

## BLASTING ABRASIVES IN THE U.S. MARKET

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**Abstract:** Every year the United States consumes millions of dollars worth of abrasive materials as blasting media. Entrained in either a gas or liquid stream or propelled by paddles or wheels, they are directed onto the surface of another material to modify that surface.

### INTRODUCTION

The U.S. Bureau of Mines estimated that in 1994 the value of mineral abrasive blasting media consumed in the United States was about \$200 million. Most open-air and enclosed blasting applications use abrasives entrained either in a gas (usually air) or a liquid (usually water). Blasting machines propel abrasive grit with paddles or wheels for indoors blasting in rooms and cabinets. The blasting medium strikes against the surface of a material to complete some type of work.

### TYPES OF BLASTING

When a blasting medium impacts a surface it results in one or more of the following types of work: cleaning, cutting, deburring, etching, finishing, or peening. The specific type or types of work accomplished depends upon the shape and composition of the impacted material. It also depends upon the type of blasting medium used, the rate, force, and duration of the application, and the type or nature of the applicator.

**Cleaning** Cleaning applications remove contaminants or coatings from a surface without any modification or change to its shape, contour, or texture. The intent is to recondition or restore the surface to near original condition.

The Steel Structures Painting Council (SSPC) and the National Association of Corrosion Engineers (NACE) each have three specifications for cleaning with blasting abrasives. These include SSPC-5 and NACE-1 for cleaning to white metal, SSPC-10 and NACE-2 for cleaning to near white metal, and SSPC-6 and NACE-3 for cleaning to a commercial cleanliness.

In most applications, cleaning to commercial cleanliness is all that is necessary. Commercial cleanliness require the removal of all oil, grease, dirt, rust, scale, and foreign materials. Yet, slight streaks or discoloration created by rust, mill scale, or tight residues of coatings may remain. The near white metal and white metal specifications are extremely rigid. At least 95% of contaminants must be removed for near white metal and 100% for white metal. Examples of blast cleaning applications include the removal of sand from foundry castings, hardened grease and oil from auto parts, scale and corrosion from pumps, turbines, and heat exchanger tubes, scale from weathered steel, rust from bridges, and light mill scale and rust in shipyards.

**Cutting** In blast cutting applications an abrasive is most often entrained in a liquid (usually water) and directed onto the surface of a material or stack of materials to cut a pattern onto the surface or to cut completely through the material. The most common cutting application makes use of some type hydrojet cutting system. The inscribing of stone and monuments often uses some type of air cutting system.

In abrasive jet cutting, abrasive grains, usually 0.18 millimeter in size, are injected into a stream of high-velocity water. The supersonic abrasive slurry impinges on the material to be cut at a pressure of at least  $5.5 \times 10^8$  Pa. Abrasive jet cutting can shape-cut materials such as marble, granite, artificial stone, concrete, aluminum, titanium, high-strength steel and steel bridge decking, automotive glass, textiles, corrugated boxboard, plastic laminates, and aerospace composites. Systems for engraving or contouring stone markers and monuments are less powerful, lower in velocity, and use larger diameter abrasives.

**Deburring** Deburring applications remove excess material from die cast, molded, sintered, or stamped pieces by blasting. It is important that no degradation of the deburred surface is caused by the deburring abrasive. Applications include the deburring of tools, dies, castings, machine parts, threads, gears, cutting and drilling tools, and auto parts.

**Etching** In etching applications blasting abrasives modify the impacted surface. The abrasive aggressively removes part of the surface material and imparts a pattern of ridges, grooves, or stipples. These patterns serve as anchors for paints, coatings, or bonding. Often, blasting results in both cleaning and etching at the same time. Examples of etching applications include the preparation of structural steel, ships, barges, tanks, concrete piers and pilings, bridges, and pipelines for painting, coating, or bonding.

**Finishing** In finishing applications the blasting medium imparts a dull, matte, textured, or polished finish to the surface of the impacted material. This matte or textured surface is not an anchor or preparatory surface but is the final finish. Fused aluminum oxide (FAO) blasting creates a matte finish on some metal surfaces, and fine silica sand can blast polish the surface of soft metals.

**Peening** In peening applications the blasting medium imparts residual compressive stresses to improve fatigue strength characteristics and to enhance the resultant working life of the component. The extensive peening of torque or load-bearing members, such as automotive springs, steering knuckles, torsion and sway bars, camshafts, crankshafts, gears, and railroad wheels is common.

