ACHIEVING EFFICIENCY IN ABRASIVE BLAST CLEANING

A **JPCL** eBook

Achieving Efficiency in Abrasive Blast Cleaning

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Introduction

This eBook consists of articles from the *Journal of Protective Coatings & Linings (JPCL)* on abrasive blasting, and is designed to provide general guidance on the efficiency of abrasive blasting and maintenance of the associated equipment.

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By Han-Jin Bae, Jae-Jin Baek, Chae-Suk Lee, Chil-Seok Shin, Byung-Hun Lee, Sang-Ryong Shin, Kwang-KI Baek, Hyundai Industrlal Research Institute, and Ki-Soo Kim, Block Painting Dept., Hyundal Heavy Industries Co. Ltd., Cheonha-Dong, Ulsan, Korea

Improving Blasting Productivity by Optimizing Operation Parameters

Editor's Note: This article apeared in JPCL *in November 2007, and is based on a paper the authors presented at PACE 2007, the joint conference of SSPC and PDCA. PACE was held in Dallas, TX, in February 2007.*

Abrasive blasting is the preferred method of surface preparation in new shipbuilding because of its economic and performance benefits. The method provides the proper surface roughness and increases the surface area, two critical factors in achieving physical and chemical adhesion between a steel surface and an organic coating. Adhesion, in fact, is the key to coating effectiveness, determining whether the coating is merely a thin sheet of material lying on the substrate or whether it becomes an actual part of the substrate.[1] Abrasive blasting, however, also requires a significant amount of labor, and its efficiency depends mainly on the blaster's skill. Achieving the economic, efficiency, and productivity benefits from abrasive blasting requires the proper selection and matching of the abrasive, nozzle, air pressure and abrasive/air mixing ratio. Unfortunately, there are not enough quantitative analytical data available on the above parameters for practical use in optimizing blast cleaning, even though many studies have been performed on the technology. Another prime reason for further study, especially for new shipbuilding, is the need to determine how to control the profile height by careful selection of the primary variables such as abrasive size and hardness, and nozzle pressure.

Precise and cost-effective abrasive blasting is especially important to shipyards, like Hyundai's above, in part because of the IMO's new rule on preparing and coating ballast tanks. All photos courtesy of Hyundai Heavy Industries

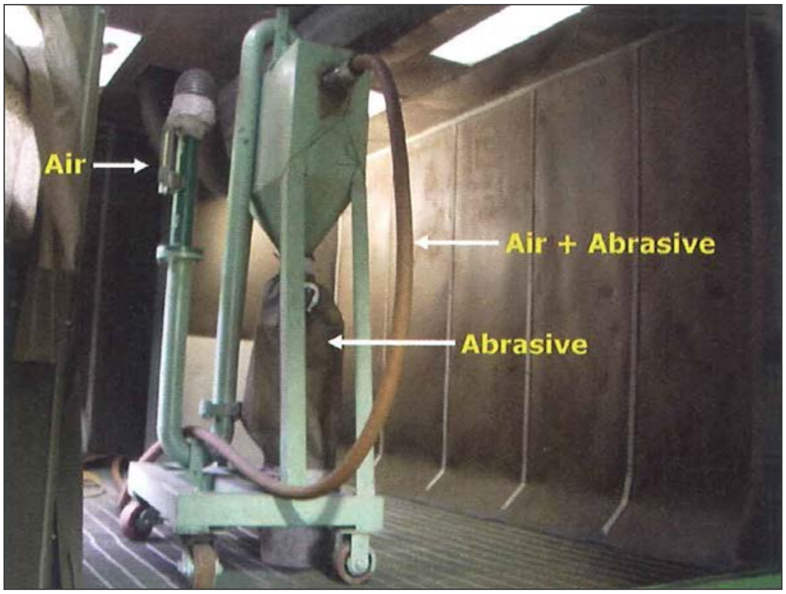

Fig. 1: Specially designed abrasive and airflow rate measuring cabinet

The International Maritime Organization's (IMO) recently adopted rule on protective coatings for ships' water ballast tanks prescribes that before applying the main coat, the damaged shop primer areas, such as burnt areas, mechanically damaged areas, and weld burn areas, should be abrasive blasted to Sa 2.5 Gr.[2] The new rule also requires maintaining the profile of a blast-cleaned surface within 30–75 μm. The rule will be phased in beginning in July 2008.

This article describes a study of the effects of key operating parameters to find the optimum window for blasting conditions. A series of tests was conducted in a laboratory-scale blasting test facility to simulate the actual blasting practice. The results clearly indicated that the newly optimized blasting condition can improve blasting efficiency and significantly reduce the amount of abrasive used. The study also showed a general trend—that blasting productivity is gradually increased with the abrasive feeding rate to a certain critical value and then maintained constantly.

Table 1: Experimental Parameters and Conditions

Test Parameters	Test Condition
Nozzle	***Insert type:*** Nozzle A (11.5Ø**, 150 mm) Nozzle B (11Ø, 120 mm) Nozzle C (12.5Ø, 117 mm) ***External fitting type:*** Nozzle D (9.5Ø, 185.7 mm) Nozzle E (11Ø, 215.9 mm)
Abrasive size	Avg.: 1 mm, 0.7 mm, 0.5 mm, 0.3 mm, O/M Operating Mix (O/M) (suggested by abrasive maker)
Hopper pressure*	6.6 kgf/cm^2, 7.0 kgf/cm^2
Abrasive hardness	Conventional abrasive: avg. 56HRC SHG (Special High Grit): avg. 64HRC
Surface treatment	Cleanliness: Sa3 Surface roughness measured with DIAVITE™ DH-5
Specimen coating	Epoxy primer (red brown)

*kgf/cm^{2}x14.2≈psi
**Ø = internal diameter in mm.

Experimental

Test Conditions and Procedure

To investigate the effect of abrasive size and hardness, nozzle geometry and pressure, and abrasive/air mixing ratio on blasting efficiency, a series of tests was performed in a laboratory-scale blasting test facility. A specially designed test cabinet was built to measure the compressed air consumption and abrasive flow rate (Fig. 1). Five types of commercial blasting nozzles were selected. (See Table 1.)

Steel specimens (500 mm wide x 1500 mm long x 3 mm high) were coated with a commercial epoxy primer (red-brown) to clearly distinguish the blast-cleaned surface and the non-cleaned steel. The coated specimens were blast cleaned to a White Metal finish (SSPC-SP 5 or Sa 3) with the abrasive flow rate adjusted through the abrasive metering valve (Fig. 2). The standoff distance from the nozzle to the specimen surface was approximately 750 mm. The area blasted per unit of time was used as an indicator of blasting productivity. Next, the test parameters were studied: nozzle pressure (using a needle pressure gauge); abrasive feed rate and air consumption (using the special cabinet made for the study); surface profile (using a proprietary digital gauge); blasting pattern (keeping each nozzle the same distance from the surface); and nozzle geometry (using X-ray images).

Abrasive and Air Flow Rate Measuring Cabinet

In a standard impingement separator, a gas-solid suspension undergoes sudden changes in the flow direction upon colliding with the collection object. However, due to their inertia, the solid particles have higher momentum than those of the gas and tend to retain the original direction of movement. So, instead of following the flow stream around the collecting

Fig. 2: Appearance of specimens after blast cleaning test

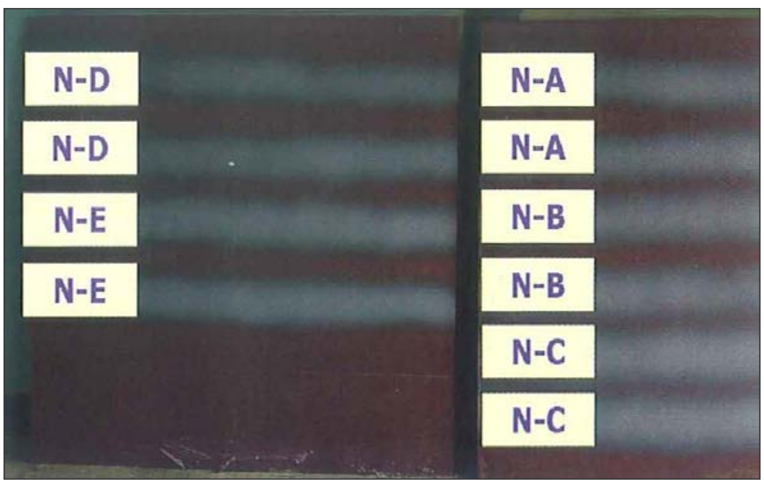

Fig. 3: Blasting pattern with nozzle type; abrasive (average 1 mm); stand-off distance (750 mm)

object, the solid particles hit the object and are separated from the gas stream. Based on this theory of operation, a special impingement separator that could measure the abrasive and airflow rate at the same time was designed and built for this study. As a collection object, a target plate (250 mm wide x 300 mm long x 10 mm high) was mounted 90 degrees to each nozzle at the center of the cabinet. The distance between the nozzle and target plate was 450 mm. The impacted abrasive media fell to the base of the cabinet for weighing, while abrasive-free air was drawn into the air flow meter.

Results and Discussion

Effect of Blasting Nozzle Type on Blasting Efficiency

The blasting nozzle is a critical point of mechanical control in a blasting system, determining whether the abrasive is properly utilized, whether optimum blasting patterns are attained, and whether the compressed air is used efficiently. Thus, the blasting nozzle affects the amount of labor, the amount of abrasive material to be consumed, and, to a great extent, the size of the compressor required.[3] Therefore, nozzle design should allow for rapid acceleration of the abrasive/air mixture to be evenly dispersed in a high velocity pattern. In this study, the effect of the nozzle's geometry on blasting efficiency was evaluated, and the optimum blasting nozzle was selected from the blasting nozzles tested. Comparative tests were performed to study blasting productivity and pattern, working characteristics, and air consumption by stages.

Step 1: Nozzle Type vs. Blasting Productivity

Blasting productivity was measured as a function of abrasive feeding rate (kg/hr) at the following experimental conditions: steel grit (G25, avg. 1 mm); hose internal diameter (32 Ø); and hopper pressure (6.6 kgf/cm^2). Blasting productivity was calculated from the measured area blast cleaned divided by the unit time of abrasive discharge (m^2/hr).

Generally, blasting productivity gradually increased with the abrasive feeding rate, up to a certain critical value, and, then, productivity was maintained constantly with a few exceptions. This result is notably different from data by other research groups.[4] According to existing data, the effect of the abrasive feed rate on productivity follows a bell-shaped curve: As the abrasive feed rate increases linearly, productivity increases toward a maximum point and then decreases as feed rate continues to increase. The decrease has been attributed to the excessive pressure drop in the blasting hose.

Our unexpected finding associated with excessive abrasive flow can be explained as follows: an increased amount of abrasive has enough impact energy to offset the pressure drop, contrary to the opinions of other researchers. Our result also suggests that choosing the proper abrasive flow rate and optimizing the abrasive valve opening are important factors in blasting productivity: excessive abrasive causes higher abrasive cleanup costs but has an insignificant effect on blasting efficiency. Optimum abrasive feeding rate is approximately 1,300 kg/hr at the above test conditions, regardless of nozzle type. Blasting productivity by nozzle shape was graded as follows: (Nozzle A = Nozzle B = Nozzle E) > Nozzle D > Nozzle C.

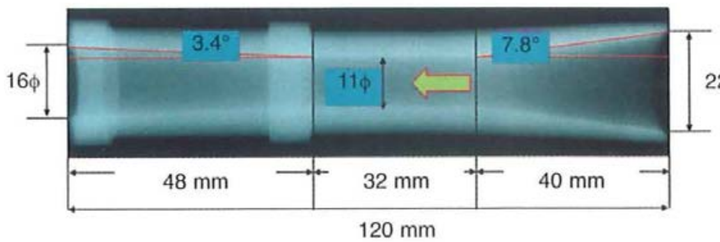

Fig. 4: Configuration and dimension of Nozzle B estimated by X-ray image analysis

Table 2: Configuration and Dimension of Tested Nozzles

Nozzle	C	B	A	E	D
Length (mm)	125	120	150	215.9	185.7
Throat (Ø)	12.5	11	11.5	11	9.5
Diverging	7.6	3.4	2.1	1.3	1.2
Converging	3.9	7.8	9.3*	7.9	8.5

*Intermittent discharging

Table 3: Abrasive Flow Rate, Nozzle Pressure and Air Consumption with Nozzle Type Valve Opening

Nozzle	Abrasive valve # of turns	Abrasive (kg/hr)	Nozzle pressure (kg/cm^2)	Air flow rate (Nm^3/hr)
A (11.5Ø, 150 mm)	4	750	5.7	395
	5	1072	5.64	380
	6	1363	5.6	360
B (11Ø, 120 mm)	4	706	5.75	370
	5	1018	5.73	340
	6	1286	5.71	320
C (12.5Ø, 117 mm)	4	927	5.5	420
	5	1272	5.45	400
	6	1650	5.42	380
D (9.5Ø, 185.7 mm)	4	654	6	290
	5	784.8	5.95	260
	6	993.6	5.93	240
E (11Ø, 215.9 mm)	4	683	5.8	330
	5	930	5.75	310
	6	1166	5.73	295

*Test conditions: hopper pressure (6.6 kg/cm^2); kgf/cm^2x14.2≈psi; grit (avg. 1 mm); hose I.D. (32Ø)

Table 4: Evaluation of Repeatability of the Special Abrasive Metering Valves

# of turns	(Unit: kg/30 sec)	
	#1 valve	#2 valve
3.5	19.26	18.76
4.5	16.86	16.64
5.5	11.66	11.28
6.5	6.44	6.0

Step 2: Nozzle Type vs. Blasting Pattern (Width)

In the evaluation of the blasting pattern, especially the blasting width, the test focused on the three kinds of blasting nozzles that performed best in step 1. In the case of identical blasting performance, the blaster usually prefers the nozzle that can create the larger blasting width.

Therefore, blasting pattern is also a critical factor in selecting the optimum blasting nozzle. Figure 3 shows the blasting patterns with selected blasting nozzles with the same distance (750 mm) between the blasting nozzle and the target surface for all tests. The distance was maintained by using a small rod attached to the blasting hose that extended to the target surface. Nozzle E was inferior to nozzle B and nozzle A in terms of blasting width (in mm): Nozzle C (156) > Nozzle B (126) > Nozzle A (122) > Nozzle E = Nozzle D (118).

Step 3: Nozzle Configuration vs. Abrasive Flow Pattern

Nozzle design also has a great effect on blasting productivity. Therefore, a number of researchers have tried to improve the nozzle geometry. As a result, the Venturi nozzle is commonly used because of its higher blasting efficiency compared with that of a conventional nozzle.

X-ray images were taken from the cross-section of the blasting nozzles evaluated to identify their internal configurations. Figure 4 and Table 2 show the configuration and dimension of Nozzle B, including the total length, throat, and converging and diverging section. The shape of the diverging section is responsible for the speed of the abrasive particles at the nozzle exit and for the blasting width. The discharge stability of the abrasive stream is due to the converging section.

The rank of diverging angles derived from the X-ray images revealed the same blasting pattern tendency seen in step 2. Nozzle B showed continuous discharge characteristics regardless of abrasive size, while a significant problem was encountered with Nozzle A. Nozzle A exhibited intermittently discharging abrasive at the nozzle exit when the abrasive size was less than 0.5 mm. These results may be attributed to the relatively rapid converging angle (9.3 degrees) of Nozzle A against that (7.8 degrees) of Nozzle B (Fig. 5 and Table 2). That is, it can be postulated that the possibility of a bottleneck in a blasting nozzle is increased with an increase in its converging angle and a decrease in abrasive size. These results indicate that the use of X-ray imaging to analyze nozzle configuration can be valuable for predicting the working characteristics of a blasting nozzle.

Step 4: Nozzle Type vs. Air Consumption

Air consumption. an additional factor in selecting the optimum blasting nozzle, is closely related to the cost of abrasive blasting. Abrasive flow rate, nozzle pressure, and air consumption for each blasting nozzle along with abrasive valve opening are summarized at Table 3. At a similar abrasive flow rate (~1,300 kg/hr), the air consumption of Nozzle B was relatively lower than that of Nozzle A. Based on the results in Table 3, Nozzle B proved to be more suitable than the other nozzles for actual field blasting conditions in the shipbuilding industry.

Fig. 5: Older spring-type of abrasive metering valve still used in some shipyards

Fig. 6: Newer type of abrasive metering valve that allows more precision than spring type

Abrasive Metering Valve

An abrasive control valve that can precisely meter abrasive media under variable conditions should be selected and adjusted to optimize the cleaning rate. Too little abrasive introduced into the airstream results in an incompletely filled blast pattern, which slows production and leaves areas on the substrate untouched. Too much abrasive causes abrasive particle collision, which wastes energy and disperses particles unevenly within the blast pattern. A properly adjusted metering valve ensures that the maximum amount of cleaning is gained from each abrasive particle.[5] Figure 5 shows the spring type of abrasive metering valve still used in some shipyards. However, this older type of valve lacks repeatability in metering abrasive flow rate and needs much effort to calibrate and select the proper valve turns.

A new type of abrasive metering valve, which provided precise control and repeatability in abrasive flow rate, markedly improved control of abrasive flow (Fig. 6). Abrasive flow rates of two special abrasive metering valves are nearly identical, indicating that the new type of valve is precise and can be used to effectively control the qualitity of abrasive media (Table 4) with good repeatability.

Abrasive Size vs. Blasting Productivity

It is well known that the finer the abrasive is, the faster the surface cleaning rate is. Settles et al. (1995) reported that large abrasive particles could not be fully accelerated at the nozzle exit because their inertia generally prevented them from accelerating as rapidly as the small abrasive particles.[5] On the other hand, some abrasive manufacturers insisted that the operating mix (work mix) of abrasives of various sizes is a vital factor in improving blasting productivity. Therefore, the effect of an abrasive manufacturer's suggested operating mix on cleaning rate was evaluated, as was the effect of abrasive size.

