Chapter 2.3
Nonmetallic Abrasives

H. William Hitzrot (original chapter)
James Hansink (2002 revision)

Introduction

Nonmetallic abrasives used for blast cleaning may be classified as mineral abrasives, slag and other by-products, and manufactured abrasives. Physical data is summarized in **Table 1.**

Types of Abrasives

Mineral Abrasives

Minerals are–by definition–naturally occurring inorganic substances. Mineral quartz sands and flint sand are the most commonly used abrasives in U.S. markets. Sands are a low-cost, readily available source of abrasive and have been used for the blast cleaning of steel since the inception of this technique. Sand particles **(Figure 1)** may range from sharply angular to almost spherical, depending on the source. Silica sands are an effective abrasive for blast cleaning new steel and for maintenance cleaning.

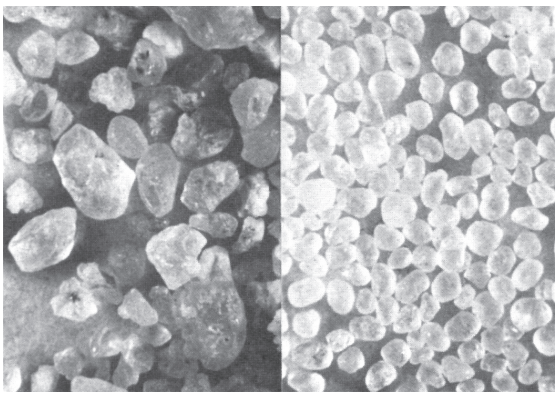

Figure 1. Silica sand abrasive (X8 magnification–8 diameters).

Exposure to dust formed during blasting with quartz-rich sands has been linked to silicosis and other serious lung-related health problems. In recent years, some companies and selected government agencies have urged the use of blast media containing less than 1.0% percent crystalline silica.

Non-quartz sands may also be used for blast cleaning. The most common of these include almandite garnet, specular hematite, staurolite, and olivine—used either by themselves or in various combinations. These sands are tough and dense and are often used in finer particle sizes than the lighter silica sand. An example of a heavy mineral sand is shown in **Figure 2.** Non-quartz heavy mineral sands are effective blast cleaning media for nearly all new steel and maintenance applications.

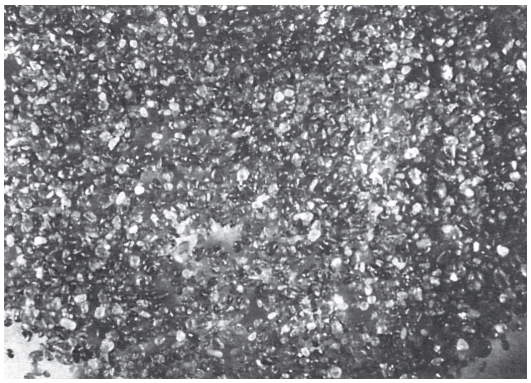

Figure 2. Heavy mineral sand abrasive (X8 magnification).

Quarried rock and crushed aggregate containing no quartz is a relatively new addition to the abrasive field. Its blocky shape and relatively low cost make it an attractive substitute for local silica sands where it is available. Volcanic basalt is the most common source material.

Garnet **(Figure 3)** is a tough, angular-to-subrounded abrasive that is especially suitable for blast cleaning steel parts and castings, i.e., cleaning in a closed system that permits recycling the abrasive. Available in a range of sizes, it can be recycled a number of times because of its toughness. Historically, the perceived high cost of garnet restricted its use to specialty cleaning applications, but this is no longer the case.

Zircon is another tough, rounded abrasive

Table 1. Physical Data on Nonmetallic Abrasives.