## SPECIFICATIONS

Federal and state agencies and professional organizations issue specifications specific to blasting media. The following are summaries of some of the more important specifications.

**Military** If a blasting medium is to be used at a U.S. Navy shipyard or at a private shipyard working on U.S. Navy vessels, then it must meet Mil-A-22262(SH) specifications. This then qualifies it for product list QPL-22262. These specifications set forth limits on the content of total metals, soluble metals, and radiation, and they specify the acceptable level of chemical conductivity. They also require certification of the material by the California Air Resources Board.

If a blasting medium is to be used for quality peening by the military or its contractors, then it must conform to military specification Mil-851B. For the highest quality peening it must conform to specification Mil-13165C.

The military specification for all blasting

media is Mil-A-21380B "Abrasive Materials For Blasting." This specification defines the types of blasting media, size ranges, allowable silica content, hardnesses, and specific gravities. It also defines where a medium is to be used in wet or dry blasting applications.

Society of Automotive Engineers The Society of Automotive Engineers specification SAE-J827 defines the chemical analysis, microstructure, density, hardness, and general appearance of cast steel shot for use in the automotive industry.

California Air Resources Board The California Air Resources Board (ARB) requires all loose grain abrasives used in the state to be certified at the ARB testing facility. The testing is conducted according to "Methods of Test of Abrasive Media Evaluation," Test Method No. Ca 371-A and as required under ARB's Title 17, Subchapter 6 entitled "Abrasive Blasting." Copies of these documents are available from the Compliance Division of the California Air Resources Board in Sacramento, CA. In addition, air pollution control agencies in Utah, Minnesota, and Louisiana have adopted the ARB tests and require only ARB-certified abrasives on state projects requiring sandblasting. The ARB's testing procedures and standards focus on the environmental effect of sandblasting abrasives, not on their qualities or cutting performance/efficiency.

Steel Structures Painting Council The Steel Structures Painting Council, a technical organization in Pittsburgh, PA that has a committee on abrasives, prepared abrasive specification SSPC-XAB1X, "Mineral and Slag Abrasives," which addresses blasting abrasives. The specification defines the requirements for selecting and evaluating mineral and slag abrasives used in blast cleaning steel and other surfaces for painting and other purposes.

Steel Founders' Society of America The Steel

Founders' Society of America, a technical organization in Ohio, has a cast steel abrasive specification SFSA-20T-66. The specification covers all cast steel abrasives for general foundry use in the blast cleaning of steel castings. The specification includes nomenclature for shot and grit sizes, chemical composition, and microstructure. It also sets limits on percent voids and cracked particles, on free graphite and ferrite, and on particle shape.

## ENVIRONMENTAL EFFECTS

With any blasting media, there is the possibility of nuisance dust. Disposal of any blasting medium, if they do not contain leachable metals, do not pose a problem as they can be sent to the local solid waste landfill. All used blasting media will contain contaminants from the particular blasting application. These contaminants may require disposal of the media in other than the local solid waste landfill.

FAO and Silicon Carbide (SiC) The environmental effects of using FAO or SiC as a blasting medium are negligible if not nonexistent. They are essentially chemically inert, is noncarcinogenic, and contains no crystalline silica. As with any blasting medium, there is the possibility of nuisance dust being generated. One possible environmental effect is the contamination of blasted materials. Because of their high hardness FAO and SiC particles may become embedded in a blasted surface.

Coal, Copper, and Nickel Slags The environmental effects of slag as a blasting medium depend on the specific slag used. The effect of a slag that contains no leachable metals and has a free silica content of 0.1% or less is negligible. Chemical properties and free silica content can vary widely between slags. Reports indicate that some slags may contain leachable metals and that the free silica content can vary from less than 0.1% to more than 1%. A slag containing leachable metals and more than 0.1%

free silica could have significant adverse environmental effects if used at certain sites.

Garnet and Olivine The environmental effects of using garnet or olivine as a blasting medium are negligible if not nonexistent. They are essentially chemically inert, noncarcinogenic, and contains little or no crystalline silica.

Metallic Abrasives Most systems using metallic shot and grit are closed systems, so the environmental effects are negligible. If used in the open, metallic abrasives pose the problem of releasing metal (iron) to the environment. Also, metallic abrasives may contaminate impacted surfaces with pieces or streaks of the abrasive. Such contamination can lead to corrosion or coating failure.