Blasting productivity as a function of representative abrasive sizes was measured at the following experimental conditions: Nozzle A and hopper pressure (6.6 kgf/cm^2). The cleaning rate was inversely proportional to the abrasive particle size. The highest cleaning rate was achieved with the smaller abrasive particles because they allowed a higher number of impacts on a unit area and a resulting high peak count (except for abrasive of 0.3 mm, which was in the excessive discharging range).

On the other hand, the effect of operating mix on blasting efficiency did not meet our expectations. For secondary surface treatment of a shop-primed surface, less and looser contamination was expected. It can be postulated that even though they impart less impact energy than large abrasives, small abrasive particles probably have sufficient impact energy for complete removal of these contaminants. Nozzle A exhibited the phenomenon of intermittently discharging abrasive at the nozzle exit when the abrasive size was less than 0.5 mm. Reducing the abrasive size from 1 mm to 0.5 mm increased the blasting productivity by 40%. (See Table 5.)

Table 5: Comparison of Blasting Productivity of Various Sized Abrasives

Abrasive size (avg.)	1	0.7	O/M	0.5	0.3*	Remarks
Blasting productivity (m^2/hr)	18.7	21.60	23.4	26.38	28.08	Nozzle A
Relative efficiency (%)	100	115	125	141	158	Hopper **

*discharge excessive; **pressure set at 6.6 kgf/cm^2

Abrasive Size vs. Surface Profile

Large abrasives cut deeper and produce deeper proftles than smaller particles with the same composition and shape. However, Keane et al. (1976) reported that coarser abrasives tend to lead to more hackles (large surface deformations) than do the small abrasives.[7] Hackles are often considered the 'onset point of pinpoint rust' because a hackle tip will protrude through the thin layer of coating, allowing premature coating failure. Moreover, the IMO's new provisions for coating ballast tanks require maintaining the surface roughness of a blast-cleaned surface between 30 and 75 μm after secondary surface preparation. Thus, the profile height produced by variously sized abrasives has received considerable attention in new shipyards all over the world.

The surface profile after each blasting test was measured in accordance with ISO 8503-4 ("Method for Calibration for ISO Surface Profile Comparators and the Determination of Surface Profile") with a proprietary stylus instrument. Among the abrasives evaluated, those measuring 0.5 mm and below met the IMO PSPC's acceptance criteria, whereas the others didn't (Table 6). The 0.3 mm abrasives, however, produced a surface texture quite different from those produced by the other abrasives and generated more dust during the blasting, causing poor visibility for workers. From these results, we concluded that 0.5 mm abrasive is the most suitable abrasive for blast cleaning.

Table 6: Surface Profile with Various Sized Abrasives (hopper pressure: 6.6 kgf/cm^2)

Abrasive	Rz(μm)	Rmax(μm)
Bare Steel	6.5~7.3	8.0~11.9
1 mm	97.3~106.2	-
0.7 mm	80.2~94.5	96.1~111.7
O/M	78.6~84.4	90.3~101.4
0.5 mm	64~73.9	79.2~96.6
0.3 mm	38.2~48	44.6~69.2

Abrasive Hardness vs. Blasting Productivity

The hardness of abrasive affects the cleaning and breakdown rates. A general rule for surface preparation has been that hard abrasives generate deeper and faster cutting action than soft abrasives. For evaluating the effect of abrasive hardness on cleaning rates, we tested and compared the performance of conventional and harder abrasives. Hardness of the conventional abrasive averaged 56 HRC, whereas harder abrasive, identified here as SHG (Special High Grit) averaged 64 HRC. With the use of 0.5 mm virgin abrasives, the SHG increased the cleaning rate by as much as 10%. For actual field application of SHG, however, further detailed testing on the lifetime of SHG is necessary because hard abrasive is generally known to have a higher propensity to fracture (friability) than conventional abrasive.

However, in terms of profile depth or height, the surface profile created by the SHG during performance testing was 65–78 μm, close to the surface roughness of 64–74 μm created with conventional abrasive (56 HRC). This unexpected result was probably caused by the shorter residence time of the harder abrasive on a unit area during blasting, compared to the residence time of the abrasive of conventional hardness. That is, if the conventional and harder abrasives were to impact an equal area for the same amount of time, the harder abrasive may produce a higher surface profile than that of a conventional abrasive.

However, during actual blasting in the shop, shipyard, or field, when surface preparation on one area is completed, the blaster rapidly begins to clean the next unblasted surface area. Hence, the harder abrasive has a short residence time on the surface (per unit area) compared to that of a conventional abrasive. Because of its shorter residence time, a harder abrasive might not be able to exhibit its full potential to create a deeper profile than that of an abrasive of conventional hardness.

Nozzle Pressure vs. Blasting Productivity

Settles et al. (1995) reported that increasing the nozzle pressure increased the dynamic pressure ($\frac{1}{2}\rho U^2$) proportionally, which, in turn, proportionally increased the drag force that accelerates the particle through the blasting nozzle.[6] (ρ is the fluid density in kg/m^3 and U is the fluid velocity in m/sec.) In addition, an abrasive equipment manufacturer qualitatively expressed the effect of nozzle pressure on blasting productivity as follows: "a reduction of 1 psi reduces the productivity by 1.5%."[8]

To identify the correlation between nozzle pressure and blasting productivity, tests were conducted by varying the nozzle type and pressure. Test results with Nozzles A and B showed that blasting productivity increased as hopper pressure increased, although Nozzle B showed relatively lower performance against Nozzle A. The abrasive flow rate of Nozzle B was lower than that of Nozzle A with the valve opening at 6 turns (Table 7). So, despite its higher pressure, Nozzle B may be inferior to Nozzle A in blasting productivity.

Table 7: Predicted and Measured Blasting Productivity with Nozzle Pressure*

Hopper pressure (kgf/cm^2)	Nozzle A (6.6)	Nozzle A (7.0)	Nozzle B (7.0)
Nozzle pressure (kgf/cm^2)	5.6	5.95	5.98
Abrasive flow rate (kg/hr)	1,450	1,500	1,315
Air consumption (Nm^3/hr)	330	370	310
Blasting Productivity (m^2/hr)	26.38	28.08	27.27
Relative efficiency (%)	100	106.5	103.4

*Valve opening- 6 turns; abrasive size: 0.5 mm; kgf/cm^{2}x14.2≈psi

Nozzle pressure increased by 0.35 kgf/cm^2 when the hopper pressure increased from 6.6 kgf/cm^2 to 7.0 kgf/cm^2. This slight pressure difference between nozzle and hopper was explained by a pressure drop caused by the abrasive particles' interference in the blasting hose and on the internal surface during the pneumatic transport of the abrasive/air mixture. The relative blasting productivity of Nozzle A was increased up to 106% by an increase in the nozzle pressure. From the above results, we also determined that the empirical equation proposed by the equipment manufacturer is reasonably accurate and can be used (although with a minor limitation) for predicting the influence of nozzle pressure on blasting productivity.

On the other hand, after blasting performance was tested with an increase in nozzle pressure, surface roughness or profile was 70–81 μm, which was higher than profiles (64–74 μm) obtained at lower nozzle pressure (6.6 kgf/cm^2). These results have two important implications. First, unlike abrasive hardness, nozzle pressure has a great effect on surface profile. Second, increasing the nozzle pressure also increases the possibility of exceeding the IMO's PSPC requirement (30–75 μm) for surface roughness. However, according to Baek et al. (1995), this serious problem could be solved by adopting sweep blasting (SSPC-SP 7, Brush-Off Blast Cleaning) with finer-sized blasting abrasive instead of performing full blasting.[9] Baek et al. reported that after full blasting, the surface roughness of a mock-up block averaged 83.1 μm at the field conditions with abrasive size averaging 0.75 mm and nozzle pressure at 6 kgf/cm^2). In contrast, surface roughness was decreased to an average of 75.2 μm when sweep blasting was used.

In our experience, areas with looser contamination, such as areas contaminated with zinc salt, appeared mainly on the shop-primed surface during the secondary surface treatment. Accordingly, it might seem that the sweep blasting could remove such contamination satisfactorily and efficiently. Based on the above results, we judged that blasting method, nozzle pressure, and abrasive size were far more important than abrasive hardness in terms of blasting productivity and surface roughness.

Conclusions

First, for higher blasting productivity with less abrasive consumption, selecting the optimal abrasive-to-air mixing ratio is important. The ratio should be based on the blasting performance curve, which shows that blasting productivity tends to gradually increase with the abrasive feeding rate, up to a critical value, and then productivity is maintained constantly. In addition, to achieve the optimum abrasive feeding rate to the actual blasting process, the proper choice and adjustment of an abrasive metering valve with high repeatability are essential.

Second, the configuration of the blasting nozzle governs work efficiency and air consumption as well as blasting productivity and its pattern. Accordingly, the selection of an optimum nozzle should be based on a comprehensive evaluation of these blasting-related parameters rather than a simple evaluation of cleaning rate. It is possible to predict the blasting pattern and working characteristics of a blasting nozzle by evaluating its diverging and converging angle using the newly proposed X-ray image analysis method.

Third, by quantitatively assessing the influence of abrasive size, hardness, and nozzle pressure on blasting performance, we have shown three factors that significantly affect blasting productivity. The proper combination of abrasive-to-air mix ratio, abrasive metering valve, and nozzle can dramatically increase the blasting productivity, whereas the effect of abrasive hardness on surface profile is unexpectedly insignificant. Furthermore, our study shows that using sweep blasting as much as possible, with small abrasive, and controlling the nozzle pressure properly can help shipyards meet the IMO's recently adopted PSPC provisions without reducing blasting produclivity.

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Abrasive Blasting:
Achieving Efficiency and Profitability

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Abrasive blasting has been important for cleaning and preparing surfaces for coating for many decades. It uses compressed air to propel abrasive particles at high speed to a coated or an uncoated surface. While abrasive blasting is technologically simple, safely converting abrasive particles and compressed air into an effective treatment takes planning and preparation, properly engineered tools and equipment, and operator skill as well as good judgment.

Planning and Preparation

An important first step calls for a thorough examination of the surface to be blasted and the environment surrounding the object or structure, as well as knowledge of job requirements, such as the degree of cleanliness (for example, SSPC-SP 10/NACE No. 2, Near-White) specified for the coating application. A job hazard analysis will aid in project planning by identifying in advance the critical issues (such as removing lead-bearing paint) to be addressed with equipment and personnel.

Properly Engineered Tools and Equipment

For high production blasting, selecting properly sized equipment and compatible components and accessories will ensure an efficient operation and successful outcome (Fig. 1). Tips on making the best choices follow.

Fig. 1: Effective and safe abrasive blasting requires the correct equipment and setup as well as a properly trained operator. All figures and tables are courtesy of Clemco Industries.

• **Air Compressor**—properly sized to produce sufficient air volume and pressure required for all equipment it will serve

The compressor is both the energy source and the workhorse of the blasting system. Compressed air is needed to pressurize the blast machine, convey abrasive to the nozzle, operate valves and accessories, and provide breathing air. Blasting requires a steady supply of air of high-pressure (psi) and high-volume (cfm), and purity when used for breathing air.

To determine the compressor size needed, add the requirements of all equipment, plus a 50 percent reserve to keep productivity high as the nozzle wears. The smallest internal diameter (ID) of the compressor air outlet should be at least four times the size of the nozzle orifice or larger.

• **Nozzle**—matched to compressor output and necessary reserve

Nozzles accelerate abrasive into a highly effective cutting force to tackle the toughest of applications. Replace the nozzle when its orifice is worn to 1/16-inch (1.5 mm) larger than its original size. A worn nozzle not only wastes air but also may lower productivity or cause injury if the liner fails. Carbide nozzles—tungsten, silicon, and boron—are most popular for the majority of blasting applications because of their long life.

Table 1: Approximate Pressure Loss Caused by Common Fittings*

Fitting	Pressure Loss	
45º pipe elbow	1-1/2 psi	0.1 bar/10 kPa
90º pipe elbow	3 psi	0.2 bar/21 kPa
pipe tree	5 psi	0.3 bar/34 kPA
swing check valve	18 psi	1.2 bar/124 kPa

*based on 100 psi (7 bar) in 1 inch (25 mm) pipe

• **Air Line**—as large as possible, with unrestrictive fittings

Using a properly sized air line is critical to getting the most from your compressor and blast system. Like the compressor air outlet, the air line ID should be at least four times the nozzle orifice size. This principle applies to air lines up to 100 feet. With longer hoses, especially those exceeding 200 feet (60 meters), check the air pressure at the blast machine while blasting to determine if air hose ID is sufficient. Air flows best through unrestricted fittings and straight air lines, so lines should be laid out in as short a length and with as few bends as possible to reduce pressure loss (Table 1). Use an air hose rated for a minimum working pressure rating equal to or greater than the blast machine's working pressure.

• **Filter, Moisture Separator, and Air Dryer**—eliminate troublesome abrasive stoppages caused by water in the air line

Water and oil are enemies of blast equipment. All compressors release moisture as a byproduct of compressing air, but some also contaminate the air with oil. The tools for removing moisture and oil vary, depending on the relative humidity in the ambient air. An air filter, installed at the blast machine's air inlet, removes oil and water that has already condensed in the air lines. Coalescing filters collect some water vapors that form small droplets. After-coolers cool the air to condense the moisture, then trap it before it is carried to the blast machine. Air dryers are most effective for removing moisture and oil.

• **Blast Machine**—with capacity, valves, and piping for high production

Based on your compressor and nozzle, choose a blast machine with an abrasive capacity of 20 to 30 minutes of steady blasting. Consult an air/abrasive consumption table (e.g., Table 2) for the amount of abrasive to be consumed by the nozzle orifice size at a given pressure. For example, a No. 6 nozzle (3/8-inch orifice) at 100 psi will consume 1,152 pounds of expendable abrasive per hour (with abrasive weighing 100 lb per cubic foot). Choosing a 6-cubic foot capacity blast machine will provide approximately 30 minutes of blasting (1,152 divided by 2 equals 576).

Air and media flow through pipes, valves, hoses, nozzles, and couplings that are all cylindrical. Any reduction in the diameters of these cylinders dramatically reduces the rate of flow. A one-inch ID cylinder has an area of 0.80 square inches. A 1/2-inch ID cylinder has an area of 0.20 square inches. Reducing the diameter of the cylinder by half reduces its area three-fourths. Pay special attention to the blast machine's external plumbing, because this is where restrictions usually occur.

A well-engineered blast machine allows smooth air and abrasive flow throughout the system. An industrial-quality blast machine features a concave head for easy filling and seals automatically with a pop-up valve—a cone-shaped casting coated for wear resistance. Most machines have a 35-degree conical bottom to allow abrasive to flow freely to the metering valve. Make sure the pressure vessel has National Board approval, an indication that it meets the American Society of Mechanical Engineers' (ASME) specifications.

Install a screen to keep out debris that otherwise would find its way into the blast machine. Cover the machine when it's not in use to keep out rain and condensation.

• **Pressure Regulator and Gauge**—for adjustment and monitoring

Install a pressure regulator with a gauge on the blast machine to set and monitor the air pressure. Maintaining operating pressure guarantees optimum performance. Use a hypodermic needle gauge to check pressure at the nozzle (Fig. 2).

Fig. 2: Needle pressure gauge used to check pressure at the nozzle.

Table 2: Compressed Air and Abrasive Consumption*

Nozzle Orifice	Pressure at the Nozzle (psi) 50	60	70	80	90	100	125	150	
No. 2 (1/8")	11	13	18	17	18.5	20	25	30	Air (cfm)
	.67	.77	.88	1.01	1.12	1.23	1.52	1.82	Abrasive (cu.ft./hr
	67	77	88	101	112	123	152	182	& Lbs/hr)
	2.5	3	3.5	4	4.5	5	5.5	6.6	Compressor hp
No. 3 (3/16")	26	30	33	38	41	45	55	66	Air (cfm)
	1.50	1.71	1.96	2.16	2.38	2.64	3.19	3.83	Abrasive (cu.ft./hr
	150	171	196	216	238	264	319	383	& Lbs/hr)
	6	7	8	9	10	10	12	14	Compressor hp
No. 4 (1/4")	47	54	61	68	74	81	98	118	Air (cfm)
	2.68	3.12	3.54	4.08	4.48	4.94	6.08	7.30	Abrasive (cu.ft./hr
	268	312	354	408	448	494	608	730	& Lbs/hr)
	11	12	14	16	17	18	22	26	Compressor hp
No. 5 (5/16")	77	89	101	113	126	137	168	202	Air (cfm)
	4.68	5.34	6.04	6.72	7.40	8.12	9.82	1.178	Abrasive (cu.ft./hr
	468	534	604	672	740	812	982	1,178	& Lbs/hr)
	18	20	23	26	28	31	37	44	Compressor hp
No. 6 (3/8")	108	126	143	161	173	196	237	284	Air (cfm)
	6.68	7.64	8.64	9.60	10.52	11.52	13.93	1.672	Abrasive (cu.ft./hr
	668	764	864	960	1,052	1,152	1,393	1,672	& Lbs/hr)
	24	28	32	36	39	44	52	62	Compressor hp
No. 7 (7/16")	147	170	194	217	240	254	314	377	Air (cfm)
	8.96	10.32	11.76	13.12	14.48	15.84	19.31	2.317	Abrasive (cu.ft./hr
	896	1,032	1,176	1,312	1,448	1,584	1,931	2,317	& Lbs/hr)
	33	38	44	49	54	57	69	83	Compressor hp
No. 8 (1/2")	195	224	252	280	309	338	409	491	Air (cfm)
	11.60	13.36	15.12	16.80	18.56	20.24	24.59	2.951	Abrasive (cu.ft./hr
	1,160	1,336	1,512	1,680	1,856	2,024	2,459	2,951	& Lbs/hr)
	40	50	56	63	69	75	90	108	Compressor hp

**Consumption rates are based on abrasives that weigh 100 pounds per cubic foot.*
• For nozzle sizes 6, 7, & 8, machines should be equipped with 1 ¼" ID or larger piping and inlet valves to minimize pressure loss.
• Air requirements measured by a flow meter during blasting; figures are lower than for air alone.
• Compressor (hp) based upon 4.5 cfm per horsepower.
• Table data are for reference only; will vary based on different conditions. Variables such as metering valve adjustment affect abrasive flow.