	Hardness (Mohr Scale)	Shape	Specific Gravity	Bulk Density (lbs/ft^3)	Color	Free Silica Weight %	Degree of Dusting	Reuse
Naturally Occurring Abrasives								
Sands								
Silica	7	ang-sb rnd	2.6	100	white	90+	high	poor
Heavy Metal	5-8		3-4	128	variable	<5	medium	good
Flint	6.5-7		2.6	80	gray-white	90+	medium	good
Garnet	7-8		4	145	pink	nil	low	good
Zircon	7.5		4.5	184	white	nil	low	good
Novaculite	7	angular	2.5	100	white	90+	low	good
Spec. Hematite		angular	5.2	200	gray	nil	medium	good
Olivise		ang-sb ang	3.5	180	green	nil	medium	poor
By-Product Abrasives								
Slags								
Boiler	6	angular	2.8	80-90	black	nil	high	poor
Copper	6	angular	3.3	100-120	black	nil	medium	good
Nickel	6	angular	2.7	84	green	nil	high	poor
Walnut Shells	3	cubic	1.3	44	brown	nil	low	poor
Peach Pits	3	cubic	1.3	44	brown	nil	low	poor
Manufactured Abrasives								
Silicon Carbide	9	angular	3.2	±105	black	nil	low	good
Aluminum Oxide	8	blocky	4.0	±120	brown	nil	low	good

(Figure 4). Its fine size limits its use to specialty blasting to remove fine scale, leaving a smooth, matte finish. Like garnet, it has higher density and greater hardness than silica sand and is considerably more costly. Zircon is also less widely available than most other media.

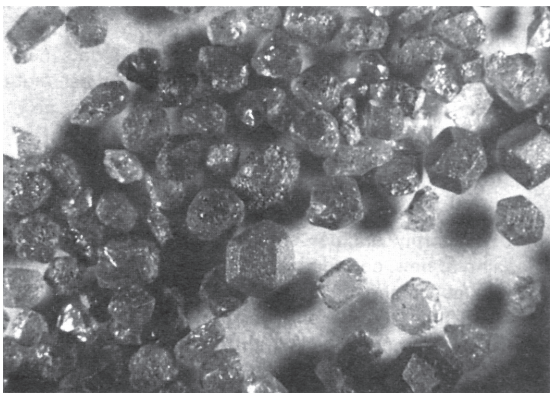

Figure 3. Garnet abrasive (X8 magnification).

Novaculite, a very pure, siliceous rock, is ground to fine sizes for specialty blast cleaning. It leaves a satin luster finish and is most commonly used to clean precision tools and castings and in other special applications.

Slag By-Product Abrasives

This group is the most common substitute media for quartz sand in general blast cleaning. The relative low cost, availability in a variety of sizes and packaging options, and low (less than 1%) free silica content make it well-suited for blast cleaning large steel structures, both for new construction and maintenance cleaning. The natural desire to conserve materials and other environmental concerns has given further impetus to converting slag by-products into commercial abrasives.

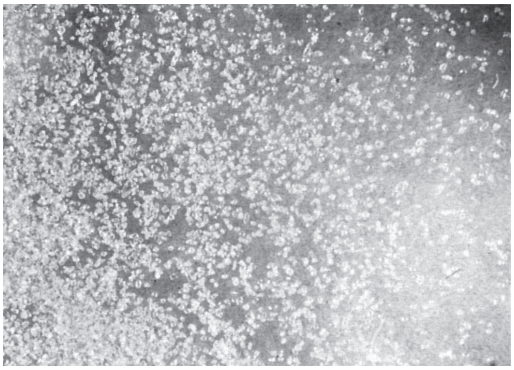

Figure 4. Zircon abrasive (X8 magnification).

Chief among the by-products used as abrasives are slags from two sources: metal smelting

Figure 5. Copper slag abrasive (X8 magnification).

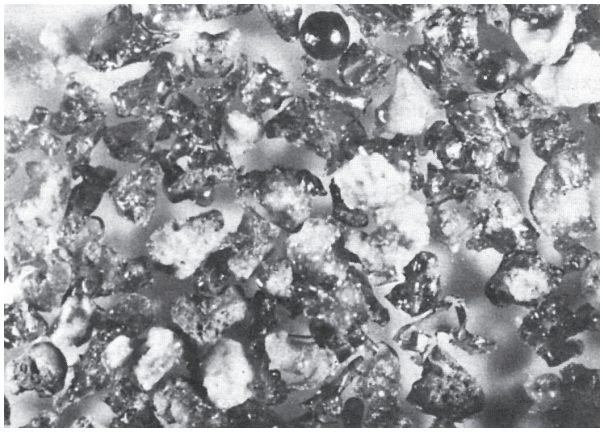

Figure 6. Nickel slag abrasive (X8 magnification).