Disposal of spent metallic shot or grit can pose a problem, because the waste contains leachable iron and contaminants derived from the particular blasting application. Disposal of spent media as a hazardous waste may be required.

Silica Sand Silica sandblasting media are essentially 100% crystalline silica, also called free silica. The Occupational Safety & Health Administration regulates the use of silica sandblasting media, because inhaling fine crystalline silica dust can cause silicosis.

During the 1980's, published data suggested that crystalline silica also is a carcinogen, and in 1987 the International Agency for Research on Cancer declared that crystalline silica a probable carcinogen for humans. As a consequence, crystalline silica now comes under the Occupational Safety and Health Administration's (OSHA) Hazard Communication Standard (HCS). The HCS requires that OSHA-regulated operations that use items containing more than 0.1% crystalline silica must follow OSHA requirements regarding worker training and notification of the hazards of such items.

Because of the silicosis and carcinogen threat, the environmental effects or perceived environmental effects of using silica sandblasting media can be significant.

Staurolite The environmental effects of using staurolite as a blasting medium are negligible if not nonexistent. Staurolite is essentially chemically inert and is non-carcinogenic. It may contain varying amounts of crystalline silica and the amount of crystalline silica present could determine its environmental effects.

### RECYCLE/RECLAIM

Often in the mineral and mineral-related industries the terms recycle and reclaim are used interchangeably. In blasting, however, these terms refer to two totally different actions. The blasting abrasives used in blast cabinets routinely recycles 3 or more times, and some recycling is practiced even in open-air blasting applications, such as at shipyards. Reclaiming requires processing spent material through a more complex system (often off-site) that removes contaminants and may grade the recovered medium into various sizes.

FAO FAO is recycled 3 to 5 times in blast cabinets and even sees some recycling in open-air applications. There are a number of facilities in the United States that reclaim spent FAO medium.

Coal, Copper, and Nickel Slag, Olivine, and Silica Sand Slag blasting medium is usually a once through one-time use abrasive. There may be limited recycling in some shipyard uses, but there is no know reclaiming of slag. Given the dollar value per ton of virgin slag, there is very little incentive to reclaim.

Garnet One cost advantage of using garnet as a blasting medium is that it can be both recycled and reclaimed. It is not uncommon for garnet to be recycled 3 to 5 times in most contained or

semicontained operations. IGA operates a garnet reclamation plant intermittently near Harvey, LA.

**Metallic Abrasives** Blasting machines designed for metallic abrasives ordinarily screen out contaminants and undersized shot. This enables metallic blasting media to be recycled as many as 50 times. There are at least four plants in the United States that reclaim metallic abrasives for resale.

**SiC** SiC in blast cabinet work can be recycled 50 to 100 times before the grains break down into sizes too small to be used again. In all other applications, SiC is essentially a once-through blasting medium. Some SiC abrasives are reclaimed, but blasting media currently are not.

## **OUTLOOK**

Essentially, all blasting abrasives are established and their uses are well defined. There is little chance for new uses and shipyard applications may continue to decline. As regulations on the use of silica sand as a blasting grit increase, this may well determine the future growth in the use of other blasting abrasives.

**FAO** FAO is an established blasting medium, so any increase in its consumption will probably come from regulations restricting the use of other blasting media in outdoor applications. If the aggressive nature of the FAO grains can be controlled, then there will be increased use of it in hydrojet cutting. Prices of FAO are and will continue to be under pressure from imports from the People's Republic of China. Chinese material is available for about \$245 per ton FOB Chinese ports, which is equivalent to about \$350 per ton delivered to US ports or about 54% of the price of North American material.

**Coal, Copper, and Nickel Slag, and Olivine** Essentially, slag is an established and well

defined blasting medium. There is little chance for new uses, and the shipyard use may continue to decline. Slag blasting medium is the second least expensive blasting medium, only silica sand is cheaper. As regulations on the use of silica sand grit increase, the logical and economical replacement or first substitute would be slag. Future growth in the use of slag abrasives are tied to the increased regulation of crystalline silica.

**Garnet** The increasing use of and types of applications for hydrojet cutting will have a positive effect on consumption of garnet. Garnet also is making some inroads in shipyard applications. As consumers become more conscious of cost per unit cleaned and etched and less oriented simply to purchase price per ton, garnet should capture an increasing share of the abrasives market currently held by silica sand and slags. As regulations on the use of silica sand as a blasting medium become tighter, the most logical and economical replacement or first substitute will be coal slag followed by copper slag. If total cost per unit treated becomes the determining factor, however, then garnet could well become the first choice substitute for silica sand. Increased regulation of crystalline silica is likely to determine at least some of the growth in the use of garnet abrasives.