• **Abrasive Metering Valve**—engineered for steady, uniform flow

Abrasive flows by gravity through the metering valve into a fast-flowing stream of compressed air. Metering valves that feed abrasive at 90 degrees cause turbulence, which leads to erratic abrasive flow, abnormal wear on piping, and inaccurate mixing of air and abrasive. Feeding abrasive into the air stream at 45 degrees allows air and abrasive to blend smoothly. A good abrasive metering valve permits precise adjustments. Air valves and other valves not specifically designed for abrasive will wear rapidly and adversely affect flow.

• **Remote Controls**—for safe and efficient operation

A blast machine must have remote controls (an OSHA requirement) that quickly stop blasting when the control handle is released. They are critical to preventing injury should the operator lose control of the nozzle. Pneumatic remotes work well at distances up to 100 feet. Electric remotes are recommended for distances greater than 100 feet and are mandatory for distances of 200 feet or more.

• **Blast Hose and Couplings**—sized to reduce friction loss

Always use appropriately sized, good quality static-dissipating blast hose, manufactured for abrasive blasting and rated at the appropriate working pressure. The blast hose ID should be at least 3 times (preferably 4 times) the size of the nozzle orifice.

Choose couplings and holders based on their suitability for job site conditions—not on their purchase price. Blast hose couplings lock together. Under pressure, the blast hose expands against the couplings to create an airtight seal. Gaskets in each coupling align and compress as the couplings are twisted into the locked position. Make sure the coupling screws are long enough to provide sufficient holding power without penetrating the inner tube. Some couplings have integral steel safety cotter pins; if yours do not, always install safety cotter pins to further secure the coupling connection. Blast hose safety cables provide an additional measure of protection and should be used at every coupling connection to prevent injury from accidental coupling disengagement.

• **Operator Safety Equipment**—protective clothing and NIOSH-approved respiratory protection for blasters and all personnel working in the vicinity of blasting—no dust is safe to breathe!

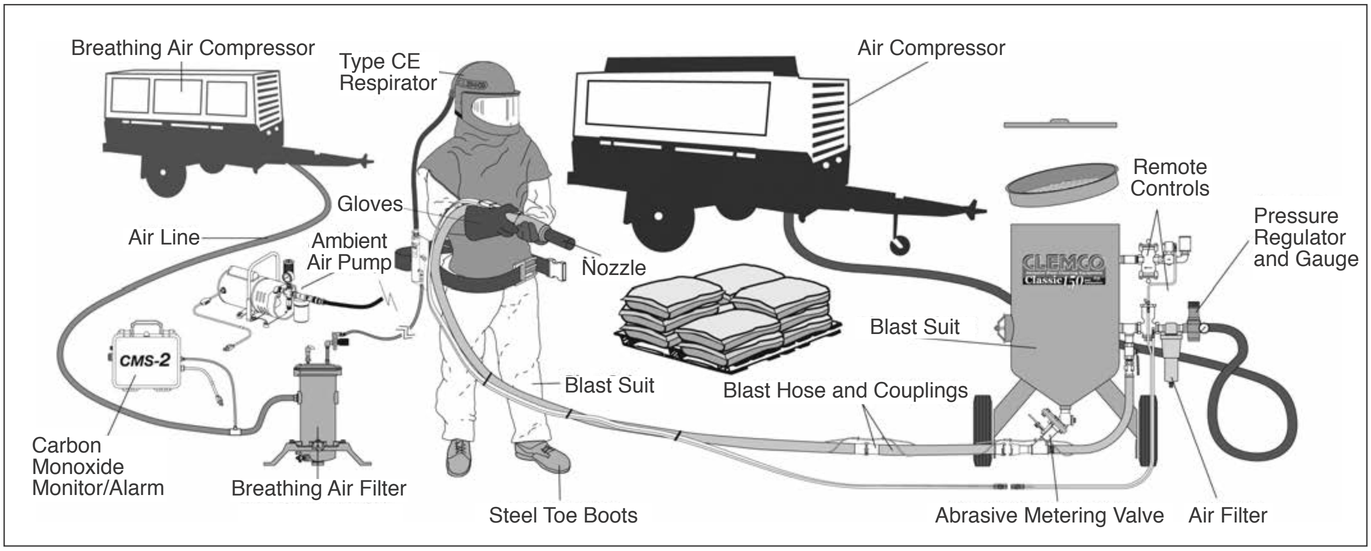

Fig. 3: Basics of proper setup for abrasive blasting

To prevent injury and illness, personal protective equipment (PPE) is absolutely necessary for blasters and everyone in the work area. OSHA enforces regulations pertaining to safe abrasive blasting. Respirators used for blasting must be tested and approved by the National Institute for Occupational Safety and Health (NIOSH). Make sure to choose an air-fed helmet that not only furnishes breathing air but also protects the head and face from rebounding abrasive and from impacts; muffles noise; and allows an unobstructed field of vision. OSHA regulations dictate that noise levels generated by the respirator at maximum air flow and measured inside an air-fed helmet not exceed 80 decibels. Make sure to use approved components and spares to preserve NIOSH approval.

• **Carbon Monoxide Alarms**—protect workers from carbon monoxide

Protecting workers from exposure to carbon monoxide (CO), a colorless, odorless, deadly gas, is easy with the installation of a CO monitor/alarm. This device prevents operator exposure to carbon monoxide by providing an audible and visual signal when unsafe CO levels are detected. CO can be produced by oil-lubricated compressors or by motor or engine exhaust that enters the intake of a compressor or ambient air pump. Always service the compressor at the recommended intervals, and install high-temperature shutdown devices or carbon monoxide alarms, or both.

Skill and Good Judgment

• **Operator**—experienced, knowledgeable, and trained

High-production, quality equipment is no guarantee to an efficient operation. An essential element in a successful blast operation is a properly trained operator. Blasting can be dangerous for the poorly trained or poorly equipped operator. OSHA regulations state that employers are responsible for training and supplying all necessary protective clothing and equipment.

• **Safety Program**—set up by employer

Employers must also establish a safety program and ensure their workers follow safe practices on every job.

Conclusion

For the best outcome, follow the rules for equipment setup and component compatibility, and equip your operators with knowledge and the best in safety and comfort equipment (Fig. 3). A few simple steps can make the difference between risks to workers and an unprofitable job on the one hand and a safe, effective, productive, and profitable abrasive blasting job on the other.

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Controlling Quality during Abrasive Blasting: Checking Environmental Conditions, the Steel, and Your Equipment

By Sara Kennedy,
Coating Society of the Houston Area

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The performance of a coating depends in large part on the quality of surface preparation. This is because coatings have been formulated to perform properly under particular conditions, such as over a specified degree of surface cleanliness and a specified anchor profile, and under certain environmental conditions. If these and other conditions are not met, coatings may not achieve their expected performance.

When dry abrasive blasting is the specified method of surface preparation, you must take many conditions into consideration before you start blast cleaning. Some of these conditions will not be addressed in this Bulletin, such as assuring the quality of abrasives, detecting and removing non-visible contaminants from steel, setting up abrasive blast equipment, techniques of air abrasive blasting, and assessing surface cleanliness and profile.

This Bulletin will focus on field tests or checks that should be conducted to make sure that the blasting operation takes place under conditions favorable to successful coatings application and performance. These tests include making sure that environmental conditions are suitable for blasting, that contaminants are not retained or introduced by the blasting process, and that equipment does not hamper productivity.

While inspectors or owners' representatives may perform many of these tests, the contractor is ultimately responsible for first-line quality control of the work and must conduct the field checks.

Checking Conditions before Blasting

Most coatings do not adhere well to surfaces contaminated with oil and grease. Blasting actually drives them further into the steel rather than removing these contaminants and thus contributes to premature coating failure. Therefore, you should always check for visual surface contaminants before blasting. If oil and grease are present, they should be removed by solvent cleaning, as specified in SSPC-SP 1. All of the blast cleaning specifications, SSPC-SP 5/NACE No. 1 (White Metal), SSPC-SP 10/NACE No. 2 (Near White), SSPC-SP 6/NACE No. 3 (Commercial Blast), SSPC-SP 14/NACE No. 8 (Industrial), and SSPC-SP 7/NACE No. 4 (Brush-Off Blast), require this step.

"If you are using recyclable abrasive, you should test it for cleanliness before and during the project."

One piece of equipment for checking for the presence of contaminants is a black light, available from blasting equipment manufacturers and inspection instrument supply companies. It operates on the same principle as black lights in discos. When you shine the light on the substrate, the clean part of the surface will appear to be dark, while areas with oil or grease typically will be shiny, although not all oils will fluoresce under the black light.

Ambient conditions should be measured before blasting. If blasting is not to be followed immediately by coating application, then it may be all right to proceed first with rough blasting to remove the existing coating, rust, and mill scale, and only verify that the ambient conditions are satisfactory before the final blast begins. If blasting is to be followed immediately by coating, then ambient conditions should be checked before blasting begins.

Among the ambient conditions you must check are the dew point, air temperature, relative humidity, and surface temperature, to be sure conditions are suitable for blasting. Otherwise, condensation will form on the steel during or after blasting and cause flash rust, which can be detrimental to the overall quality of the coating performance.

Fig. 1: Monitor with 24-hour uplink to internet with secure access allows surface temperature, ambient conditions, and dew point spreads to be checked from a remote location. Courtesy of Munters Moisture Control Services

To measure ambient conditions, you can use electronic gages that measure dew point, relative humidity, and surface temperature (Figs. 1 and 2). Or you can determine ambient conditions the old-fashioned way with the following tools:

- a surface temperature gage,
- a sling psychrometer for measuring dry bulb (air) and wet bulb temperature (Fig. 3), and
- psychrometric charts to calculate relative humidity and dew point.

Dew point is the temperature at which moisture condenses on a surface. For example, if the dew point is 70 F (21 C), condensation will occur if the steel is at or below 70 F (21 C). As a general rule, final blast cleaning should take place only when the surface is at least 5 degrees F (3 degrees C) above the dew point. For example, if the dew point is 70 F (21 C), the steel temperature should be at least 75 F (24 C). This rule provides a margin of error in case of instrument inaccuracies, quickly changing weather conditions, or human error.

Dew point can be calculated using the psychrometer and psychrometric tables from the U.S. Weather Bureau Service. The psychrometer is a hand-operated or motorized instrument that has two glass thermometers. One glass thermometer has on its bulb a clean sock or wick made of cloth. This is called the wet bulb. The uncovered thermometer is called the dry bulb. To use the psychrometer, first wet the sock thoroughly. Then, whirl the psychrometer if it is hand-operated, so that the instrument spins at a steady, medium speed for about two minutes. Observe the temperatures at 20 to 30 second intervals.

When you obtain three consecutive readings of the same temperature on the wet bulb thermometer, record the readings from both thermometers. In the case of the fan-operated psychrometers, turn on the fan and allow it to run for approximately two minutes, then record the readings. On the psychrometric chart labeled "dew point," you will find instructions for calculating that value.

Then, measure the surface temperature. The easiest instrument to use for this task is a magnetic temperature gage that attaches to the steel. Place the gage on the steel and allow it about two minutes to stabilize. If the surface temperature is 5 degrees F (3 degrees C) above the dew point, then conditions are suitable for final blasting.

The readings should be taken where the work is being performed, because conditions can vary across a structure. If the work is taking place in many locations at the same time, note that dew point problems will occur in the coldest (shaded) portions of the structure first.

Relative humidity can be calculated using the values obtained from the psychrometer and the psychrometric charts labeled "relative humidity." As a general rule, final blasting should not be done if relative humidity is at or above the maximum relative humidity for coating application. Note that for some coatings, being above a minimum relative humidity may also be an issue.

Fig. 2: A handheld digital gage for measuring air temperature, surface temperature, and relative humidity. It uses the values to calculate dew point and the difference between the dew point and the surface temperature. Courtesy of Defelsko

Checking Blasting Abrasives and Equipment

Abrasives and equipment should also be checked for cleanliness before blasting, and the equipment should be checked for efficiency.

Abrasives can be easily and economically checked for oil, dirt, and salts in the field with the following equipment: clean jars with tight lids, distilled water, and chemical test papers. A small amount of the abrasive is placed in the jars, covered with distilled water, and shaken. The abrasive will settle to the bottom of the jar. If an oily film appears on the top of the water after the abrasive settles, the abrasive is contaminated and should not be used. If the water becomes very cloudy, there may also be an issue with the abrasive that requires further investigation.

Test papers and portable meters will indicate the presence of some soluble salts, and litmus papers will indicate the presence of some acids or bases.

Fig. 3: A sling psychrometer (above) along with a surface temperature gage and psychrometric charts can be used to determine dew point and relative humidity. Courtesy of Bacharach

If you are using recyclable abrasive, the abrasive should be tested during the job (using the jar and water) to make sure the reused abrasive is clean. SSPC-AB 2 provides an additional battery of tests that can be conducted to check the cleanliness of recyclable steel abrasives.

ASTM D 4940 is another method for evaluating the presence of soluble salts on abrasives. It involves measuring the conductivity of a water/abrasive mixture.

The blasting equipment should also be examined. You will have to depressurize the blasting equipment and take it apart to check some of its components. The compressor and the moisture trap or moisture separator must be checked for contaminants, and the nozzle lining must be checked for wear.

The compressor has oil and moisture separators that remove oils and moisture from the air passing through the compressor. Make sure the compressor is level. Otherwise, the separators will not work properly, and oil and moisture will get into the hoses (and onto the steel).

A second moisture trap or moisture separator, not part of the compressor, should be used to catch any remaining moisture that might be trapped in the hose that connects the compressor to the blast pot. Be sure that this separator is as close to the blast pot as possible to catch any moisture that has condensed in the hose. Also be sure that the moisture trap is set on automatic bleed so that moisture drains out of the trap to the ground and does not remain in the blasting system. These measures will help keep the abrasive and substrate dry during blasting so that rust bloom does not appear.

The nozzle lining should also be checked for wear before blasting operations begin and during blasting if your production rate drops. An orifice nozzle or throat gage can be used to check the inside diameter of the nozzle lining. The gage consists of a china marking chalk and a tapered rod that is marked to indicate different diameter readings.

Using the china marker, "color" the gage around the diameter mark that represents the nozzle that you are using. Put the gage in the back side of the nozzle, twist it, and pull it out. The china markings will be scored by the nozzle orifice, and you can determine the orifice diameter by reading the gage. If the diameter is larger than required (generally one nozzle size larger than a new nozzle), then the lining of the nozzle has worn out and needs to be replaced. Otherwise, your production rate may be lower than desired.

You will have to put the equipment back together and carefully re-pressurize the system to check the air that comes from the blasting equipment for moisture and oil. This can be done with a blotter test.

Clean white rags, blotters, or even coffee filters can be used to test the blast air. To conduct the blotter test, close off the abrasive valve so that no abrasive gets into the air stream. One way is to place the rag or blotter in front of the nozzle or other air outlet, and turn on the air for one minute. If the rag is wet, then moisture is escaping, so you should adjust the moisture separators. If the rag is dirty, oil is in the air stream, and the oil separator should be checked. ASTM D 4285 describes another method that involves blowing the air onto blotter paper and rigid plastic for a minimum of one minute.

"To avoid injury you must depressurize the blasting equipment before you check the compressor and other components."

Before beginning blasting operations, you should also check for proper pressure at the nozzle. Generally, 90–100 psi at the nozzle is the pressure range suitable for efficient production. The pressure reading should be obtained at the nozzle, not at the compressor. Pressure at the nozzle can be checked with a needle pressure gage. This device consists of a hypodermic needle attached to a pressure gage with pressure increments marked on its face.

The hose should be directed toward the substrate and turned on, with air and abrasive flowing. The needle should be inserted into the hose right behind the nozzle in the direction of the flow of the air and abrasive. The face of the gage can then be read. The compressor pressure can be adjusted if pressure is below 90–100 psi or the source of the pressure drop is determined and corrected. Alternatively, changes to the hoses (diameter or length) or nozzle sizes can be made.

Checking the Steel after Blasting

After blasting, make sure you have removed all dust from the blast-cleaned surface, either by blowing down the surface with clean compressed air or vacuuming the dust with a vacuum available from equipment manufacturers. Dust on the surface can interfere with the coating's ability to bond to the surface. If you blow down the surface, first check the cleanliness of the air again with the blotter test described earlier. After blowing or vacuuming the surface, you can brush a clean white cloth across the surface. Be sure not to touch the steel with your bare hand. Oils or salt from your hand can be transferred easily to the surface and contaminate it. If dust appears on the cloth, you need to blow down or vacuum the surface again.

You can also check for non-visible contaminants, especially soluble salts, which are detrimental to coating performance. Portable test kits, available from test equipment manufacturers and from testing and inspection firms, are to be used to analyze the surface. SSPC-TU 4 describes the various test methods. The test kits help you quantify the amount of chloride and other salts remaining on the steel surface after blast cleaning. You will have to get the opinion of your supervisor or the coating manufacturer to determine if the level of contaminants measured is detrimental to coating performance. These kits are available from test equipment manufacturers and from testing and inspection firms.

Once the blast-cleaned surface is free of dust (and other contaminants), you should check surface profile and degree of cleanliness to see that you have met the specifications.

Record Keeping

The quality control checks that you make should be documented and kept as part of your quality control records for the job. This way, you have historical information for verifying compliance with specifications.

Conclusion

Remember that the quality control measures you take will help you ensure that abrasive blasting operations create a surface suitable for coating application. Moreover, while inspectors may be on the job conducting similar tests, you should not be intimidated by the inspectors and should conduct your own quality control checks. Their efforts and your own will help you provide the high-quality work needed for successful coating application and performance.