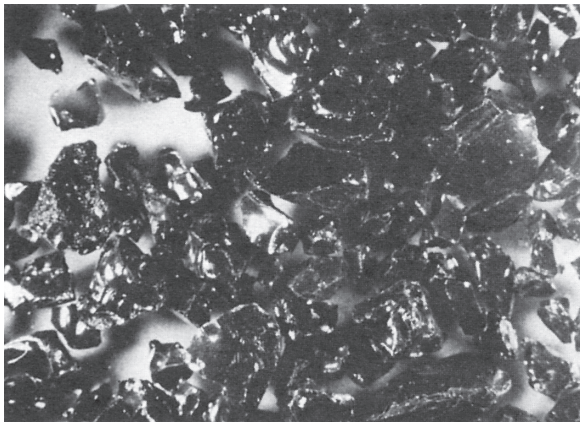

Figure 7. Coal-fired, boiler-bottom ash (X8 magnification).

(Figures 5 and 6) and electric power generating (bottom ash) **(Figure 7).** Smelting and boiler slags are generally glassy, homogeneous mixtures of various oxides, which give them uniform physical properties important for abrasive applications. These abrasives have a sharply angular shape suitable for efficient blast cleaning of both new steel and corroded or painted steel surfaces. Slags are available in the full range of abrasive sizes—coarse (8 sieve) to fine (100 sieve).

Figure 8. Walnut shell abrasive (X8 magnification).

Figure 9. Corncob shell abrasive (X8 magnification).

Not all slags can be used as abrasives. They need to be tough, have a bulk density of 80 to 100 lb/ft.^{2}, and exhibit a minimum amount of breakdown on impact in order to be effective.

A second by-product abrasive is vegetable media, including walnut shells **(Figure 8)** and peach pits. Tough but lightweight with a bulk density of 42-47 lb/ft^2, such shells are excellent for removing paint, fine scale, and other surface contaminants without altering the metal substrate. Shell products are available from

10 to 100 sieve. Corncobs **(Figure 9)** are another agricultural product used for specialty cleaning to remove surface contaminants, such as grease and dirt, without destroying or altering the paint or metal substrate. Corncobs are also available in a full range of sizes.

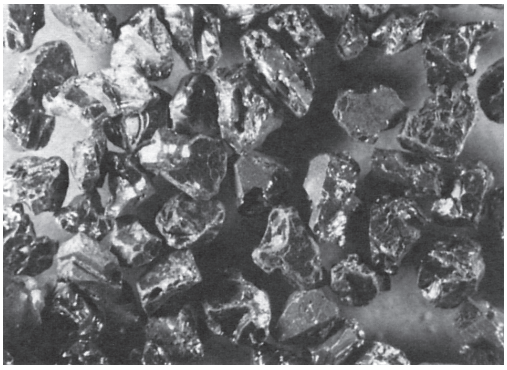

Figure 10. Silicon carbide abrasive (X8 magnification).

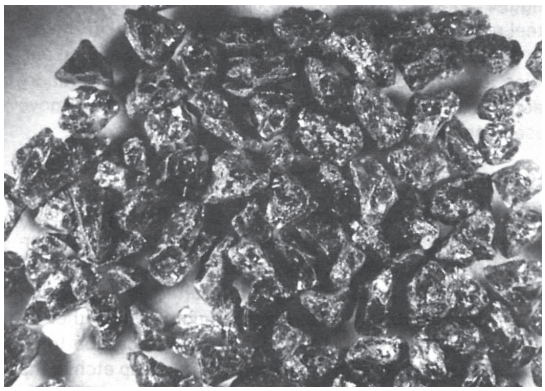

Figure 11. Aluminum oxide abrasive (X8 magnification).

Manufactured Abrasives

Nonmetallic, manufactured abrasives are made from a wide variety of raw materials and can be produced for specific abrasive properties, such as toughness, hardness, or shape. Some examples are silicon carbide **(Figure 10),** a tough angular abrasive for specialty etching; aluminum oxides **(Figure 11)** for blast cleaning materials such as stainless steel; and glass beads **(Figure 12)** for peening and cleaning small, delicate parts and molds. In recent years, a range of softer manufactured products designed to remove dirt, grease, and light corrosion has been introduced. These include dry and wet ice, sodium bicarbonate, and plastic grains.