**Metallic Abrasives** The production of steel shot and grit closely tracks the index for the production of raw steel. Therefore, production will increase in years of economic growth and war years and will decrease during periods of economic downturns. Metallic abrasives appear to be a mature blasting medium, and the likelihood of new markets emerging is limited.

**Silica Sand** Essentially, silica sand is a well-established medium, and there is little chance that new applications for it as a blasting abrasive will emerge. Silica sand is the least expensive blasting medium. As regulations on its use

increase, sandblasting applications will seek substitutes and its consumption will decline.

**SiC** Essentially, SiC is a well-established blasting medium. One area of possible growth in demand is hydrojet cutting. If the use of hydrojet cutting continues to increase, some applications will require or choose SiC as the cutting medium.

**Staurolite** Essentially, staurolite is an established blasting medium, but there is some chance for new uses. There are some applications where staurolite's physical characteristics are preferred to other blasting agents. Staurolite blasting medium are among the less expensive blasting media, only silica sand and slags are cheaper. As regulations on the use of silica sand as a blasting media increase, the logical and economical replacement or first substitute would be a slag or staurolite, depending upon transportation costs. Some future growth for staurolite blasting medium will be tied to the increased regulation of crystalline silica.

## **BLASTING ABRASIVES**

As noted earlier, there are many different types of blasting media. Both organic and mineral abrasives are used in blasting applications. Included below are information and data on FAO, coal slag, copper slag, garnet, metallic shot and grit, nickel slag, olivine, silica sand, SiC, and staurolite.

**FAO** Regular or brown FAO (also known as artificial corundum) is made by fusing calcined abrasive bauxite in an electric arc tilt pour or tapping furnace. The material is more than 99% fused, more than 94%  $Al_2O_3$ , and at least 50% monocrySTALLINE. It has a hardness greater than 9.0 on the Mohs scale and a specific gravity of about 4.0. High-purity, white or pink FAO, (also known as artificial corundum) is made from extremely pure alumina obtained by the

Bayer process. High-purity FAO is at least 99.5%  $Al_2O_3$ , and it is harder but more friable than the regular grade.

**Production** The U.S. Bureau of Mines considers the United States and Canadian FAO production facilities as a single industry. Exolon-ESK Co. produces regular-grade material at Thorold, Ontario. General Abrasives Triebacher, Inc. produces regular-grade and high-purity materials at Niagara Falls, NY and regular grade at Niagara Falls, Ontario. Saint-Gobain/Norton Industrial Ceramics Corp. produces high-purity FAO at Huntsville, AL and both regular and high-purity grades at Chippawa, Ontario. Washington Mills Electro Minerals Corp. produces regular-grade material at two plants at Niagara Falls, Ontario and high-purity FAO at Niagara Falls, NY. Additionally, several companies in the United States import crude and refined FAO. The countries of origin for most of the refined material are, in descending order, Austria, Japan, Brazil, and China, according to Bureau of Census data.

**Consumption and uses** During 1994, blasting media, one of approximately 10 end uses for FAO, accounted for only about 21% of the total value of FAO consumed in the United States. Its blasting applications are cleaning, cutting, deburring, etching, and finishing. Applications include air-suction blast cabinets, open-air large surface area blasting, certain shipyard weld blasting, and special applications for microblasting and blast polishing. The two largest applications are cleaning and etching.

Many different industries use FAO to blast clean parts or assemblies. The cleaning may involve the simple removal of corrosion or mill scale from parts before assembly or the preparing of parts or entire assemblies for painting or coating. Railroad and subway systems use FAO to clean rails, and at least one military specification requires it for the cleaning of aircraft carrier flight decks. The largest

single use is in wire and cable manufacturing for the cleaning of finished products.

The medical and dental industries also use FAO. The medical industry uses it to clean needles. The dental industry's new kinetic cavity preparation system uses about 4 million micron-size FAO particles per second to remove decay. Dentists also use the kinetic system to clean bonding work. Bonding involves using plastic to repair chips, fractures, or deformities in teeth and to seal them. Until the introduction of the FAO blasting system it was difficult, if possible, to clean stains from bonding work. The kinetic system can be used in either a cleaning or an etching application.