JPCL

Taking Care of Abrasive Blasting Equipment: Productivity and Safety Depend on Timely Maintenance of Equipment and Operator

By Patti Roman, Clemco Industries

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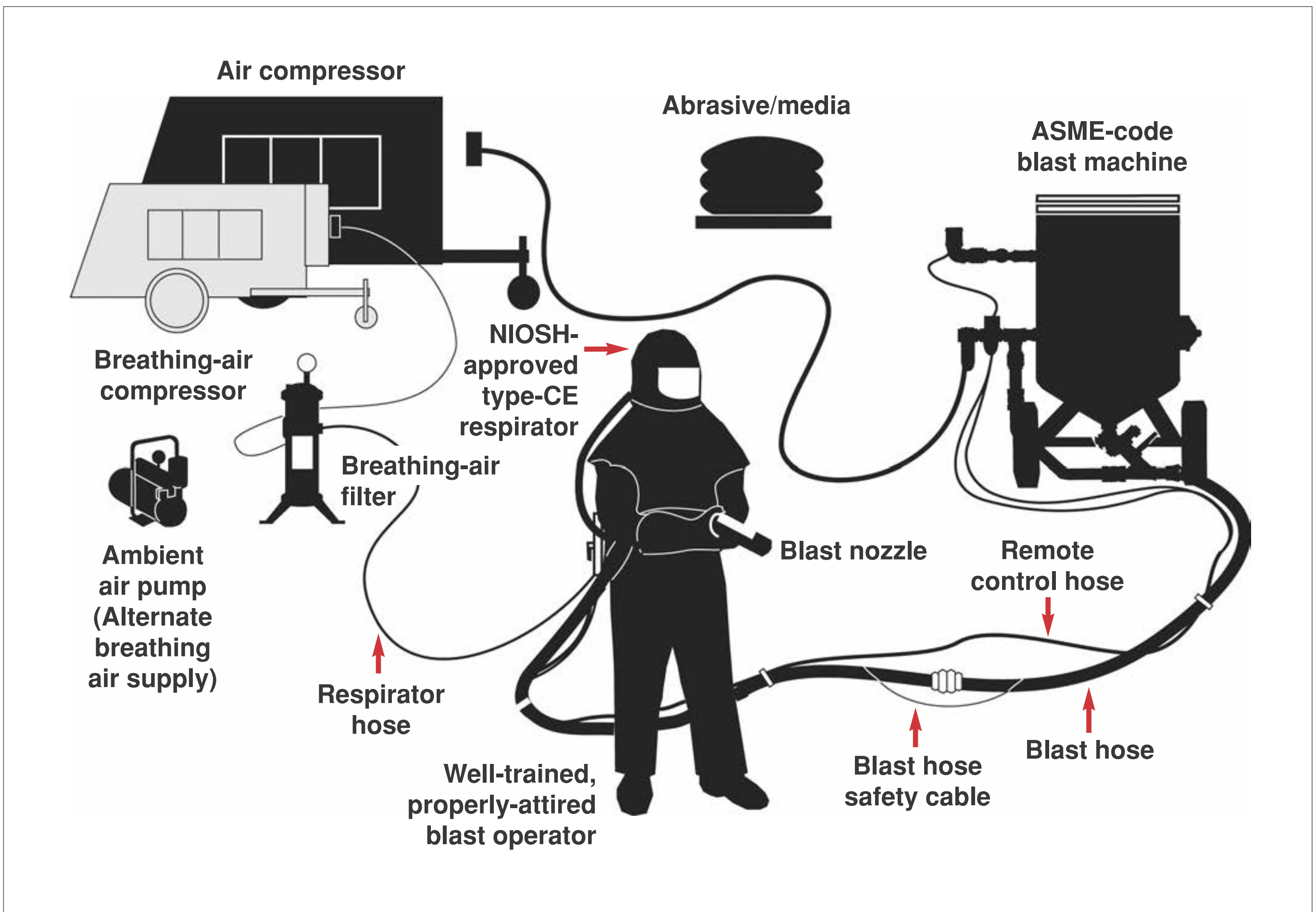
In 2004, among other worries, business owners have to be concerned about two things: earning a profit while remaining competitive and providing a safe environment for their workers. Using job tools effectively contributes to operational success. To that end, one sure way to stay on course is to make certain that every component of the blasting job is properly maintained. Spending a little time checking equipment upfront can ensure smooth sailing during the job while protecting workers and avoiding costly downtime.

Because blasting performance is the direct result of elements functioning in concert, poor performance by one element will hamper the system's effectiveness. To be effective, the blasting operation must achieve maximum productivity at the highest level of safety. Maintaining productivity and assuring worker safety are the primary objectives of preventive maintenance.

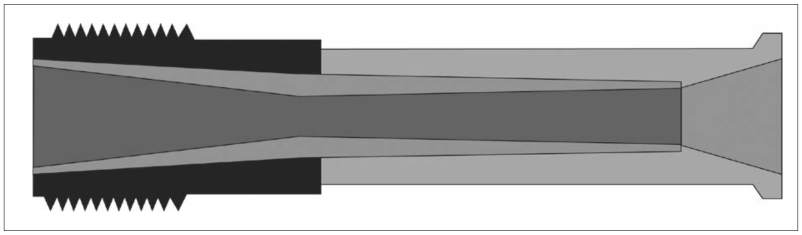


Abrasive blasting set-up
Illustrations courtesy of Clemco Industries Corp.

Maintaining Productivity

Maintaining Volume and Pressure of Compressed Air Is Critical

The blast machine is the core component of the blast operation. Air (in combination with media) fuels it and energizes it to power the operation and do the work. Air is the energy that makes it all possible, and air blasting operations rely upon an adequate volume (cubic feet per minute—cfm) of clean, dry air at the needed pressure (psi) for optimum performance. Making sure that the air flows into the blast machine and out through the nozzle sounds simple enough. But that's the challenge—ensuring that air flows through the system and exits only through the nozzle. Air leaks are a common enemy of blast operators. They sap the system of its power, waste compressed air, and can endanger blast operators. In and around blast machines, air leaks can occur at pipe connections, air hose fittings, blast hose couplings, and nozzle holders, as well as around valves.



The nozzle is one abrasive blasting component that should be checked weekly for wear to the liner.

Air leaks reduce the volume of air available for blasting and place additional demand on the compressor to deliver the needed pressure. Air leaking from areas holding abrasive makes those areas particularly vulnerable. They are subject to damage from erosion caused by abrasive that the escaping air carries.

Replacing Components before They Fail Is Wise

Another enemy to performance is worn components. They hinder productivity and create safety hazards. A worn abrasive metering valve interferes with the operator's ability to use the proper amount of abrasive. Using too rich a mix of abrasive to air reduces the blast velocity, thereby reducing productivity and running up job cost by wasting abrasive. It's important to make repairs with the original equipment manufacturer's parts to ensure proper fit. A gasket of the wrong size is as good as a missing gasket.

Establish Good Maintenance Habits

To maximize performance of blast equipment, establish a simple routine to perform a system check before a problem occurs. An added benefit of this good habit is that it buys time, allowing you to order the replacement parts you need to optimize equipment function. Sure, you should always have a supply of parts on hand, but monitoring the equipment for wear is an effective productivity tool and also buys peace of mind. The replacement schedule will no doubt vary from job to job, depending upon the application and the number of daily blasting hours. However, it's important to keep in mind that an idle blast machine can develop problems from non-use. Blast hose, for example, can decay over time no matter where it is stored. Of course, leaving the machine and accessories outside exposed to the elements accelerates the decay process. So before putting a machine into service, it's best not to assume that it is in the same condition it was in when it was placed into storage.

Assuring Operator Safety

The obvious considerations for assuring operator safety involve many of the above-mentioned equipment-related items: checking fittings and components for wear before there's a problem. Loose-fitting couplings, missing screws or ill-fitting ones that penetrate the hose wall, and non-functioning remote control handles all can endanger the operator.

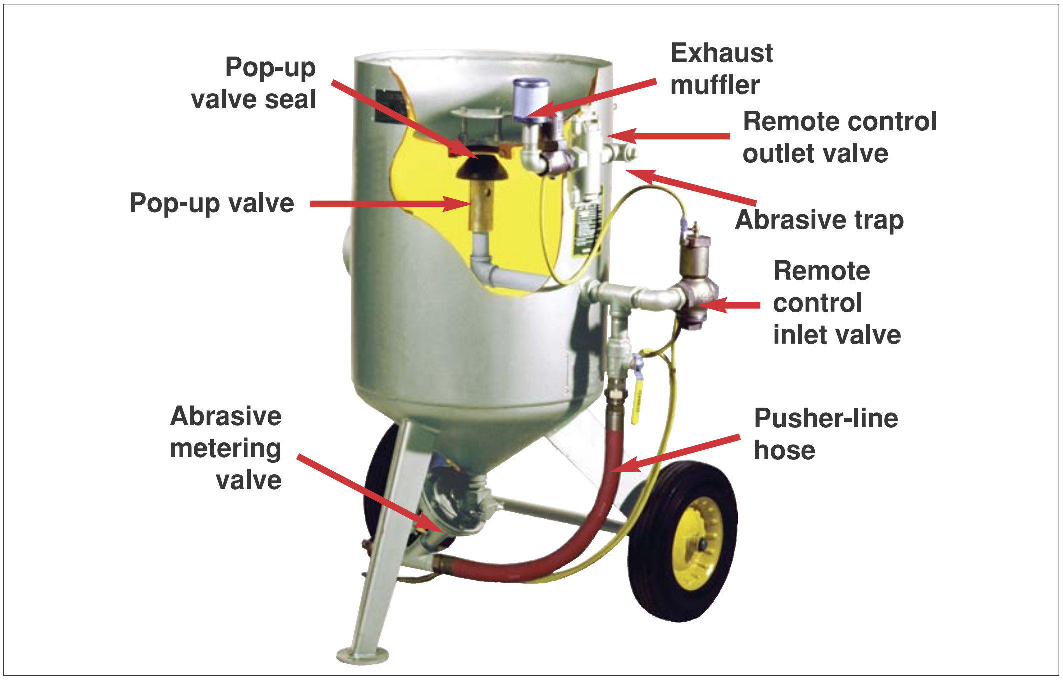
The performance of the blast operator is just as critical to overall productivity as the blast machine is. Keeping the operator 'maintained' involves providing him with clean, properly fitting and maintained respiratory protection, which includes the right equipment for the application and good quality (Grade D) breathing air. This keeps him safe and comfortable. A well-equipped operator is more efficient and productive than an ill-equipped operator. (Grade D breathing air is made up of 19.5 to 23.5% oxygen by volume, no pronounced odors, no more than 5 mg/m³ of condensed hydrocarbons, no more than 10 ppm of carbon monoxide, and no more than 1,000 ppm of carbon dioxide, a definition established by the Compressed Gas Association in the U.S.)

Additionally, maintaining the operator involves ensuring he is properly trained on how to use the equipment and how to perform needed on-site equipment checks. There's no substitute for reading the equipment owner's manual.

Conclusion

On the next page, you'll find some easy steps to follow before beginning the blasting session to make sure your equipment is ready to go to work for you.

Stay ahead of the curve: think air, think wear, and think inside and outside the pot!



Cutaway of ASME-code blast machine showing key components to check for wear

Patti Roman is vice president of marketing for Clemco Industries Corp. She started with Clemco in 1975 and has held various sales- and marketing-related managerial positions. She graduated with a BA from the University of Southern California and received a master's degree in international business from Saint Louis University. She has written articles for various industry publications.

Blast Machine Performance Checklist

DAILY OR MID-SHIFT INSPECTION

Blast Machine and Accessories

- ☐ Empty the abrasive trap (when equipped), and clean or replace the abrasive trap screen. A clogged screen slows depressurization time and can cause abrasive to remain in the blast hose, wasting abrasive.
- ☐ Inspect the blast hose for wear; look for soft spots and external damage. Soft spots mean the hose is worn. Replace the blast hose when these signs appear. Monitoring blast hose helps you avoid blast hose blowouts.
- ☐ Check to make sure that couplings are securely installed on the blast hose, and that lock pins and safety cables are in place. Loose-fitting couplings allow air to leak. Should a fitting fail under pressure, safety cables prevent a whipping hose.
- ☐ Make sure a nozzle washer is in place between the nozzle and the nozzle holder. A worn or missing washer can cause an air leak, which in turn erodes the nozzle entry and the nozzle holder threads.
- ☐ Inspect the remote control handle and control hoses. A properly functioning remote system gives the operator the power to control the 'on' and 'off' functions of the machine. This is crucial to a safe operation and is a safety requirement in the U.S.

WEEKLY INSPECTION

Blast Machine and Accessories

- ☐ Inspect nozzles for wear by measuring the size of the orifice. A larger orifice demands greater air volume to maintain the desired blasting pressure. Replace the nozzle when its orifice measures 1/16-inch (~1.6-millimeters) larger than its original size. The industry standard in the U.S. for nozzle orifice size is in sixteenths of an inch. A No. 3 measures 3/16-inch, No. 4 measures 4/16-inch (1/4-inch), etc.
- ☐ Inspect metering valve and fittings for leaks.
- ☐ Inspect all couplings and coupling gaskets for leaks.
- ☐ Check the blast machine for leaks. Leaks interfere with the pressurization of the machine. Leaks can develop around the pop-up valve if the seal or the valve itself wears out. Leaks may develop around the inspection door or at the pipe fittings at the bottom of the cone. If machine leaks are allowed to continue, air and media escape and cause erosion and, sometimes, irreparable damage to the blast machine.
- ☐ Check external piping and valves for leaks. If leaks are found, repair immediately.

MONTHLY INSPECTION

Blast Machine and Accessories

- ☐ Inspect air filter element, and clean the bowl.
- ☐ Inspect the exhaust muffler for blockage and wear.
- ☐ Lubricate the remote control valves.

Checklist courtesy of Clemco Industries Corp.

On the Cleanliness of Compressed Air for Abrasive Blasting

How clean must the compressed air be for abrasive blasting? How is cleanliness determined?

Editor's Note: These responses to this forum query appeared in JPCL *in August 2011.*

Patti Roman
Clemco Industries

One of the most critical elements of a successful abrasive blast operation is the compressed air that energizes the system. Moisture and oil are the enemies. They cause abrasives to form clumps, which can clog metering valves, hoses, and nozzles. If moisture reaches the surface being cleaned, it can cause steel to rust; oil can cause coating adhesion problems and blistering, resulting in coating failure.

A 40–50 micron air filter, installed at the blast machine's air inlet, is typical for removing particulate matter from compressed air for abrasive blasting. This filter will remove moisture that has condensed but will not remove water vapor. In high-humidity areas, additional drying is often needed. After-coolers or air dryers are needed to prevent abrasive bridging, which means the air channels through the abrasive in the machine but the abrasive does not flow. Some abrasives are more moisture-tolerant than others. Finer mesh materials will be more susceptible to moisture problems. And some abrasives manufacturers treat their material to enhance flow.

When a blast operator blows down the surface following blasting, it is important that the air is dry. If it is not, and moisture hits the freshly blasted surface, water spotting can occur. Water spotting can affect the coating application.

Compressed air is used to power abrasive blast machines as well as to provide breathing air for blast operators. For blasting, removing moisture and oil assists abrasive flow and prevents oil contamination on the blasted surface. These types of contamination are visible and obvious, and can be identified using methods described in ASTM D4285, "Standard Test Method for Indicating Oil or Water in Compressed Air."

When compressed air is used for breathing air, the term cleanliness takes on new meaning. OSHA regulations state that breathing air must meet the specification for Grade D, as established by the Compressed Gas Association. Grade D defines minimum and maximum limits on oxygen and other gases. Breathing contaminated air can be deadly, so this serious discussion should be the topic of another PSF.

Gary Mabry
T & G Services

It is critical that the compressed air supply for abrasive blasting is not contaminated with oil or water. To ensure that the air is dry and clean, conduct a blotter test prior to starting each work shift and at reasonable intervals throughout the day. If contaminants are evident on the blotter test, all filters and driers that should be present in the supply line must be opened and blown out until the air is clean and passes the blotter test. If you can't achieve a passing test, added filters can be used, or the air source should be replaced.

Lee Edelman
CW Technical

The air supply must be free of oil, water, and other contaminants. Cleanliness is checked by doing a blotter test at the air manifold. The air supply should have moisture traps in-line and a proper aftercooler system.

Carl Havemann
www.corrosioneducation.co.za

There are two contaminants to test for, oil and moisture. Check for oil using proper proprietary oil mist test equipment. The acceptance criterion is that no oil is allowed. To check for moisture, blow the compressed air onto clear glass for 30-60 seconds; then check for condensation. The acceptance criterion is that no moisture allowed. (A five-minute test is too long, in my opinion.) **JPCL**

The Importance of Air Compressor Maintenance

By John Placke,
Ingersoll-Rand Co.

Editor's note: This article appeared in JPCL *in October 2005.*

In protective coatings work, air compressors are used in blasting operations. The function of an air compressor is to provide compressed air energy for the blasting operation. If air compressors are not properly maintained, they can bring a job to a halt. This article will explain how one type of air compressor works—a rotary screw air compressor—and what you can do to keep your compressor in working order.

Readers should note that compressor maintenance should be performed in accordance with the manufacturer's recommendations. Manufacturers have different requirements based on their equipment configuration. Follow the manufacturer's guidelines as a minimum, and add additional requirements to meet your needs based on the environment where the equipment will be used. Figure 1 on the next page is an example of a manufacturer's preventive maintenance program that can be modified to meet the user's needs based on area conditions.

Readers should also note that air from these compressors is not designed, intended, or approved for breathing air. Compressed air should not be used for breathing air applications unless treated in accordance with all applicable codes and regulations.