Since production can require a great deal of energy, manufactured abrasives may be more costly than by-product slags and quartz sand. For this reason, such abrasives are not commonly used for bulk cleaning jobs where the abrasive cannot be recovered for reuse. The tough, durable nature of most manufactured abrasives makes them particularly adaptable to recycling as many as 20 times. Consequently, net cost can be comparable to that of the by-product abrasives.

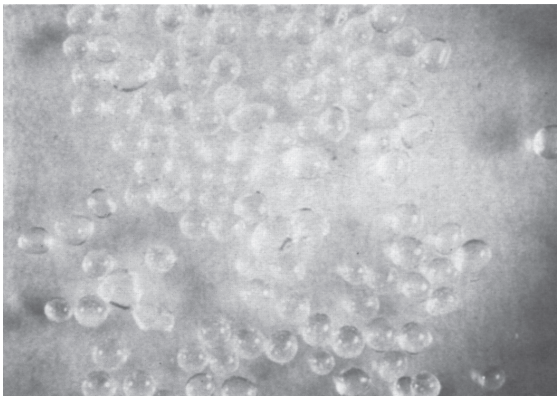

Figure 12. Glass bead abrasive (X8 magnification).

Choosing the Right Abrasive

The variety of materials available make it necessary to know how to select the proper abrasive appropriate for a given job. An abrasive has four parameters that determine its performance: shape, hardness, density, and size. It is important to know how each of these parameters affects surface preparation.

Shape (Angular Versus Round)

Because of their scouring action, angular-to-subangular particles are best suited for removing soft friable surface contaminants such as paint, rust, and dirt. **Figure 13** illustrates scouring. Round particles may be better suited for removing brittle contaminants like millscale or oxidized coatings. Spherical particles are also used to produce a peening action when little or no change in surface configuration is permitted.

Hardness and Durability

Hard, tough particles are best suited for blast cleaning jobs where the primary objective is to remove surface contaminants. Harder particles leave less residue on the surface, and tough, durable particles

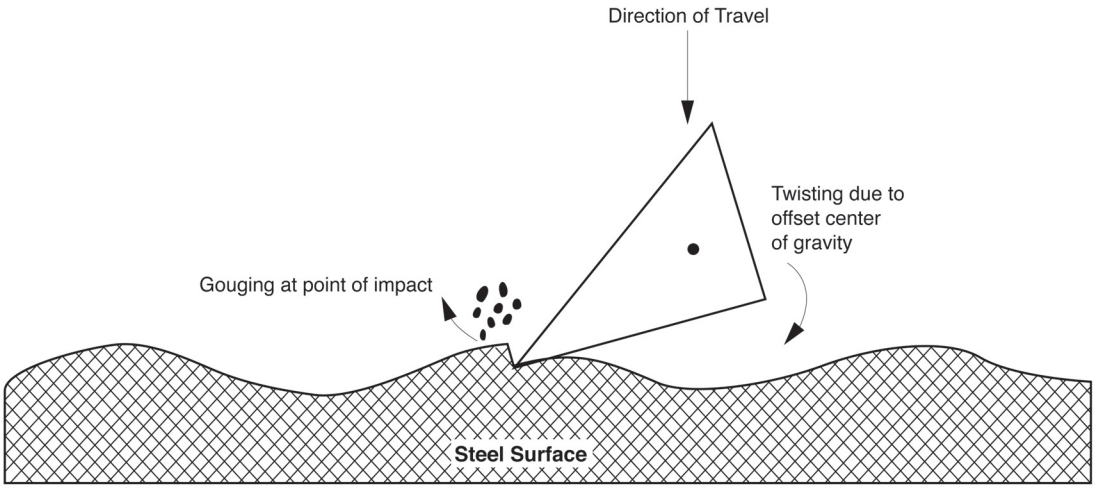

Figure 13. Impact of angular abrasive particle on steel surface.

minimize dusting. Grains with especially good durability—like some garnets—may survive impact to be collected and reused several times.