When blast cleaning surfaces with FAO before painting or coating, etching also can occur. Often it is the intent that the procedure serve this two-fold purpose. Because of its hardness FAO will etch all but the hardest surfaces, leaving a good profile for paint and coating adhesion.

Additionally, it is common to blast debur titanium metal parts and both sintered and cemented carbide tools. Not as commonly, FAO is used to blast polish glass and to produce matte finishes on glass, certain dimension stones, and metals.

**Coal Slag** Coal slag is a mixture of ferro-aluminum silicate, calcium silicate, and silica that is a by-product of burning coal in electric power generation plants. Its free silica content varies from less than 0.1% to 1.00%. Coal slag has a Mohs hardness of about 7.5 and a specific gravity of about 2.78. Processing the slag from power plants involves crushing, screening, grading, drying, and packaging for shipment. "Black Beauty" is the Reed Minerals Division of Harsco Corp's. trade name for coal slag. Today, many consumers use this name as a generic term for all coal slag abrasives.

**Production** Many coal-burning electric power plants in the United States produce coal slag. Yet, more important to the blasting industry are the companies and plants that process the slag into blasting media. In total, 8 companies currently operate 26 plants. Reed Minerals is by far the largest with 15 plants, followed by Grangrit (Stan-Blast Abrasives), Inc. with 3 plants, Foster Dixiana Corp. and Stan-Blast Abrasive Company, Inc. each with 2 plants, and Genstar Stone Products Co., Virginia Materials & Supplies, and Tidewater Materials each having a single plant.

The actual process of treating and preparing coal slag can vary greatly from plant to plant. The simplest plants only screen, grade by size, and package for shipment. The most complex plants crush, screen, upgrade with magnetic separators, grade by size, dry, and package for shipment. The material is sized into three grades, -10+40 mesh, -12+40 mesh, and -30+60 mesh.

**Consumption and uses** The major use for coal slag is as a blasting medium. Other uses include applications as roofing granules, additives for ceramics, and aggregates for asphalt coatings. Abrasive applications are primarily for etching and to a lesser extent for cleaning. Blasting applications are at shipyards, for cleaning concrete piers, pilings, and dock works, tank cleaning, bridge cleaning and etching, cleaning mill scale and rust from steel, and cleaning and etching heavy equipment and truck frames.

Shipyards, including new ship construction and ship and barge repair and maintenance, used to be the largest consumers of coal slag abrasives. With the decline of US shipbuilding and yard work, however, the end use pattern has changed. Currently, it appears that the largest end uses are the cleaning and etching of outdoor structures, primarily bridges, before painting, repainting, or coating them. Shipyard

applications now place second.

**Copper Slag** Copper slag is a mixture of ferro-silicate, ferro-aluminum silicate, calcium silicate, magnesium silicate, and silica with trace amounts of antimony, arsenic, copper, and lead. It has a specific gravity of 3.4 to 3.6 and a Mohs hardness between 7 and 8.

**Production** There are 8 operating primary, 4 operating secondary, and several inactive copper smelters in the US, each with the potential to supply slag for abrasive applications. Currently, 4 companies operate 4 plants processing copper slag. Apache Abrasives in Texas, Minerals Research & Recovery, Inc. in Arizona, MDC Industries, Inc. in Pennsylvania, and RDM Multi-Enterprises, Inc. in Montana. The largest single marketer of copper slag in the United States, Kleen Blast Abrasives, imports 100% of its material from Canada.

The actual process for treating and preparing copper slag can vary greatly from plant to plant. The simplest plants only screen, sized, and package for shipment. The most complex plants may crush, screen, upgrade with separators, grade by size, dry, and package for shipment. The material is graded by size into five grades, -8+12 mesh, 16 mesh, -16+30 mesh, 35 mesh, and -30+60 mesh.

**Consumption and uses** The major use for copper slag is as a blasting medium. Other uses include applications as roofing granules and as aggregate for asphalt coatings. Abrasive applications are primarily etching and to a lesser extent cleaning. Applications as a blasting medium are at shipyards, for cleaning concrete piers, pilings, and dock works, bridge cleaning and etching, cleaning mill scale and rust from steel, cleaning and etching heavy equipment and truck frames, and cleaning nonferrous car bodies, light steel and hardwoods.