Definitions and Principle of Operation

The term rotary screw is used to describe this kind of compressor because the rotors inside the compressor resemble screws, and they rotate like screws. A rotary screw compressor draws air in from the outside, compresses it for the blasting equipment, then discharges it. The air is compressed and moved by two positive-displacement rotors. Positive displacement means that the volume of air that goes into the compressor is equal to the volume of air that is discharged. Both rotors are different. The "male" rotor is shaped to fit inside the lobes of the "female" rotor. Normally, the male rotor has four lobes, while the female rotor has six lobes. The male and female rotors turn, and this turning motion is what compresses the air (Fig. 2).

Rotary compressors are oil-flooded and consist of five main systems.

- Cooling and Lubrication
- Separation
- Regulation
- Automatic Blowdown
- Electrical

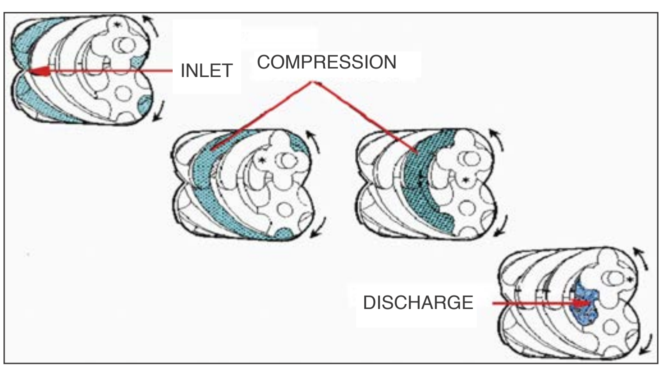


Fig. 2: In a rotary screw compressor, the four-lobed "male" rotor and six-lobed "female" rotor turn to compress air.

Preventive Maintenance:

	Daily	Weekly	Monthly	Quartery	Biyearly	Yearly
SMALL SIZE UNITS (P100 – P600)				250 hours	500 hours	1000 hours
LARGE SIZE UNITS (P100 – P1600)				500 hours	1000 hours	2000 hours
COMPRESSORS OIL LEVEL	C					
ENGINES OIL LEVEL	C					
RADIATORS COOLING LEVEL	C					
METERS/LAMPS	C					
AIR FILTER SERVICE GAUGE	C					
FUEL TANK (FILL AT SHIFT END)	C				EMPTY	
WATER/FUEL SEPARATOR EMPTY	C					
DISCHARGERS OF PRE-CLEANER OF AIR CLEANER		C				
ALTERNATOR BELTS		C				
BATTERY CONNECTIONS/LEVEL		C				
TIRE PRESSURE/TREAD		C				
WHEEL BOLTS			C			
HOSES (OIL, AIR, INTAKE, ETC.)			C			
AUTOMATIC SHUTDOWN SYSTEM TEST			C			
AIR PURIFICATION SYSTEM VISUAL			C			
COMPRESSOR OIL RADIATOR EXTERNAL			C	CLEAN		
ENGINE OIL RADIATOR EXTERNAL			C	CLEAN		
CLAMPS				C		
AIR PURIFICATOR ELEMENTS				WI		
FUEL/WATER SEPARATOR ELEMENT					R	
COMPRESSOR ELEMENT				B	A	
COMPRESSOR OIL					R	
WHEELS (BEARINGS, SEALS, ETC.)					C	C
ENGINE COOLER TEST					C	R
SHUTDOWN SWITCH LOCKOUT TEST						C
SCAVENGING ORIFICE & COMMON ELEMENTS						CLEAN
OIL SEPARATOR'S ELEMENT						R
HOOK AUGEN BOLTS	CHECK BEFORE TOWING					
LIGHTS (DRIVE, BRAKES & FLASHER)	CHECK BEFORE TOWING					
ENGINE OIL CHANGE, FILTERS, ETC.	REFER TO THE ENGINE OPERATOR'S MANUAL					

A = CHANGE ONLY TO THE SMALL SIZE UNITS
B = CHANGE ONLY TO THE LARGE SIZE UNITS
C = CHECK (ADJUST OR REPLACE AS NEEDED)
R = REPLACE
WI = WHEN INDICATED
* REFER TO THE MANUAL FOR NXP
** REJECT IF NOT APPLICABLE TO THE SPECIFIC UNIT

Fig. 1: Example of a manufacturer's preventive maintenance program.
Images courtesy of Ingersoll-Rand Co.

Cooling and Lubrication System

The cooling system in rotary screw compressors have a "cool box" design. Air is drawn from outside, across the airend (integral filter), engine, and lastly, through the coolers. In the lubrication system, the oil performs three specific tasks. First, it cools the airend by taking away the heat of the compression. Second, it seals the clearance (space) between the rotors. Third, it lubricates all moving parts of the system.

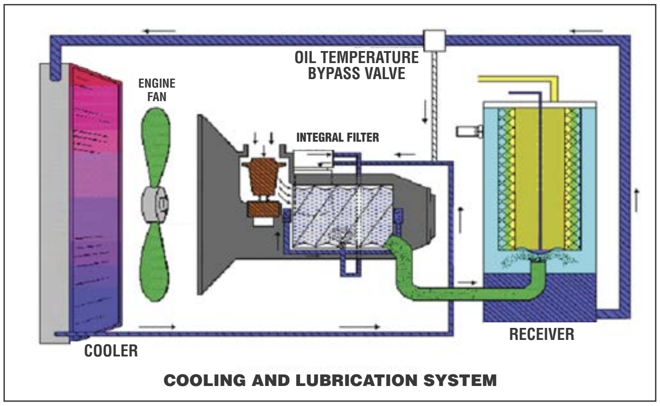


Fig. 3: Schematic showing flow of the air and oil mixture passing through the cooling and lubrication system.

Looking at the schematic (Fig. 3), you will notice that oil is injected under pressure into the rotors and bearings. A compressed air and oil mixture flows from the airend to the receiver tank; most of the oil falls immediately to the bottom of the tank. Oil then flows to the temperature bypass valve, where it is directed to the cooler or re-circulated through the oil filter and back into the airend. Since oil is the life-blood of the compressor, it is very important to keep this system operating at its peak performance, the oil and filter should be changed at recommended intervals (usually around 500 hours), using approved filters and fluids. Intervals may be decreased due to environmental conditions. For example, if you are in a very humid area and your compressor idles for extended periods, the oil doesn't get hot enough to take the moisture out of the oil, so the frequency of the oil and filter change should be increased. Keeping the lubrication system in optimum condition ensures long compressor life.

Separation System

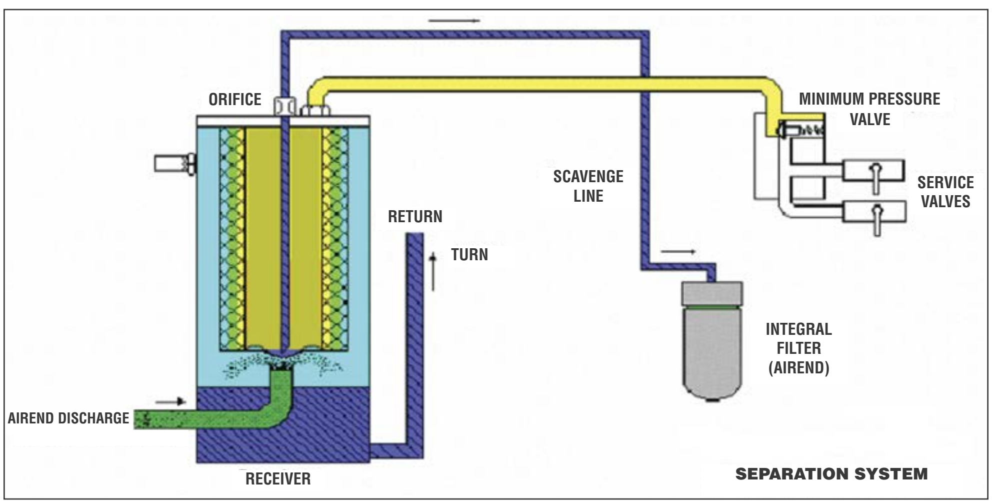


Fig. 4: The oil and air mixture from the airend is forced into the separator receiver, where any remaining oil is then removed from the air.

The air and oil mixture from the airend is forced into the separator receiver (Fig. 4). Most of the oil falls immediately to the bottom of the tank. Any remaining oil is removed from the air by the separator element and diverted back to the airend through a scavenger line. The remaining air is directed to the service valves for use. To properly maintain the separator system, the separator element should be changed at 1,000-hour intervals, and the scavenger orifice must be checked. If this system is not properly maintained, you will experience a condition called "oil carry-over." Oil carry-over describes an excessive amount of oil mixed with the air coming out of the service valves.

Regulation System

The regulation system is designed to maintain the correct air pressure in the system (Fig. 5, p. 26). When the system has no air pressure, the engine speed cylinder is spring-loaded to full fuel position, and the unloader valve is spring-loaded to the open position. When the unit is started, the compressor begins to make air. As the air pressure builds up, it will overcome the spring pressures, simultaneously closing the unloader valve and causing the air cylinder to slow the engine down. The purpose of the unloader valve is to open and close the compressor intake. During startup, the unloader is closed, allowing the engine to warm up before it is loaded. When the engine warms up and the service air button is depressed, the compressor will make air until it is at rated pressure.

The regulation orifice is carefully sized to match the characteristics of the regulation system, and it is perfectly normal for air to bleed from the orifice whenever air pressure is applied to the unloader and engine speed control cylinder. The pressure regulator controls system pressure.

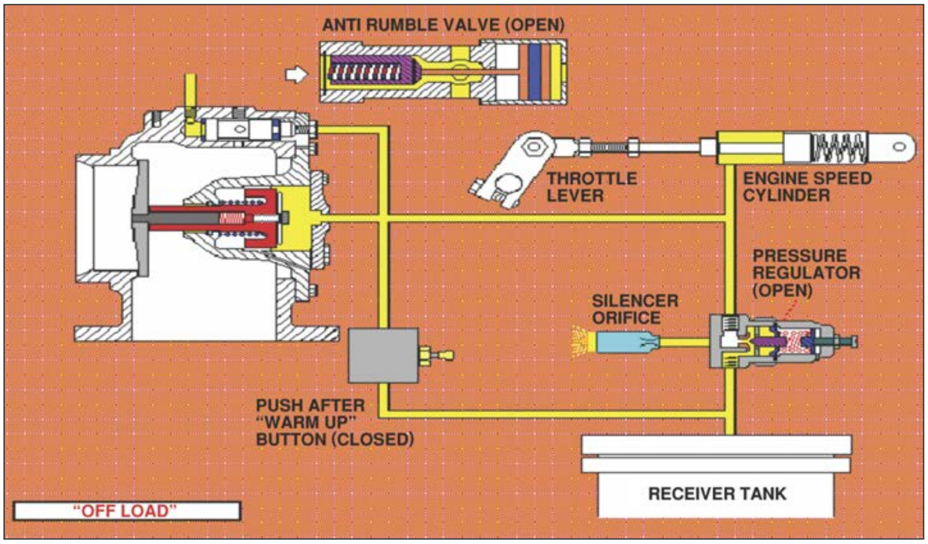


Fig. 5: The regulation system is designed to maintain the correct air pressure in the system.

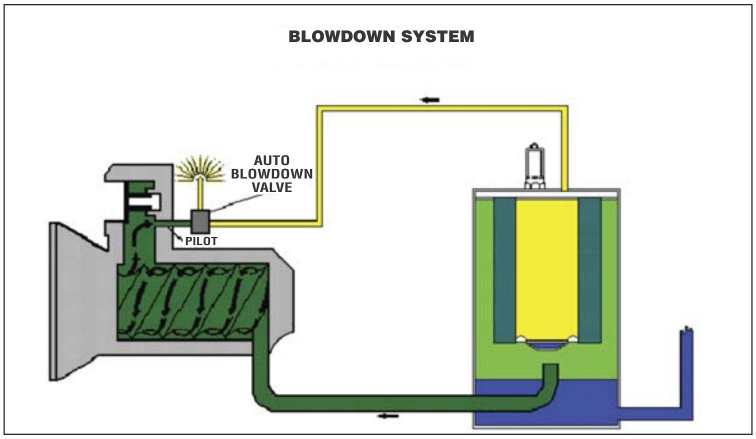


Fig. 6: The blowdown system relieves compressed air from the tank once the unit has been shut off.

Blowdown System

The main purpose of the blowdown system is to relieve compressed air from the tank once the unit has been shut off (Fig. 6). The automatic blowdown valve is normally kept closed by the internal spring. During shutdown, the valve is piloted to the open position by the pressure generated in the compressor unit, enabling the air in the separator tank to be released to the atmosphere. An outlet with an orifice/muffler controls the blow down speed. This system requires no maintenance.

Electrical System

The electrical system provides a means to control the compressor during start, operation, and shutdown. The circuit is also designed to protect the engine and compressor components in the event of an unsafe operating condition. This system should be checked weekly for loose or broken wires and corroded connections.

Compressor Maintenance

A good maintenance program is critical to equipment life and performance, and will save you money.

Preventive maintenance keeps your machine ready to perform on a moment's notice. A good program is one that identifies the need for service based on time intervals and equipment hours. Additional items that also need to be considered when developing a program are environmental conditions such as dust, ambient temperatures, and humidity, where filter changes may be required before the recommended intervals. You may also contact the equipment manufacturer to see if any optional equipment is available for your compressor.

Most equipment manufacturers have developed a preventive maintenance schedule for their equipment, and it must be followed as a minimum. Manufacturers cannot account for all operating conditions. So take these recommendations, and make your own plan.

By establishing a sound maintenance program, you can ensure that your equipment will reach or exceed its expected life.

Preventive maintenance on your air compressor will save time and money by preventing premature engine and compressor failure and ensuring trouble-free service.

JPCL

By David Dorrow,
Mineral Aggregates Inc.

Fishing for the Best Abrasive

Editor's note: This article appeared in JPCL *in March 2011.*

Back when I was a youthful dad, I took my two young daughters down to the creek behind our house to teach them how to fish. When we opened the tackle box, their jaws dropped as their eyes scanned the many lures neatly spread out on the bottom of the box. Big and small, hard and soft, some lures were heavy, to fish on the bottom, or light, to float on the surface. My girls asked, "Daddy, which one is the best?" With a wink, I said, "They are all the best! It just depends on what fish you're trying to catch, the day's conditions, and where you're going to fish."

If you asked me a similar question about picking the best abrasive product for a job, I would give a similar answer. "It depends." It all comes down to project parameters, surface conditions, and your expected outcome. Before selecting the "best" abrasive, you must answer several questions about the surface preparation project.

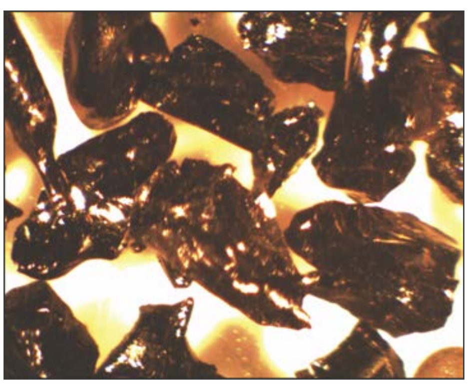
- What is the current surface condition: adhering paint, a brittle coating that is peeling, or mill scale?
- What are the goals and expectations after blasting? For example, is the surface being prepared for a new coating or cleaned to create a uniform visual finish that will be left uncoated?
- Will the surface profile need to meet the specification for the coating system or is it more important that the abrasive blast at fast cleaning rates?

Before selecting the best abrasive for a project, you must understand the characteristics of abrasives and how they affect the resulting finish. Like fishing lures, abrasives come in many sizes, hardnesses, shapes, and densities. Each abrasive's characteristics will affect the blast cleaning process and final results.

Particle Size

The size of the abrasive particles affects both the productivity and surface profile. Decreasing abrasive particle size can dramatically increase cleaning rate, with more particles impacting the surface per unit time when compared with the use of a coarser abrasive. However, increasing abrasive size may be necessary to remove heavy coatings and scale. The general rule is: "Use the smallest size abrasive particle that will do the job."

Coarse abrasives generally leave a deeper and less uniform profile than finer abrasives. If a low profile is required, choose a finer abrasive. Conversely, use a coarse abrasive for a heavier profile. The normal tendency is to use a very coarse abrasive because it will knock off the paint, rust, scale, and other debris. But a coarse abrasive sacrifices coverage or cleaning rate. If a smaller abrasive will work just as well, use it because it will greatly increase cleaning rate.



Fine iron silicate abrasive (copper slag) under magnification

Hardness

It is generally believed that the harder the abrasive is, the better it will perform. Very hard abrasives, however, tend to shatter on impact, expending most of the energy in particle disintegration and dust generation. A softer abrasive will transmit all of its energy to the surface, clean faster, and minimize dust. Similar to selecting abrasive size, select the minimum abrasive hardness that will effectively do the job. Hard abrasives will remove all coatings and surface contaminants and impart a profile on the surface. Very soft abrasives such as walnut shells and corn cobs are used to remove oil and grease and sometimes paint, leaving the existing substrate intact. In this case, the abrasive should break down on impact, carrying away the contaminants. If the intent is to remove only the coating and not disturb the substrate, use a slightly harder, friable abrasive such as soda ash, dry ice, or plastic pellets.

Productivity test, conducted under third-party guidance, on heavily pitted and rusted steel structure at a steel mill. Round and angular abrasives were tested for productivity and usage.