Soft abrasives remove light contaminants without disturbing the metal substrate or, in some cases, the coating system. Walnut shells and corncobs are soft enough for cleaning valves or turbine rotor blades and for removing grease from motors and dirt or other deposits on paint films.

Coating System

Most coating manufacturers recommend a minimum surface texture on the abrasive-cleaned surface for good coating adhesion – commonly about 2.0 mils (50 μm). The coating system will therefore also influence the choice of abrasive for surface preparation.

Cleanliness

Not all abrasives yield the same degree of surface cleanliness. An abrasive sized to be effective for a commercial blast (SSPC-SP 6) may not be able to economically provide a near-white (SSPC SP 10) or white-metal (SSPC-SP 5) blast-cleaned surface. It is important to know whether an abrasive can meet the specified degree of cleanliness efficiently.

Environmental Constraints

Safety and environmental requirements affect the choice of abrasive. The need to minimize dust or airborne free silica may require replacing sands with by-product slags or other minerals or replacing open blasting with an enclosed operation.

Enclosed blasting is often associated with abrasive reclamation and reuse. This dictates the selection of a durable, higher quality media. Although the most commonly recycled abrasives are the ferrous/steel media, manufactured and naturally occurring abrasives that exhibit excellent durability can also be considered for recycling. The carbide and alumina abrasives and naturally occurring garnets and heavy mineral sands can be reused many times.

Abrasive Evaluation Tests

This section discusses certain key physical and chemical properties of abrasives:

Size consist is defined as the size distribution of abrasive particles and is best determined by sieve analysis, as outlined in ASTM D 451. A consistent range of abrasive particle sizes must be maintained to produce a consistent surface and cleaning rate.

Abrasive breakdown is a measure of a particle breakdown after impact. The greater the particle breakdown, the poorer the cleaning rate. That is, if most of the particle energy is dissipated, little energy is left for removal of surface contaminants. Some manufacturers list a breakdown value, and standard test procedures have been established in California. Regardless of the abrasive used, breakdown is most strongly affected by operator skill.

Dust generation is the amount of dust generated by an abrasive on impact. Excessive dust

can create visibility problems during blasting and cause environmental problems at the job site. Dust generation may be minimized by the use of well-trained and supervised operators and well-maintained equipment.

The **pH values** of an abrasive should be nearly neutral when the abrasive is mixed with water. Some suppliers note the pH on the technical data sheet accompanying the abrasive. This value is easily checked and should be routinely monitored. An abrasive with an acid pH (less than 7.0) can cause premature corrosion of steel and coating failure.

A **soluble chloride test** is important, because chlorides may impart a detrimental residue. Most chemical laboratories can routinely analyze for soluble chlorides and field test kits are available for real-time determination of chloride levels. If the abrasive source is near seawater, routine checking for soluble chlorides is recommended.

The manufacturer generally provides an analysis for **free silica.** The level of free silica should comply with governmental regulations and customer requirements.

Trace toxic contaminants that may be present in slag abrasives should be reviewed prior to use, and suppliers should provide an analysis for potentially toxic substances.

Acknowledgements

The authors and SSPC gratefully acknowledge the participation of Joe Brandon and Hugh Roper in the peer review process for this chapter.

About the Authors

H. William Hitzrot
Bill Hitzrot, prior to his retirement, was an active member of SSPC for about 30 years, chair of the abrasives committee and member of the SSPC Board of Governors. He was also an active participant in the Chesapeake Chapter of SSPC. Bill retired as vice president of Chesapeake Specialty Products, a manufacturer of steel abrasives and iron oxides for industrial use. He remains active in SSPC assisting in updating publications and training programs in the areas of surface preparation and abrasives.

James D. Hansink
Jim Hansink has more than 30 years experience in the mining and mineral business. He holds technical degrees in geology and engineering from St. Louis University and an advanced degree in management from MIT. He has been responsible for development and marketing of sand, slag, and garnet properties, and he has held executive management positions with several international mineral companies. Jim is currently president of Garnet Services, Inc., a Seattle-based consulting and mineral brokerage firm.