Shipyards, including new ship construction

and ship and barge repair and maintenance, were the largest consumers of copper slag abrasives. The decline in US shipbuilding and yard work, however, has changed the end use pattern. Currently, the largest end uses are for cleaning and etching of outdoor structures, primarily bridges, before painting, repainting, or coating them. Shipyard uses are now second.

**Garnet** Garnet is a general name for a family of complex silicate minerals having similar physical properties and crystal form. The general formula for garnet is  $A_3B_2(SiO_4)_3$ , where A can be calcium, magnesium, ferrous iron, or manganese. B can be aluminum, ferric iron, chromium, or rarely titanium. The most common garnet species are  $Mg_3Al_2Si_3O_{12}$  (pyrope) and  $Fe_3Al_2Si_3O_{12}$  (almandite). Almandite and almandite-pyrope solid solution garnets are the best abrasive garnets. Other garnets used include andradite, grossularite, and pyrope. Garnet displays the greatest variety of color of any industrial mineral, coming in all colors except blue. Its Mohs hardness varies from 6.5 to 9.0. Grossularite and uvarovite have a hardness of 6.5 to 7.5, andradite is 6.5 to 7.0, and pyrope, almandite, and spessartite are 7.0 to 7.5 in hardness. There are reports of almandite having a hardness between 8.0 and 9.0. As with color and hardness, the specific gravity of garnet varies considerably. It may be as low as 3.2 or as high as 4.3 depending on chemical composition. Pure garnet contains no free silica.

**Production** Currently five firms produce garnet from five plants in two states in the US. Each company has distinctive products. Barton Mines Corp's garnet in Warren County, NY, garnet is a mixture of almandite and pyrope and is at the top of the hardness range. The NYCO Minerals, Inc's. garnet in Essex County, NY and that produced by International Garnet Abrasives Inc. (IGA) in Clinton County, NY are a mixture of andradite and grossularite. The crude garnet concentrate also may contain

diopside-hedenbergite ( $\text{Ca}[\text{MgFe}]\text{Si}_2\text{O}_6$ ). NYCO recovers a crude garnet concentrate as a byproduct at its wollastonite operation, and IGA produces refined garnet products from that concentrate. Paterson Materials produce garnet at Wingdate, NY. Emerald Creek Garnet Co. mines and processes garnet in Benewah County, ID.

**Consumption and uses** The aluminum aircraft and shipbuilding industries in California and the Pacific Northwest use lower quality, lower cost alluvial garnet, primarily from Idaho, as a blasting medium. The aircraft industry uses garnet for peening, and the shipyards use it to clean and etch. Similar uses in the eastern United States are for cleaning and peening aluminum and other soft metals and for cleaning and etching metal in structural steel fabrication shops.

Hydrojet cutting is one of the most rapidly growing uses for garnet. Entrained in a high-pressure stream of water, fine garnet grit can cut a wide variety of materials.

In blasting applications the most widely used domestically produced garnet is  $-1.0+0.3$  mm in grain size, and the next most widely used grade is  $-0.59+0.21$  mm. The most popular grade of imported garnet in the US blasting market is  $-0.59+0.25$  mm material from Australia. Hydrojet cutting's most popular grade is  $-0.25+0.177$  mm, which may account for as much as 90% of the garnet used in this market segment.

**Metallic abrasives** Metallic abrasives include steel shot and grit, chilled or annealed iron shot and grit, and cut wire shot. Steel and iron shot essentially are cast spheres made by spraying molten metal into a quenching water bath. Steel and iron grit are either broken or crushed shot. Cut wire shot is, as the name implies, made by cutting wire of various diameters and materials. The length of the cut is usually equal to the

diameter of the wire. Steel shot and grit make up the bulk (90%) of metallic abrasives used.

**Production** Ten companies operating eleven plants make metallic abrasives --four producing cut wire shot, two producing iron shot and grit, and seven producing steel shot and grit. Some plants produce both iron and steel abrasives.

The manufacture of steel shot and grit requires premium steel scrap that is low in sulfur and phosphorous. An electric furnace melts the scrap to refine and alloy it under very close chemical and metallurgical specifications. The molten metal is metered through nozzles and made into spheres by being struck by high-pressure water sprays or by mechanical means. A water bath quenches the hot spherical shot. Rotary or batch furnaces dry and then heattreat the shot. After heat treatment the shot is again water quenched. The spherical shot is tempered, cooled, and screened to standard sizes. Grit is made by crushing the fully hardened shot, screening the resulting media and tempering.