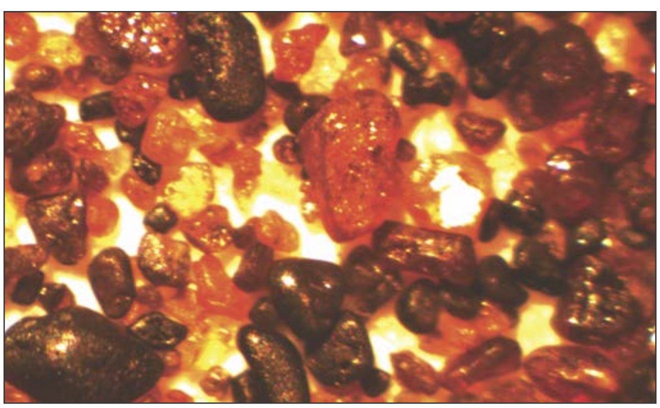
Shape

If the steel surface has a soft, pliable coating to be removed, an angular abrasive will be more productive than a rounded abrasive. Conversely, if the surface has a hard, brittle coating or mill scale, a rounded abrasive is preferred to pop off the coating or scale rather than pick away at it with a grit-like abrasive. An angular abrasive creates an angular and generally not very uniform surface profile. You will get a less angular but more peened surface if you use a rounded particle, such as steel shot or a heavy mineral sand (e.g., staurolite and olivine, which are naturally occurring and low in free silica). Both surfaces are acceptable, but different in appearance. Generally, angular particles work best when removing soft, pliable coatings, whereas shot or rounded particles are more effective in removing hard, brittle coatings (often aged) and mill scale. A mixture of both particle shapes is recommended for some jobs. Angular abrasives are generally used for coatings and rust removal; rounded sands are often used to remove mill scale from bare steel.

Density

Abrasive density can have a major impact on productivity. Generally, the higher the density, the better the productivity. Higher density particles impart more energy to the surface and, therefore, do more work. Application rate is the amount of abrasive required to achieve the level of cleanliness required. Generally, the denser the abrasive, the faster it will clean; thus, the denser abrasive will have a lower application rate compared to a less dense abrasive. As the mass or specific gravity of a particle increases, so does the amount of work being done by the particle. Therefore, if you change from a sand abrasive with a specific gravity of 2 to a garnet abrasive with a specific gravity of 4, you should expect an increase in cleaning rate because the higher specific gravity particle will do more work. If all else is held constant (such as nozzle pressure and particle size), productivity will increase with the garnet.

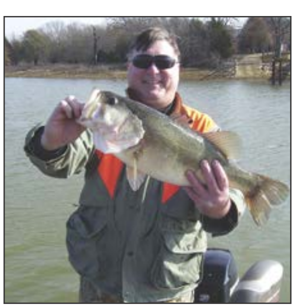
Preliminary blast cleaning trials using several different abrasive products with different sizes usually can determine the most productive abrasive product for the surface conditions. This is especially true for large surface preparation projects where productivity improvements can translate into huge increases in profits. To perform a productivity test, mark a section of the surface into grids, blast the section, and measure the area cleaned. Calculate the time required to blast the area and the amount of abrasive used. This will give you all the metrics required to calculate your surface preparation costs.



Extra fine staurolite abrasive under magnification

As with fishing lures, most people already think they know their "best" abrasive because they have been using it for years. However, to be a true professional, you must be willing to experiment, change, and adapt to the surrounding conditions. Surface conditions have a major influence on the type, shape, size, density, and hardness of abrasives, and you must to be knowledgeable in the art to pick the best.

And don't forget: Abrasive blasting and abrasives are subject to regulations for environmental and worker protection. Regardless of the abrasive and cleaning method for a job, you must comply with all relevant regulations.



David Dorrow is the president of Mineral Aggregates Inc., which develops marketing solutions for mineral co-products from the steel, smelter, and other industries. With more than 30 years of experience in the abrasive markets, he is a member of SSPC and has served on its Abrasive Steering Committee; Surface Preparation Steering Committee; and Development Committee for SSPC-AB 1, Mineral Abrasive Specification.

Author with large mouth bass caught with the best lure for the "job"
Photos courtesy of the author.

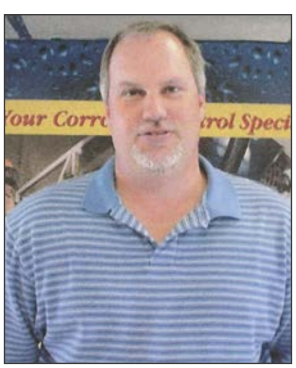
Abrasive Selection Requires Evaluation of Needs, Cost, and Productivity

By Lori Huffman,
JPCL

Editor's note: This article appeared in JPCL *in November 2006.*

Jeff Theo of Vulcan Painters

Tom Westerman of Corpus Christi Equipment



Tim Poor of CESCO

Gone are the days when inexpensive silica sand was the abrasive of choice for contractors looking to maximize productivity, minimize cost, protect their workers as well as the environment, and achieve the cleanliness and surface profile required by project specifications.

Now that high-silica abrasives, with their link to silicosis in workers, are roundly shunned by the painting industry and a greater variety of alternative abrasives is available, contractors are presented with a much larger decision tree when selecting abrasives for surface preparation. This article presents tips on selecting the right abrasive for the job from two abrasive distributors and one painting contractor.

Factors Influencing Selection

Abrasives may be divided into four categories: non-metallic, naturally occurring, byproduct, and manufactured, says Jeff Theo, vice president of Vulcan Painters, Inc. (Bessemer, AL). A basic requirement for any abrasive is that it be clean, dry, and free of dust to yield the most productivity during abrasive blasting.

The two most important considerations in selecting specific types of abrasives are anchor profile and cleanliness requirements set out by the coating specification, says Tom Westerman, owner of Corpus Christi Equipment Co. (Corpus Christi, TX). The anchor profile achieved by an abrasive is directly related to its size and angularity. The larger and more angular the abrasive, the greater the resulting anchor profile, he says. However, the cleaning rate for abrasives is inverse to particle size, with larger abrasives achieving slower cleaning rates. Westerman suggests that contractors select the finest abrasive that can yield the desired anchor profile to boost cleaning rates.

The type of steel substrate to be prepared (such as new steel or coated steel) influences the choice of abrasive, as well, says Tim Poor, abrasive rental and service manager for CESCO (N. Charleston, SC).

The bottom line is important in the selection of abrasives—the overall cost of coating materials rather than the actual cost of the abrasive, that is. Contractors have to look at how abrasive selection and its relation to anchor profile depth can add to the cost of materials, says Westerman. In short, "the deeper the profile, the more coating material required to fill it," he says.

Abrasive selection is also influenced by local regulations and productivity issues, says Westerman. For example, a fabricator with a blast room may choose a different type of abrasive (one that can be recycled, for instance) than that selected by a field contractor.

Environmental issues such as dusting and waste disposal also play a role in abrasive selection, says Theo. Contractors have to look at the dusting characteristics of abrasives when determining the best abrasive for a job involving the removal of hazardous wastes, for example. Should waste minimization requirements pertain to a painting job, a contractor must weigh the use of additive-treated abrasives against the use of recyclable abrasives to achieve "total waste minimization." And, in considering recyclable abrasives, the contractor should compare the number of reclaims possible with each abrasive and evaluate the ease of cleaning for each product.

The cost of transporting abrasives is another factor that can make one abrasive more attractive than another for contractors. For example, the cost of transporting slag abrasive a few hundred miles by freight can increase its total price by 25% or more, says Theo.

> A finer particle mix of coal slag and even garnet, say 20/40 or 30/60, will achieve the same anchor profile as 16/40 silica sand and close the gap on production rates for cleaning as well, says Westerman.

The possibility of abrasive embedment during blasting can also encourage the contractor to select one abrasive over another, notes Theo. Contractors must evaluate candidate abrasives to ensure that their potential for surface embedment does not exceed the cleanliness requirements laid out in the specifications, he says.

The influence of hardness on the suitability of one abrasive over another is a "gray area," according to Westerman. "When you dissect the hardness issue, it's a lot like shopping for carpet. There are some variations [among abrasives], but they aren't that great," he says, referring to abrasives such as sand, coal slag, garnet, and aluminum. In fact, hardness can be a liability. For instance, says Westerman, the hardness of steel abrasives can affect their ability to be recycled. "If they're too hard, they break down too fast," he says.

From Sand to Slag

With concerns over the hazards of silicosis having caused contractors to turn away from silica sand, the transition to other abrasives has not necessarily yielded an apples-to-apples result in achieved anchor profiles, says Westerman. When contractors began to use coal slag in place of silica sand, they found that the same particle mix of the two abrasives, 16/40, resulted in different anchor profiles. A 16/40 silica sand yields an anchor profile of 1.5 to 2 mils (37.5 to 50 microns); a 16/40 coal slag gives an anchor profile of 2.5 to 3 mils (62.5 to 75 microns), says Westerman. A finer particle mix of coal slag and even garnet, say 20/40 or 30/60, will achieve the same anchor profile as 16/40 silica sand and close the gap on production rates for cleaning as well, he says.

Don't Discount Operators or Equipment

Blasting equipment and the workers who operate it can affect the outcome of surface preparation, no matter how judiciously the abrasive is chosen. The surface cleanliness achieved during abrasive blasting is determined by how fast a worker is moving the blast stream over the surface, says Westerman. For instance, a worker abrasive blasting at 100 psi with an abrasive with a 20/40 particle mix will impart a 2.5-mil (62.5-micron) anchor profile to the steel surface, but he or she will take 25% more time to clean the steel to a Near White (SSPC-SP 10) finish than to achieve a Commercial Blast (SSPC-SP 6). The link between experienced blasters and productivity with any type of abrasive is critical, says Westerman.

In addition, the diligence of workers monitoring equipment and the functioning of that equipment can negatively impact the quality of the blast. "You have to be aware of air pressure," says Westerman. "A 20/40 coal slag will give a pretty consistent anchor profile, but air pressure fluctuations during abrasive blasting can cause fluctuations in profile."

What's Being Used?

Coal slag is used in the majority of abrasive blasting jobs in the southeast U.S, says Westerman. He attributes the popularity of coal slag to several factors: cost and the prevalence of field projects and outside shop blasting. Although coal slag can be less expensive than other abrasives, its price has increased as much as 40% over the last decade, notes Westerman.

Garnet is gaining market share in Westerman's region due to the advantages it offers in recyclability and its fairly stable cost. "The cost [of garnet] has come down in relation to other abrasives," he says. "Garnet is selling for roughly what it cost ten years ago." Other abrasives commonly used in his area include aluminum oxide, glass beads, and steel abrasives, all of which are used primarily in shop-related work.

Theo notes that many shop blasting facilities in the southern U.S. are using blends of steel grit and shot to balance cleaning, profiling, and productivity considerations. As for field operations, coal slag abrasives still dominate, in part because the regional availability of abrasives such as garnet is limited.

Poor's company has seen a threefold increase in the use of staurolite abrasive since it stopped selling silica sand. Coal slag is also a big seller, and crushed glass is gaining users, as well. He notes that garnet is becoming more popular, owing to its ability to be reused.

Common Mistakes in Abrasive Selection

Same As It Ever Was

One common mistake contractors and fabricators make in selecting abrasives is sticking with what they know, rather than what is best for the job, says Westerman. "We see a lot of people use one type of abrasive for everything. They aren't evaluating abrasives for individual jobs."

For example, a contractor might use a 12/40 abrasive on the interior of a small storage tank to achieve an anchor profile of 3 mils (75 microns) to comply with lining requirements. The contractor mistakenly uses that same abrasive to prepare the exterior of the tank, which may only require a 1.5- to 2-mil (37.5- to 50-micron) profile. By not changing abrasives to meet the needs of the specific job, the contractor has used more abrasive than necessary, has generated more anchor profile than required, and will need increased coating materials to achieve the specified dry film thickness on the exterior of the tank. In addition, the contractor loses productivity in blast cleaning time, while increasing energy, labor, and material costs, as well as increasing wear on blasting equipment, says Westerman.

Likewise, he says, it is common to see contractors using fine abrasives as a standard practice, without changing to a coarser abrasive when tougher jobs like steel refurbishment come along. A coarser abrasive takes less time to remove heavy rust and thick existing paint, he says.

The most expensive mistake that a contractor can make in regard to abrasive selection is not sizing and choosing the appropriate abrasive for the specified profile, says Theo. Once a contractor has exceeded the profile requirements laid out by the owner, there is little that can be done to correct the problem.

Know the Existing Coatings

When contractors aren't sure of the type of coating they must remove from steel, they run the risk of choosing an unsuitable abrasive and wasting money as well as time, says Poor. Often, uninformed workers in this situation take a "more is better" approach to blasting, using excessive amounts of the wrong abrasive in an attempt to remove the coating, and end up redoing their work with a different abrasive, he says.

Mind the Equipment, Not Just the Abrasives

Another abrasive-related mistake occurs when contractors don't pay attention to the operation of their blasting equipment, says Westerman. Venturi nozzles are the most commonly sold abrasive blasting nozzles today because their design boosts productivity by 10% over standard straight-bore nozzles, he says.

However, this gain in productivity is quickly lost when contractors do not closely monitor nozzle wear. Many times, contractors will not change a worn venturi nozzle until they notice a loss of air pressure, by which time they have already consumed unnecessary energy and abrasives, he says. "A 10% (air pressure) production loss isn't something you can notice easily," he says, especially when the worker monitoring the abrasive blasting equipment may also be responsible for tracking environmental conditions, safety procedures, and regulatory compliance on the job.

Where We Are...

Abrasive selection may be a more complex proposition than it used to be, but with careful consideration of available products, the specification's requirements, and the contractor's needs, the best abrasive for the job can be found.

JPCL

By Hugh Roper,
Wheelabrator Abrasives;
Ray Weaver; and
Joe Brandon, NAVFAC

Peak Performance from Abrasives

Editor's note: This article appeared in JPCL *in June 2006.*

The authors show how to control peak count and profile in abrasive blasting to optimize cleaning and coating of new steel.

In the June 2005 *JPCL*, we reported that the peak count in a surface profile can be measured and controlled and that it affects coating performance.[1] We based our findings on carefully controlled tests of coatings adhesion over profiled steel surfaces that varied only in peak count—the number of peak/valley pairs in a given unit length. The present article is a practical follow-up to the 2005 article. Here, we describe how to adjust peak count and profile height by careful selection of the basic blast parameters, especially abrasive size, hardness, and particle velocity. To show how to adjust peak count, we need to restrict as many other surface profile variables as possible. Because conditions vary widely on previously painted steel, we will limit our discussion to controlling peak count on new steel that has at least some mill scale remaining (Rust Conditions A and B). [2]

In our experience, the primary variables in controlling peak count and profile are abrasive particle hardness, density, size, and the velocity of the abrasive particles as they strike the substrate. Less significant variables are the substrate to be cleaned, the angle of impingement of the abrasive, the friability (fracturing) of the abrasive, and the degree of cleaning. In this article we will explore the relative effects of these variables and their interrelationships. We will also describe practical blast cleaning techniques and materials tests that facilitate achieving a uniform surface with the specified parameters. The concepts presented here generally apply to both air abrasive blasting and wheel blasting; differences will be noted.

Primary Variables Affecting Peak Count and Profile Height

Defining and Measuring Peak Count and Profile Height

Peak count, P_C, is the number of peaks per linear inch (peaks per linear centimeter) recorded as a stylus moves across a fixed length of the blast cleaned surface. For simplicity, a peak can be thought of as movement of the stylus from below the mean line to above the mean line, and to below the mean line again. The mean line is halfway between the highest peak and the lowest valley in the evaluation length of the stylus instrument. A detailed description of peak count and profile height as measured by stylus instruments is given in ASTM D 7127.[3] Key words used in describing a blast cleaned surface are defined in the box on page 33 and are illustrated in Fig. 1.

Effect of Abrasive Size on Peak Count

Based on our collective experience only, not on a controlled scientific study, we think that peak count is predominantly controlled by abrasive size. As illustrated in Fig. 2, only a small portion of the abrasive particle penetrates the substrate. For a given depth of penetration, the larger particle will create a greater distance between peaks, and hence a lower peak count. As will be discussed later, the abrasive size distribution must be controlled in order to control both profile height and peak count. To a lesser extent, abrasive velocity, hardness, and density also affect peak count, and other factors have a minor effect.

Effect of Abrasive Velocityand Density on Peak Count

Abrasive velocity also affects peak count, but not as much as particle size. The greater the velocity and the heavier the abrasive particle, the deeper the steel penetration and consequently, the greater the distance between peaks (the lower the peak count), as shown in Fig. 3.

Key Words[1]

- **Deadband:** *That distance above and below the mean line that a continuous trace line must cross in both directions (up and down) to count as a single peak.* The deadband disregards small, spurious peaks due to noise. The deadband width is usually adjusted to fall in the range from 0.04 to 0.05 mils (1.0 to 1.25 µm).
- **Evaluation Length:** *A sequence of five consecutive sampling lengths.* The evaluation length is the part of the stylus travel that is used in computing the surface profile parameters. The two end sampling lengths are used only for calibration. The evaluation length in the experimental work done by the authors was 0.16 inch (4.0 mm), which was a common instrument setting before ASTM D 7127 was written.
- **Mean Line:** A line half way between the highest peak and the lowest valley in the evaluation length and centered between the two lines defining the deadband.
- **P_C–Peak Count:** *The number of peak/valley pairs, per unit of length, extending outside a "deadband" centered on the mean line.* Because the deadband width is so small compared to the size of the peaks and valleys encountered in coatings work, the deadband region is essentially the mean line. For all practical purposes, a peak would be recorded if a continuous trace starts below the mean line, goes above it, and then below it.[2]
- **Peak/Valley Width:** The distance between crossings of the deadband region in the same direction defines the width of a peak/valley pair.
- **R_{max} :** *The largest peak to valley measurement is determined from the five sampling lengths, and the largest of these five values is R_{max}.* The distance from the highest peak to the lowest valley within each sampling length is measured. The largest of these five peak/valley distances is recorded as R_{max}.[3]
- **R_t :** *The distance between the highest peak and the lowest valley within any given evaluation length.* Unlike R_{max}, when measuring R_t, it is not necessary for the highest peak and the lowest valley to lie in the same sampling length.[4]
- **Sampling Length:** *The nominal interval within which a single value of a surace parameter is determined.* One fifth of the evaluation length.[5]
- **Traversing Length:** *Seven sampling lengths comprising the evaluation length and the pre-travel and post-travel segments.*[6] The traversing length is the total length of travel of the stylus during one trace.

