRASIVES MANUFACTURERS IN 2000

Company	Location	Product
The Exolon-Esk Company	Hennepin, IL	Silicon carbide.
Do.	Thorold, Ontario, Canada	Fused aluminum oxide (regular).
Norton Company	Huntsville, AL	Fused aluminum oxide (high-purity) and aluminum-zirconium oxide.
Do.	Worcester, MA	General abrasive processing.
Do.	Chippewa, Ontario, Canada	Fused aluminum oxide (regular and high-purity) and aluminum-zirconium oxide.
Do.	Shawinigan, Quebec, Canada	Silicon carbide.
Washington Mills Electro Minerals Corp.	Niagara Falls, Ontario, Canada	Fused aluminum oxide (regular).
Do.	Niagara Falls, NY	Fused aluminum oxide (high-purity).
Washington Mills Ltd.	do.	Fused aluminum oxide (regular).

TABLE 2
PRODUCTION OF CRUDE SILICON CARBIDE AND FUSED ALUMINUM OXIDE
IN THE UNITED STATES AND CANADA 1/

Product	1999 r/			2000		
	Quantity e/ 2/ 3/ (metric tons)	Value e/ 2/ (thousands)	Yearend stocks (metric tons)	Quantity e/ 2/ 3/ (metric tons)	Value e/ 2/ (thousands)	Yearend stocks (metric tons)
Silicon carbide 4/	65,000	\$38,500	W	45,000	\$26,300	W
Aluminum oxide, regular, abrasives 5/	85,000	29,000	W	90,000	29,400	W

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

1/ Data are rounded to no more than three significant digits.

2/ Due to rounding, does not match total quarterly Mineral Industry Survey estimated data.

3/ Quantities are rounded to the nearest 5,000 tons to avoid disclosing proprietary data.

4/ Approximately one-half of the quantity and value consists of material for metallurgical and other nonabrasive applications.

5/ Regular grade normally accounts for about 85% of total output, and high-purity material accounts for the remainder.

TABLE 3
U.S. PRODUCERS OF METALLIC ABRASIVES IN 2000

Company	Location	Product (shot and/or grit)
Chesapeake Specialty Products	Baltimore, MD	Steel.
Ervin Industries, Inc.	Adrian, MI	Do.
Do.	Butler, PA	Do.
Do.	do.	Do.
Frohn North America, Inc.	Austell, GA	Cut wire.
Marwas Steel Co.	Scottsdale, PA	Do.
Metaltec Steel Abrasives Co.	Canton, MI	Steel.
National Metal Abrasive Inc.	Wadsworth, OH	Do.
Peerless Metal Powders & Abrasive Pellets, Inc.	Detroit, MI	Do.
Pellets, Inc.	Tonawanda, NY	Cut wire.
The Platt Brothers, Inc.	Waterbury, CT	Do.
Premier Shot Co.	Cleveland, OH	Do.
U.S. Filter Abrasive Materials	Fortville, IN	Cut wire, steel.
Wheelabrator Abrasives, Inc.	Bedford, VA	Steel.

TABLE 4
ANNUAL PRODUCTION AND SHIPMENTS FOR METALLIC
ABRASIVES IN THE UNITED STATES, BY PRODUCT 1/

Product	Production		Shipments 2/	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1999:				
Steel shot and grit	278,000	\$122,000	282,000	\$122,000
Cut wire shot and other e/	2,010	7,150	2,010	7,170
Total	280,000	129,000	284,000	130,000
2000:				
Steel shot and grit	266,000	118,000	270,000	121,000
Cut wire shot and other e/	2,140	7,120	2,130	7,120
Total	269,000	125,000	272,000	128,000

e/ Estimated.

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

2/ Includes reported exports.

TABLE 5
U.S. IMPORTS OF ALUMINUM OXIDE AND SILICON CARBIDE, BY COUNTRY AND TYPE 1/

Country	1999		2000	
	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)
Crude aluminum oxide:				
Canada	55,600	\$22,400	48,800	\$19,700
China	31,200	6,800	45,200	8,080
Russia	1,320	638	5 3/	24 3/
Venezuela	2,600	1,470	16,200	7,240
Other	566	249	169	117
Total	91,400	31,500	110,000	35,200
Ground and refined aluminum oxide:				
Austria	8,910	12,200	10,000	13,700
Brazil	6,900	4,850	7,530	5,400
Canada	22,500	8,390	39,900	14,300
China	23,600	6,440	43,500	11,600
France	1,660	2,290	2,890	3,310
Germany	7,380	8,640	8,150	10,400
Italy	1,210	1,140	1,860	1,720
Slovenia	1,110	699	1,290	696
Other	1,130	2,380	1,730	3,520
Total	74,400	47,000	117,000	64,700
Crude silicon carbide:				
Canada	27,100	17,800	15,600	9,280
China	123,000	33,200	133,000	41,500
Russia	3,960	1,690	4,510	2,000
Venezuela	616	282	251	108
Other	523	635	7,980	3,830
Total	155,000	53,600	162,000	56,700
Ground and refined silicon carbide:				
Brazil	2,300	1,840	5,420	3,440
Canada	247	78	296	205
China	3,490	2,540	13,500	8,230
Germany	1,470	5,630	1,930	6,110
Japan	1,250	7,570	1,750	10,400
Norway	2,600	5,890	2,830	6,980
Mexico	347	383	382	431
Russia	2,070	839	1,440	477
Other	473	1,130	769	1,290
Total	14,200	25,900	28,300	37,600

See footnotes at end of table.

TABLE 5--Continued
U.S. IMPORTS OF ALUMINUM OXIDE AND SILICON CARBIDE, BY COUNTRY AND TYPE 1/

Country	1999		2000	
	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)
Metallic abrasives:				
Canada	24,900	\$10,200	22,900	\$10,300
France	846	317	2,760	2,690
Germany	1,240	2,250	1,560	1,070
Japan	339	586	451	770
United Kingdom	1,730	1,140	2,520	1,090
Other	995	628	3,330	1,600
Total	30,100	15,200	33,500	17,600

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

2/ Customs value.

3/ All or part of these data have been referred to the U.S. Census Bureau for verification.

Source: U.S. Census Bureau.

TABLE 6
U.S. EXPORTS OF ALUMINUM OXIDE, SILICON CARBIDE, AND METALLIC ABRASIVES,
BY COUNTRY AND TYPE 1/

Country	1999		2000	
	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)
Crude aluminum oxide:				
Canada	1,960	\$2,490	2,080	\$2,660
Germany	1,950	7,510	2,160	7,390
Mexico	2,280	2,020	1,680	2,070
Netherlands	883	603	905	830
Other	1,950	7,770	2,200	10,600
Total	9,020	20,400	9,020	23,500
Crude silicon carbide:				
Japan	58	954	187	834
Mexico	131	471	871	1,290
Sweden	32	11	79	29
Other	77	1,020	69	627
Total	299	2,460	1,210	2,780
Ground and refined silicon carbide:				
Canada	6,800	5,500	7,260	4,660
Japan	236	998	318	2,160
Mexico	690	691	750	737
Other	530	1,280	483	1,150
Total	8,260	8,470	8,810	8,710
Metallic abrasives:				
Belgium	631	233	551	197
Canada	14,600	6,090	16,000	6,750
Japan	498	460	1,040	531
Mexico	7,350	6,520	8,820	7,360
United Kingdom	2,490	2,610	1,040	1,350
Other	1,010	1,970	1,400	2,450
Total	26,600	17,900	28,900	18,600

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

2/ Customs value.

Source: U.S. Census Bureau.