**Consumption and uses** One use for steel shot or grit is the cleaning of small, medium, and large steel and malleable grey iron castings. Another use is the batch or continuous cleaning of heavy-duty parts and forgings. Steel shot and grit clean bar and rod stock, billets and slabs, stainless sheet and strip, and carbon and silicon sheet and strip mill products. Pipe, structural shapes and plates, and welds also are cleaned by steel shot or grit. Shot and grit are used in deburring and radiusing small and delicate parts, machined parts, and medium-size ferrous and nonferrous parts. Plastic and rubber products are deflashed with them, and the peening of thin, intermediate, moderately heavy, and heavy metal sheet is done using various sizes of steel shot. It is used in reconditioning automotive components and metal containers, for etching before painting, galvanizing or plating, and for a final textured finish.

Shot and grit also may be used as a toner carrier for copy machines, barrier material in radiation shields, weight additive in high-density concrete, and as ballast in ships. The mining industry uses shot as grinding media and in the gang sawing of dimension stone such as granite and marble.

**Nickel Slag** Nickel slag is essentially a mixture of magnesiumferro-silicate and silica with trace amounts of other nonleachable minerals. It has a specific gravity of 3.4 to 3.6 and a Mohs hardness between 7 and 8. Reportedly, its free silica content is less than 0.01% by weight. "Green Diamond" is the trade name for nickel slag.

**Production** Green Diamond Abrasives produces nickel slag abrasives and other products using slag from a smelter near Riddle, OR. Glenbrook Nickel Co., a wholly-owned subsidiary of Cominco American Resources, owns and operates the smelter. Processing the slag includes crushing, screening, grading to size, and packaging for sale. Kayway Industries, Inc. of Winnipeg, Manitoba imports nickel slag abrasives for sale in the United States.

**Consumption and uses** About 70 to 75% of the nickel slag processed in the United States annually is consumed as an abrasive. Uses include blasting to clean and etch in shipyards, on concrete structures, on major steel structures such as bridges, and on major pipelines such as the Trans-Alaskan. Other uses for nickel slag include roofing granules, construction overlay, and as a filler.

**Olivine** Olivine ( $Mg_2Fe_3SiO_4$ ) is a greenish, transparent to translucent mineral generally found as granular masses or disseminated grains or crystals. Olivine has a Mohs hardness of 6.5 to 7, a specific gravity of 3.2 to 3.6, and a conchoidal fracture. It is a common constituent of basic igneous rocks such as basalt and

gabbro, and dunite is an olivine-rich rock.

**Production** Currently two firms produce olivine from three mines in two states. Applied Industrial Materials Corp. (AIMCOR) operates two mines, one each in North Carolina and Washington, and processing plants in Indiana, North Carolina, and Washington. Olivine Corp. operates one mine and a processing plant in Washington.

**Consumption and uses** Abrasive blasting accounts for only about 11% of annual production of olivine in the United States. Foundry uses are the largest consumer followed, by refractory applications. AIMCOR markets olivine blasting media under the trade name "Green Lightning." AIMCOR produces six or seven blasting grades according to customer specifications. It appears that the largest uses of olivine as a blasting agent are to clean buildings and to clean and etch some structural steel, such as bridgework.

**Silica Sand** Silica sandblasting media are round, subangular, or angular grains of fracture-resistant crystalline silica. They are of uniform hardness (7.0 on Mohs scale), resistant to high temperature, chemically inert, crush resistant, and have a specific gravity of 2.65.

**Production** In 1994, 48 companies operating 84 mines produced, processed, and marketed silica sandblasting media in the United States. The ten largest producers were Cobb Industrial Corp., Oglebay Norton Co., Specialty Sand Co., Pioneer Concrete of Texas, Inc., The Morie Co., Inc., RMC Lonestar, Mid-State Sand and Gravel Co., Inc., Huey Stockstill Inc., Foster Dixiana Corp., and Unimin Corp.

Processing silica blasting sands includes washing, drying, screening to size, and packaging for shipment. There are essentially five grades of blasting sand, but the terminology for them varies from company to company.

Consumption and uses Producers in the United States marketed approximately 1.6 million metric tons of blasting abrasive media valued at about \$37.5 million in 1994. Blasting applications include cleaning, etching, cutting, deburring, and finishing. Peening is the only blasting application in which silica sand is not used. The largest application is for etching. Because of its high hardness, silica sand routinely removes some of the blasted surface, leaving a good profile for paint and coating adhesion. Silica sand is the most commonly used blasting agent at shipyards, and on structural steel, marine structures, and storage tanks for removing paint, strip coating, and the preparation of corroded or rusted steel.