1. Definitions shown in italics are taken from ASTM D 7127 "Standard Test Method for Measurement of Surface Roughness of Abrasive Blast Cleaned Metal Surfaces Using a Portable Stylus Instrument."
2. Pc is called "Peak Density" in ASME B46.1-2002 and "Peaks Per Inch Count" in SAE J911.
3. Rmax is called "Maximum Roughness Depth" in ASME B46.1-2002.
4. Rt is called "Maximum Height of the Profile" in ASME B46.1-2002.
5. The five sampling lengths within the evaluation length are also defined as "Sampling Lengths" in ASME B46.1-2002.
6. This length is also "Traversing Length" in ASME B46.1-2002.

Controlling Profile Height

Profile height is also primarily controlled by abrasive size, hardness, velocity, and density. We have found that the easiest way to adjust profile in the field is by changing the velocity; changing the abrasive requires more labor and money. Other factors contribute much less to profile height. The faster the particle is moving when it strikes the steel substrate, the deeper the penetration; and thus the displaced metal will form higher peaks. In a wheel machine, particle velocity is increased by increasing the wheel speed. In dry abrasive blasting, the particle velocity can be increased by choice of nozzles (see sidebar on page 38) or by raising the air pressure at the nozzle.

According to the laws of physics, both energy and momentum are conserved in any collision. In collisions where the target (steel) or the abrasive particle is deformed, most of the energy is converted into heat. Because thermal energy is difficult to measure exactly, precise quantitative analysis of energy transfer is difficult. However, we do know generally that the heavier and harder a particle is and the faster it moves, the more work it does on the surface.

The Effect of Specific Gravity (Density)

Specific gravities (or densities) of abrasives and their velocities determine how much work is done on the substrate. Specific gravity is the ratio of the density of a substance to the density of water. A ratio is a dimensionless quantity, i.e., it is not measured in feet, grams, or any other unit of measurement. Specific gravity is simply a number, the same number in metric or U.S. customary units. The specific gravity of steel, for example, is 7.8: It weighs 7.8 times more than an equal volume of water. Since one cubic centimeter of water weighs one gram, one cubic centimeter of steel weighs 7.8 grams.

To illustrate the effects of specific gravities of abrasives, consider a one-pound (0.45 kg) air-filled soccer ball and a one-pound solid steel ball both moving at the same speed. Both the soccer ball

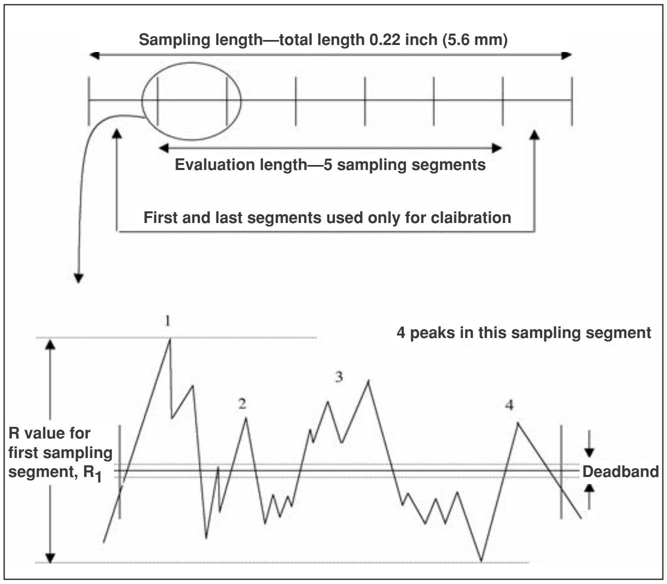


Figure 1: Schematic illustrating the profile parameters

- The vertical scale is distorted because for abrasive blast cleaned steel, the deadband is typically 0.04 to 0.05 mils (1 to 1.25 µm) while the R value is typically 2 to 4 mils (50 to 100 µm). At 100 peaks per inch (40 peaks/cm), the average distance between peaks is 10 mils (250 µm).
- The distance from the highest peak to the lowest valley in the first sampling length is R_1; the distance from the highest peak to the lowest valley in the second sampling length is R_2; and so on. The largest of R_1 to R_5 is defined as R_{max}.
- The average value of R_1 to R_5 is defined as R_z, which is not defined in ASTM D 7127.
- R_t is the distance from the top of the highest peak in the evaluation length to the lowest valley in the evaluation length. The highest peak and the lowest valley do not have to lie in the same sampling length.
- The peak count, P_c, expressed as peaks per inch (peaks per centimeter), is computed from the number of peaks counted in the evaluation length (five sampling lengths). The "peak" to the left of peak #2 is not counted as a peak since it does not cross the deadband.
- When measuring R_{max}, R_z, and R_t, "distance" is measured perpendicular to the mean line as shown in the figure.
- The mean line is half way between the highest peak and the lowest valley in the evaluation length and is centered between the two lines defining the dead band.

The profile height is best described by R_{max}, which is the largest peak to valley measurement in any of the five sampling lengths that together comprise the evaluation length. The total trace has five sampling lengths. The procedure for measurement of surface profile with stylus instruments is described in ASTM D 7127. Profile height is more traditionally measured with replica tape per ASTM D 4417, Method C.* Currently, most job specifications that specify profile refer to ASTM D 4417. However, if peak count is measured with a stylus instrument, R_{max} is computed at the same time as P_C with no additional effort. Field trials done by the authors show that profile height as measured with replica tape and a micrometer correlates closely with R_{max}. A small systematic error usually causes the value for R_{max} to exceed the value from the tape by a few tenths of a mil (a few micrometers).

*ASTM D 4417 Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel, ASTM International, West Conshohocken, PA 19428

and the steel ball will have the same kinetic energy. Which would do more damage as it strikes the side of a wooden house? The steel ball. Why? First, its area of impact would be small, thereby concentrating the stopping force. Second, because the steel ball is hard and will not deform, most of the energy is transferred to the surface. The soccer ball, on the other hand, would not create much damage, if any, because it would absorb most of the kinetic energy internally by deforming. The larger surface impact area of the soccer ball will distribute the stopping force over a significantly larger area, thereby reducing the force at a specific point.

Similarly, consider two balls the size of baseballs, moving at the same speed. One is made of wood, and the other is made of solid steel. Clearly, the steel ball will be much heavier. Imagine both balls hitting the side of a house. Because kinetic energy depends on mass (or weight), the steel ball has significantly more kinetic energy and will do more damage when it hits the house.

Specific gravity should not be confused with bulk density of abrasive, although they are related. Bulk density is the weight per unit volume of many abrasive particles taken together and includes the air spaces between the particles. Specific gravity is related to the density of material from which the abrasive particle is made.

Relationships of Size, Hardness, Velocity, and Specific Gravity

Because of the relationships among size, hardness, velocity, and specific gravity and their relative influence on peak count and profile height, several choices must be made—abrasive type, size, and air pressure (wheel speed).

The size, hardness, and velocity needed to achieve a given peak count and profile height will be influenced by the specific gravity of the chosen type of abrasive. Here is the usual sequence of steps for selecting abrasive.

- Select a type of abrasive compatible with the available equipment.
- Because peak count depends most on size, choose the size of abrasive expected to achieve the desired peak count.
- Adjust the velocity of the abrasive to achieve the desired profile height.

With more experience, you will need to make fewer adjustments in velocity.

There are limited bands of peak count and profile height for a given abrasive type. Velocity can be increased by changing the nozzle type or increasing the pressure at the nozzle. However, there is a minimum pressure below which productivity is usually not acceptable. Likewise, there is a maximum pressure for blasting, as determined by the capabilities of the equipment, the operator's comfort or ability, or the friability of the abrasive. Too high of a velocity will shatter the abrasive upon impact, thereby reducing its energy transfer and cleaning action.

Metallic abrasives are functional over a much wider range of operating pressures (velocities) than nonmetallic abrasives. Wheel blast machines use only metallic abrasives. Particle velocity is adjusted by controlling the wheel speed.

Because each job has its own peculiarities and because adjustments are limited, a rough idea of what peak count and profile to expect from a given set of conditions is needed. Table 1, compiled from random testing results from many field cleaning and profiling applications on steel substrates, provides nominal peak count/profile height combinations to expect for common blasting parameters (90–100 psi with proper nozzle selection and normal abrasive size).

The values in the Tables were extracted from our notes. Blasting was done with new abrasive, not a balanced operating mix. A balanced operating mix

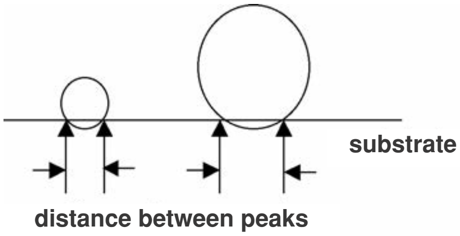


Figure 2: Effect of particle size on peak count.
The distance between peaks will be greater for larger abrasive particles for a given depth of penetration (i.e., peak height). This diagram is an idealized schematic, as the great majority of commonly used abrasive particles are not spheres but are irregularly shaped.

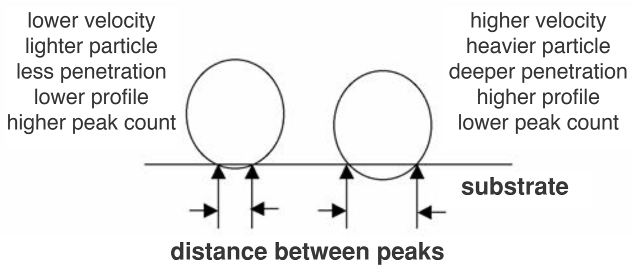


Figure 3: Effect of velocity and density on peak count.
The distance between peaks will be greater for a given size abrasive particle as the depth of penetration increases. The particle on the right has a higher velocity than the particle on the left; or the particle on the right has a greater density than the particle on the left, all else being equal. This diagram is an idealized schematic, as the great majority of commonly used abrasive particles are not spheres but are irregularly shaped.

Table 1: Approximate Values of R_{max} (Profile Height) and P_C (Peak Count)*

Abrasive	R_{max} (mils)	P_C (peaks/inch)
G-40 steel grit	2.0 – 4.5	120 – 180
G-25 steel grit	3.0 – 5.5	90 – 120
G-18 steel grit	4.0 – 7+	50 – 75
20/40 flint silica sand	1.0 – 3.5	130 – 220
20/40 boiler slag	0.8 – 3.0	100 – 180

1.0 mil = 25 µm   100 peaks/inch = 40 peaks/cm

*These combinations can be expected for a common set of parameters under normal blasting conditions. Actual values may differ from those shown here because of differences in wheels, wheel speed, horse power, nozzle design, air pressure, hardness of substrate, hardness of abrasive, flow rate, blend of particle sizes supplied, etc.

Table 2: Classification of Peak Count as High, Medium, or Low

Classification	Peaks/Inch	Peaks/Centimeter
High	110 – 150+	40 – 60+
Medium	75 – 110	30 – 40
Low	50 – 75	20 – 30

of steel abrasive can be expected to give values for R_{max} and P_c as much as 15% below those shown in the table. New steel abrasive has a higher percentage of larger abrasive particles than a balanced operating mix because larger abrasive breaks down faster than smaller abrasive. The suggested classification for peak count as high, medium, or low in Table 2 is based on average measurements of profiles produced from many different combinations of blasting parameters.

Much data has been accumulated on profile height for different abrasives under various conditions. The most prominent reference is A. B. Williams' *Abrasive Blast Cleaning Handbook*.[4] Because measuring peak count is a recent concept in the coating industry, no corresponding bank of data for peak count exists. However, our experience over the past fifteen years has led us to believe that peak counts between 90 and 150 peaks/inch (35 and 60 peaks/cm) are suitable for optimum performance of most industrial coatings. Although a wide range of peak counts is achievable, it is usually desirable, based on coating adhesion tests, to have the highest peak count that will allow complete wetting by the coating being used.

For a coating to perform well, it must first be able to wet the surface completely, i.e., the coating must penetrate to the bottoms of the narrowest valleys. It can be difficult to determine if a coating fully wets the surface. A reasonable guess on whether complete wetting will occur can be made based on the rheological properties of the coating. Most common solvent-borne industrial coatings, like epoxies and polyurethanes, will completely wet a high peak count surface; however, our experience indicates that some of the newer high-solids coatings do not wet surfaces as well as solvent-borne coatings.

The wetting characteristics of high-solids coatings may be altered by changing the temperature of the material or the substrate. A high-solids coating may have significantly different flow characteristics in the cool morning than it has in the hot afternoon. Similarly, a coating that performs well in the summer months in the northern states may not perform as well in the winter. However, today's state-of-the-art technology offers many methods of controlling the viscosity and wetting ability of most coatings.

The following hypothesis is beyond the scope of this article but needs to be verified elsewhere by testing: of two comparable coatings (same generic type and suitable for the same job), the one that best wets the surface should be able to outperform the other one. Over a low peak count surface, the two coatings should be comparable. Over a high peak count surface, the better-wetting coating should outperform the coating that cannot provide complete wetting. This result would be consistent with previous work of the authors.[1]

Secondary Variables Affecting Peak Count and Profile Height

Substrate: The hardness of the substrate will affect the depth of penetration of the abrasive, which in turn affects peak count and profile. The range of hardness encountered in most industrial painting operations is not that great to have much effect, although the most common structural steel, ASTM A 36, can range from 25 to 38 Rockwell C hardness. By heat treating steel abrasives, Rockwell C hardness can range from 40 for "soft" shot to 65 for hard grit.

Abrasive Hardness: The hardness of steel abrasive has a moderate effect on profile. A metallic abrasive should be at least four points harder on the Rockwell C scale than the substrate. The less the abrasive particle itself is deformed, the more energy there is available to use in deforming the substrate. If the abrasive is not at least four points harder on the Rockwell C scale than the substrate, the abrasive will not perform well and will round-up quickly (grit hardness of 45 HRC rounds up like shot quickly and is not recommended for surface preparation for coatings), and the full benefits of using metallic abrasive for coating application will not be realized.

Metallic abrasives are available in various hardness ranges. Cost is not a factor in choosing hardness because all hardness levels from one manufacturer usually cost the same. The choice of hardness in wheel machines is normally based on economic considerations of cost versus productivity. A general rule for airblast operations is that it is best to use the smallest, hardest, heaviest abrasive that will accomplish the work at the highest productivity level and the lowest cost.

Angle of Impingement: The angle at which the abrasive strikes the substrate will affect peak count and profile. If the abrasive particle hits the substrate at a glancing (oblique) angle, the momentum change of the particle will not be as great as if the particle were to strike the surface at an acute angle of 60 to 80 degrees. Consequently, the depth of penetration will be less for oblique incidence, resulting in a lower profile.

Friability: The friability (fracturing or shattering ability) of an abrasive affects peak count and profile because friability limits the maximum useful impact velocity. Energy absorbed by the abrasive during fracture is energy not transmitted to the surface. An abrasive particle that remains intact upon rebound from the surface will impart more energy to the surface than a particle that shatters upon impact. A pronounced effect of shattering is the more finely textured surface produced by nonmetallic abrasives compared to the well-defined, sharp craters produced by metallic abrasives. Metallic grit, unlike shot, produces irregularly shaped angular craters that are well defined. Scanning electron microscope images at 50 to 100X clearly show a difference in texture among surfaces blast cleaned with metallic grit, metallic shot, and nonmetallic abrasive.[5] When the abrasive particle shatters, the fragments also strike the surface, leaving craters commensurate with the size and speed of the fragments. The largest particles that do not shatter upon impact and the largest fragments from particles that do break up determine the profile height and the peak count of the surface.

Degree of Cleaning: The degree of cleaning can have a small effect on peak count and profile. Our field experience has shown that for a fixed set of blasting conditions, the highest peak count occurs in a surface prepared to SSPC-SP 10, Near-White blast cleaning. In commercial blast cleaning, SSPC-SP 6, every minute area has not necessarily been subjected to a direct impact. With Near-White blast cleaning, all of the surface has been impacted at least once, and a significant amount of the surface has been subjected to multiple impacts. Some of these “second, third, or fourth” impacts will flatten existing peaks, but some may land in a crater, further pushing up the adjoining rim to form a higher peak.

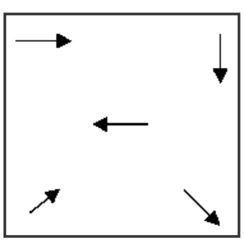


Figure 4: Five traces should be made with the direction of travel of the stylus going in different directions. The traces should be dispersed over the test area.

If blasting is continued to SP 5, White Metal, there will be fewer peaks and the profile height will decrease slightly. A reason for this effect could be that continued blasting has a tendency to flatten the first set of peaks but in turn produces smaller new peaks because of work hardening of the surface. Work hardening is more pronounced with steel shot than with grit. Overblasting to achieve a bright white metal surface can overwork the substrate of the steel surface and degrade the performance of the applied coating.

A Hypothetical Example

In an attempt to tie these concepts together, we offer a hypothetical example of field work. The job is to blast the interior of a tank. The job specification calls for SSPC-SP 10, Near White, a 2.0- to 3.0-mil (50- to 75-micron) profile, and a high peak count surface (P_C = 120 peaks/inch). Size #8 nozzles have been chosen and the hoses, the number of blasters, pot size, and compressor capacity have been properly matched. For a variety of reasons, Wondergrit coal slag has been chosen as the abrasive.

Here is the procedure the contractor should follow before ordering the abrasive for the job.

1. Determine the correct size of particles needed. Based on Table 1, size #20 should give a high peak count surface in the specified profile range. Get a sample bag of abrasive. Load 100 lb (45 kg) of this abrasive (WG-20) into the blast pot and conduct a field trial.

2. With flow rate and everything else adjusted for optimum performance, blast an area of at least one square foot (0.1 m^2) to SP 10. Document all blast parameters such as nozzle pressure, standoff distance, angle, etc.
3. Make five traces with the stylus instrument described in ASTM D 7127, one in each corner and one in the center of the square, as shown in Fig. 4. For each trace, move the stylus in a different direction—forward, backward, left, right, or either direction along a diagonal. Measure profile with replica tape if the specification requires it. Determine peak count, P_C, and profile height, R_{max}, by averaging the values from the five traces.
4. Suppose the results are a peak count of 100 peaks/inch and a profile of 2.4 mils. Because peak count needs to be 120, use a smaller abrasive. Therefore, repeat the test (Steps 1 to 3) with #30 abrasive (WG-30).
5. Suppose the new abrasive, WG-30, gives a peak count of 125 peaks/inch, but the new profile is only 1.8 mils. Since the smaller abrasive lowered the profile, compensate by increasing the velocity. Therefore, repeat steps 1 to 3 using WG-30 at a higher nozzle pressure.
6. Assuming that both peak count and profile height are now within the specified limits, order the abrasive, and instruct the blast crew what pressure to use.

In addition to finding a set of blast parameters that will meet the specification, the contractor can now begin to collect and document information about how this abrasive behaves with different nozzles under different pressures and at different sizes. After gaining some experience with common abrasives and nozzle pressures, the contractor will be able to adjust both the abrasive size, hardness, and the pressure to meet specific peak count and profile requirements for a particular job. The other side of the coin is for engineers to only specify combinations of peak count and profile height that can be achieved in the field.

Obtaining a Uniform Blast

Even though a test patch indicates that the peak count and the profile meet the specification, several factors such as those described below may complicate the task of meeting the specification on the rest of the structure.

Non-Uniform Abrasive

Perhaps the most frequent cause of a non-uniform surface is variation of particle size within the abrasive. This variation may be from batch to batch, or even from bag to bag within the same batch. During bulk storage and handling, the fines tend to separate from the coarser abrasive. As abrasive is being packaged, one bag may have a higher percentage of fines than another bag. The surface produced from these two bags of abrasive will differ, both in peak count and in peak height. Production rate will also differ.

If abrasive is delivered to the job site in a bulk carrier, some breakdown and separation by particle size will probably occur during loading, transportation, and unloading. If the abrasive is blown into the trailer at too great a velocity, the particles can break down as they hit the walls of the container. A similar effect can occur during unloading. By the time the abrasive reaches the blast pot, the percentage of fines has increased significantly from what it was when tested in the lab at the abrasive source. Contractors have sent newly delivered bulk abrasive through the separator and found much of the abrasive unusable. In short, the abrasive should be checked for size compliance not only at the point of origin but also at the point of use.

Variation in abrasive size can also occur during recycling if the dust separation system is not set up properly. In addition, the working mix should be replenished with new abrasive at the same rate as abrasive is being consumed. It is better to add a little new abrasive to the hopper every hour than to add a large quantity of new abrasive all at once at the end of the day.

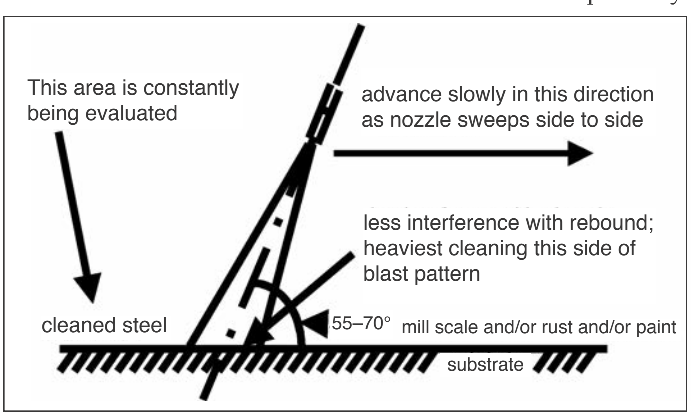


Figure 5: Proper movement and angle of nozzle when blasting with recyclable abrasive. The nozzle undergoes a back and forth sweeping motion cleaning an area about 2 ft (60 cm) wide while slowly advancing over the non-cleaned steel.

Choosing a Nozzle

Several critical factors affect nozzle selection for a particular job. Nozzles come in a variety of materials, shapes, and sizes for a reason. As a general rule, long nozzles are preferred over short ones unless access to tight spaces is needed. At a given pressure, abrasive velocity depends on the design of the nozzle. Profile is affected by abrasive velocity. Hence, any test runs should be made with the nozzle chosen for use on the job.

Straight bore nozzles are used for spot blasting or cleaning welds because they have a small, well-defined blast pattern and minimal overspray. In straight bore long nozzles, the abrasive will attain the speed of the air stream. These nozzles work well at distances up to 36 inches (90 cm). Medium and short straight bore nozzles are used in tight spaces. Particle speed is lower in a medium nozzle than in a long nozzle and even lower in a short nozzle. Decreased productivity is associated with decreased particle speed.

Tungsten Carbide Long Venturi Nozzles

Venturi nozzles have a constriction that can almost double the air speed, and thus the abrasive speed, compared to a straight bore nozzle. This increased particle velocity makes Venturi nozzles more efficient than straight bore nozzles.

The long Venturi nozzle is most commonly used because it accelerates the abrasive particles to the highest speed and creates a large, uniform blast pattern. When working in close quarters, a medium or short Venturi nozzle may be used. The particle speed is lower for shorter nozzles, but the rebound is not as aggressive, making them better suited for blasting in close quarters.

Double Venturi nozzles are another variation of the Venturi principle. Most have short entries with a short flat throat section. The nozzles look like two short nozzles end to end, with a series of holes to allow entry of air into the abrasive air mixture flowing through the nozzle. The influx of air to the nozzle creates mild turbulence that makes the pattern considerably larger in the second section, with minimal reduction of the abrasive velocity. These nozzles work well with fine abrasives on large, open surfaces because the incoming air can spread the abrasive particles more easily and create a considerably larger blast pattern without decreasing the velocity significantly. These nozzles work well when fine steel abrasives are used (40 grit and smaller). These nozzles work best at pressures above 100 psi (690 kPa). Double Venturi nozzles are also used at low pressure (20-50 psi [140-340 kPa]) with low density or agricultural abrasives for stripping coatings from delicate surfaces such as those of aircraft, automobiles, and log homes.

Approximate Service Life in Hours for Different Nozzles with Various Abrasives

Nozzle Material	Abrasive		
	Steel Grit*	**Sand**	**Al Oxide**
Aluminum oxide	20–40	10–30	1–4
Tungsten carbide	500–800	300–400	20–40
BP 2000 SiAlON	800–1,200	300–400	50–100
Boron carbide	1,500–2,500	750–1,500	200–1,000

* Stabilized workmix
From Boride catalog (used with permission)
Estimated values are for comparison. Actual service life will vary depending on blast pressure, media size, and particle shape.

Yet another variation of the Venturi principle is the long entry/long exit (bazooka type) nozzles, which operate at high pressures (120 to 150 psi [800 to 1,000 kPa] and can create considerably larger blast patterns than conventional Venturi nozzles. The long entry/long throat/long exit nozzle is most effective with small abrasives, especially heavy fine steel abrasives at elevated air pressures.

Long life nozzles are made from aluminum oxide, tungsten carbide, silicon carbide composite, or boron carbide. Cost and ruggedness are the main driving forces in the choice of material. The life of a nozzle depends on both the material from which it is made as well as the abrasive that is used (see Table above). The relative lifetime of hoses and other in-line components is similar to that of nozzles, with aluminum oxide being the most aggressive and steel being the least aggressive abrasive.

An often overlooked source of size separation occurs within blast pots, especially large pots serving multiple blasters. As abrasive flows to the control valve at the bottom of the pot, fines tend to build up away from active ports and near the center of the load. Fines also tend to build up along the sides.

Eventually, these fines break loose, often all at once, and the blaster inadvertently blasts with "dust" for up to a minute. During this time, productivity decreases, profile is altered, and excessive dust is created. The best preventive measure is to use one or two blasters per pot with each automatic-fill pot holding enough abrasive for approximately 20 minutes of blast cleaning.

Blast Techniques

The worker holding the blast nozzle influences the uniformity of the surface. Blast techniques should vary somewhat to suit the nature of the abrasive. With recyclable abrasive, the nozzle centerline should be held at a 55- to 70-degree angle to the surface. Because of the high specific gravity (density) of steel abrasive, the abrasive does not slow down significantly as it travels through the air. Hence, the standoff distance using steel abrasive can be 4 to 10 feet (1.2 to 3 meters) without seriously affecting the blast profile.

For less dense recyclable abrasives like garnet, the standoff distance is the more conventional 18 to 24 inches (45 to 60 cm), but the angle should still be 55 to 70 degrees. Productivity is highest if the blaster "pulls" the nozzle along in front of the cleaned surface, while also sweeping the nozzle from side to side or up and down to blast the surface. This blast technique allows him to better evaluate the uniformity and degree of cleaning through the overspray as he is blasting (Fig. 5), rather than evaluating a larger area, sections of which may need additional cleaning.

As steel abrasive rebounds from the surface, some abrasive is driven back into the surface after colliding with the incident abrasive stream. These secondary impacts also contribute to the cleaning and profiling.

If the abrasive flow rate is reduced, there will be fewer rebound collisions, and the particles will hit the surface at a higher average velocity. Having less abrasive moving through the nozzle also increases particle velocity. The increased velocity, in turn, will slightly increase the profile height and will also help the abrasive more easily remove tightly adherent foreign matter from the surface. However, productivity may be reduced slightly because of fewer impacts per unit time. Thus, when a hard-to-clean spot is encountered, the abrasive flow rate should be reduced until that spot is cleaned. Then, the blaster should readjust the flow to optimize productivity. Some modern equipment allows the blaster to control flow rate remotely by a switch mounted close to the nozzle.

When blasting with non-recyclable abrasives like sand or slag, the blaster should hold the nozzle perpendicular to the surface about 18 to 24 inches (45 to 60 cm) away. Maximum productivity occurs at a nozzle pressure between 80 and 100 psi (550 and 690 kPa).

These optimum blast angles should be determined empirically as blasters gain experience. Optimum blast angles differ because a non-recyclable abrasive usually shatters upon impact, with fragments flying in all directions. At a 90-degree angle, maximum energy is transferred to the surface. However, if a recyclable abrasive is shot directly at the surface (at 90 degrees), it will rebound intact into the incident abrasive stream. The collision between the incident particles and the rebounding particles will reduce the velocity and quantity of abrasive before it reaches the surface, thereby reducing cleaning ability.

Summary

From the authors' experience, the optimum steel profiles for a wide range of standard industrial coatings that will completely wet the surfaces are a 2- to 3-mil (50- to 75-micron) profile height and a peak count between 110 and 150 peaks/in. (40 and 60 peaks/cm). Opti-mum peak count for a particular coating depends on its rheological properties.

A general rule for adjusting peak count to optimize coating performance is to use the smallest, hardest abrasive that will do the job. To obtain a uniform surface, control the blast technique and the particle size of the abrasive. The coating must be able to wet the surface completely.

Although we have established that peak count affects coating performance,[1] complete detailed experimentation is yet be performed to establish the optimum range of peak count and profile height for specific coatings or coating types.

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Checking Abrasives in the Field

Many SSPC and ISO standards can be used in the laboratory to check the quality of abrasives, including particle size, moisture content, and contamination. However, what are the most important quality checks to be carried out in the field when using new abrasive?

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David Dorrow, Mineral Aggregates Inc.

Purchasing an abrasive from a reputable manufacturer—one who has run the gauntlet of qualification testing performed by a third-party certified lab—is the first step in the quality control process.

An experienced and alert set of eyes can be the consumer's next line of defense. Training employees to visually inspect abrasive and to diligently collect and review samples from each load is essential for jobsite quality control. When a bulk load of material is pneumatically being conveyed into a bulk storage hopper, is there a plume of dust rising into the sky? If the abrasive is generating dust during low pressure unloading, it will generate a lot of dust during high pressure blasting, causing poor visibility and decreased productivity.

Has a standard abrasive sample been kept from the start of the job to which all future samples can be visually compared? Has a sample been kept from each subsequent load for visual reference?

When samples are collected, one visual change to look for in an abrasive is a slight change in color. For instance, a sand abrasive may change from white to beige, while a slag abrasive may change from black to amber or green, indicating a potential change in product quality. Bulk density, hardness, and friability changes are most evident when color changes.

A simple test can be performed on the jobsite to check for oil contamination on an abrasive. Use a clean, uncontaminated scoop or hand trowel to collect a representative sample of the abrasive and place the abrasive sample into a glass of water. Look for a "shiny" oil slick to appear on the surface of the water, signifying oil is present on the abrasive.

This same abrasive sample and cup of water, along with a simple, inexpensive, pocketsize conductivity meter, can be used to test for non-visible contaminants like chlorides and sulfates. This concern is more significant for abrasives that are processed near the coast, as they may have been washed or quenched in brackish water or contaminated during transportation by barge on the Intracoastal Waterways. If you experience flash rusting on a freshly blasted steel surface, it is either from the chlorides on the abrasive or from preexisting chloride contamination on the steel surface.

Customers should also visually check the abrasive for impurities and contamination that can come either from the manufacturing process, the raw material, or the transportation and delivery system. While on the jobsite, a worker can easily use two quarters (or other coins) to test the friability of the impurities by rubbing a few granules between the quarters.

Mined or by-product abrasives typically contain impurities, but the important factor is that the impurities are as hard and inert as the abrasive material. Soft, friable impurities in an abrasive, on the other hand, may smudge on impact and visually spot the surface. This spotting is a concern for coating adhesion. If the abrasive contains impurities to the extent that you see the surface being contaminated during blasting, contact the manufacturer or look for a different quality abrasive.

The "quarter" test can also be used for evaluating the friability of the abrasive granules. However, this test should be viewed as only a general one for friability, as the pressure one applies to begin crushing the abrasive particles may not be consistent.

A visual inspection of the abrasive can reveal significant changes in the product gradation or operating mix; however, having a set of sieves on site to check the abrasive gradation or operating mix is useful. A sieve is an 8" or 12" round pan that has screen wire with specific size openings stretched across the bottom that can easily retain the varying sized abrasive particles. At a minimum, the abrasive should be checked with a maximum sieve size and a minimum sieve size to assure that the specific abrasive size that was selected is the same one that was delivered. A pot screen with ¼-inch openings is a must on all blast pots to catch large contaminants and oversized abrasive particles, eliminating potential downtime needed to clean out a blocked pot or nozzle.

The value of a diligent employee committed to quality verification cannot be overestimated and will go a long way in reducing on-site abrasive problems.

Anthony (Bud) Budzinski joined Reed Minerals in 1997. His main responsibilities include quality control and research and development. He also provides technical customer support.

Bud Budzinski, Reed Minerals

In most cases, a quick inspection of the abrasive before blasting can identify problems before they cause delays. Below are several quality checks that can be performed easily on abrasive materials before blasting.

- *Confirm the material type and amount.* Is the abrasive material on site the correct product? Don't rely on product labeling; visually check the material before use. Do you have enough material to complete the job? Inventory your material and order additional material before you run out.
- *Product certifications.* If a job requires the abrasive material to have a specific certification, check the shipping paperwork for this designation. In some cases, additional documentation is required and should be obtained before beginning a job to avoid being shut down upon inspection.
- *Moisture.* Did the material arrive in good condition? Inspect the packaging for rips or punctures that could allow moisture to penetrate the packaging and, ultimately, the material. Bulk bags that have been improperly stored can absorb moisture from the top as well as wick moisture from the bottom. Damp or wet material will flow poorly and will clump in your hand when squeezed.
- *Material contamination.* Whenever possible, examine the material for contamination before use. Always place a screen over your blast pot opening to catch any oversize granules.
- *Material additives (liquid).* If the abrasive was ordered with a liquid additive such as dust suppressant, the abrasive should be noticeably less dusty when handled and may even have a slight odor. Check if the dust suppressant was over applied by taking a handful of abrasive and squeezing it in your hand. If the abrasive clumps or sticks to your hand, it may be over-oiled.
- *Material additives (granular).* It may be necessary to use abrasives that contain granular additives such as heavy metal neutralizers. In most cases, these additives can be distinguished from the actual media by their size and color. If you are not sure if the product contains the necessary additive, contact your product sales representative or distributor before use.
- *Conductivity/chlorides.* Soluble salts, especially chlorides that remain on blasted surfaces, contribute to flash rusting and coating failures. These salts are found on the surface of certain types of abrasive granules and can leave a residue following blasting. Look at your abrasives closely; sometimes the salts can be seen on a granule's surface and appear as a white residue. Otherwise, blast a small area and test the surface using a portable field chloride tester before proceeding.

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Jeroen Keswiel, EUROGRIT BV

One of the most important on-site quality checks of abrasives is the conductivity test. This can be done in two ways, both described in ISO standard 11127.

For testing the abrasive in the field, determination of water-soluble contaminants by conductivity measurement (ISO 11127-6) is the most appropriate method, as it is a relatively simple procedure and no chemicals are needed. You only need a conductivity-measuring bridge and conductivity cell, together with some glass sample flasks and demineralized water. Determination of water-soluble chlorides per ISO 11127-7, however, cannot be done in the field because a laboratory setting is needed to handle the chemicals and procedures involved in the test.

ISO standard 11126 prescribes the limits on conductivity and water-soluble chlorides of each abrasive.

Hardness can also be tested in the field with a glass-slide test, but this may not really be necessary. Hardness will be tested once in a while in a lab or in the office; the test can easily be done in the field, but, normally, most abrasives are quite stable in hardness and the need for on-site testing is reduced.

Grain size distribution and moisture are more difficult to test in the field. For the sieve analysis, you need either a digital imaging particle size/shape analyzer or a number of test sieves with a "shaker," which makes it more difficult to do in the field. The moisture test also requires equipment that is not really portable. Normally, grain distribution and moisture are tested in a laboratory, where the necessary equipment is located. JPCL