The second largest application is for cleaning. The most commonly used abrasive for blast cleaning buildings and concrete structures, rail cars, and industrial tanks and silos is silica sand. Other uses include cleaning light mill scale, rust, and corrosion from ferrous and nonferrous metals.

Silica sand is used to blast a frosted finish on glass. It also is used to blast finish or polish soft metal surfaces. Rotating or vibrating deburring machines and certain cutting operations use a small amount of silica sand.

SiC SiC is made by fusing high-purity silica sand and petroleum coke or another source of carbon by passing a high-voltage electric current from carbon electrodes at each end of a furnace through a graphite core. Small amounts of sawdust and salt are added to help control the reaction. The resulting product is 85 to 90% SiC. It has a hardness greater than 9.5 to 9.6 on the Mohs scale and a specific gravity of 3.12 to 3.22.

Production The U.S. Bureau of Mines considers the production of SiC in the United States and Canada as a single industry. Exolon-ESK Co. produces SiC at Hennepin, IL;

General Abrasives Triebacher, Inc. produces it at Niagara Falls, Ontario; Saint-Gobain/Norton Industrial Ceramics Corp. produces it at Shawinigan, Quebec; and Superior Graphite Co. produces it at Hopkinsville, KY. Additionally, several US companies import crude and refined material. The countries of origin for most of the refined SiC are, in descending order, Norway, Canada, Germany, Japan, Mexico, and Sweden. China and Canada are the largest suppliers of imported crude, according to Bureau of Census data.

Consumption and uses During 1994, blasting was one of the smallest of the approximately 12 major end uses for SiC. It accounted for only about 0.4% of the total value of SiC consumed in the United States. The major drawback to using SiC as a blasting medium is that it wears out blast nozzles extremely fast because of its very high hardness.

SiC blasting applications are cleaning, cutting, and finishing in air-suction blast cabinets. Other applications include microblasting and blast polishing in the glass industry, stone cutting in the monument industry, and hydrojet cutting. The two largest applications are cleaning and cutting.

Staurolite Staurolite is a naturally occurring, complex, hydrated aluminosilicate of iron having a variable chemical composition. The mineral most commonly is found as opaque, reddish brown to black crystals. It has a Mohs hardness between 7 and 8 and a specific gravity ranging from 3.74 to 3.83.

Production E.I. du Pont De Nemours & Co., Inc. produces staurolite as a byproduct of heavy mineral concentrates recovery from beach sand deposits in Clay County, north-central Florida. Electrostatic and magnetic separators remove staurolite from the concentrates after scrubbing, washing with caustic, rinsing, and drying. The resulting material consists of about 77% clean,

rounded, and uniformly sized grains of staurolite, with minor amounts of tourmaline, ilmenite and other titanium minerals, zircon, and quartz.

Consumption and uses The major use for staurolite is as a blasting medium for the impact finishing of metals and the blast cleaning of buildings. The blasting media trade names are "Starblast" (80 mesh) and "Biasill" (90 mesh). Some coarser material (55 mesh) also is used as a blasting medium. Staurolite also is used as a molding material in nonferrous foundries and in some portland cement formulations.

### SUMMARY

Cleaning, cutting, deburring, etching, finishing, and peening are all, except for hydrojet cutting, mature blasting applications. New or expanded use opportunities in a mature industry are limited. In fact, maturity often results in decreased use because of improved technologies. The use and growth in consumption of blasting media are dependent upon a strong and expanding economy. Therefore, the near term (i.e., next 5 years) does not appear to hold much promise for significant growth in the blasting media business. Military and civilian uses will be stable or may even decrease because of military cutbacks and a changing civilian economy. The rebuilding of infrastructure may strengthen the blasting market because of increased bridge repair and maintenance.

Tighter regulation of crystalline silica will decrease the demand for silica sandblasting media and improve the demand for other blasting media, except possibly for SiC. SiC is the least likely to benefit from increased regulation of silica sand because of its price and its excessively aggressive nature. Organic and mineral abrasive blasting media are not in short supply, nor will they be in the foreseeable future. They are a very necessary part of the

US economy. They are "blue collar" commodities, doing "blue collar" work, but like all things "blue collar" the US economy could not exist without them.

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