Abrasive Blasting Systems

Part Three

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We are presenting this informative article as a series. In this issue we will cover Pressure Blast Machines, Nozzles and Operator Safety.

PRESSURE BLAST MACHINES

A blast machine is primarily a storage device to hold abrasive for release into an air stream. Although it appears to be a little more than a steel tank, there are a number of integral parts that make sizable differences in safety, convenience, and efficiency. Poorly designed blast machines are one of the biggest culprits responsible for lost air flow and pressure. Basic engineering logic reveals that the greatest air flow efficiency takes place when restrictions are eliminated and friction losses are kept to a minimum.

In the United States, blast machines, being pressurized containers, must be fabricated, tested, and approved according to American Society of Mechanical Engineers (ASME) standards. The type of steel and welding methods is specified by ASME pressure vessel codes. Most commonly, blast machines are rated and approved at working pressure of 125 psi (880 kPa). ASME's standard requires a pressure safety margin of 50% above working pressure, thus, dictating hydrostatic testing at a minimum of 188 psi (1300 kPa).

Machine design should avoid complicated configurations that deter from smooth abrasive flow through the system. Gravity-fed blast machines have proven to be a simple, trouble-free scheme when fitted with concave heads (tops) and conical bottoms. The machine top should be equipped with a semi-elliptical head, which stores more reserve abrasive and provides greater slope for abrasive flow into the machine than the conventional flat-dished head. Most heavy granular abrasives have an approximate 32° angle of repose; consequently, cone bottoms should be shaped at no less than a 35° angle to ensure complete and uninterrupted abrasive flow.

Machines used with lighter media, such as glass bead and plastic, require a steeper angle of 60° on the bottom. Using lightweight media in flat or 35° outlets will cause continual flow problems, especially with a moist air supply.

Special attention must be paid to the outside plumbing of blast machines because this is where the majority of air flow and air pressure is lost. Actually, there is always friction-generated pressure loss in any size pipe, but the key is to minimize loss. Full airflow at high pressure in 1-1/4 in. (32 mm) piping cannot be attained if it is being fed through a 3/4 in. (19 mm) valve, because the small valve is starving the larger piping of air.

When working with air hose, blast hose, air piping, air valves, and for that matter, anything in an air line, think BIG—VERY BIG (see Fig. 1). Any restriction or obstruction will cause tremendous loss of costly air supply; therefore, it is wise to check every fitting and valve size in the entire piping arrangement.

Fig. 1. When working with air hose, blast hose, air piping, air valves, or anything in the air line, think big. Half the diameter is only a quarter of the surface area (1-in. diameter is 0.8 in.², whereas 0.5 in. is only 0.20 in.²).

ABRASIVE METERING VALVES

Regulating abrasive into an air stream is a highly critical aspect of surface impact performance. The method and accuracy of metering abrasive have dramatic effects on production speed and cleaning efficiency. The primary objective of an abrasive metering valve is to use the energy of every abrasive particle to work the surface as intended. When too little abrasive is used, particles are widely spread over the blast area, which slows down blasting production and leaves untouched surface voids. Too much abrasive is equally detrimental to cleaning rates because excessive particles collide with each other, rather than being uniformly dispersed over the blast pattern area. Exorbitant abrasive usage also results in costly waste and labor. Consequently, it just makes good sense to utilize well-built, properly designed, metering valves.

A logical approach to feeding abrasive into an air stream is to bring it in at a 45° angle in the same flow direction as the air. This concept allows a natural blending of air and abrasive material without creating flow obstacles. The overall result is a smooth, steady supply of abrasive for consistent blast patterns on the surface.

REMOTE CONTROLS

All abrasive blast machines must be furnished with automatic remote controls that are designed to shut off machines as quickly as possible. In the United States, installation of remote controls is an OSHA regulation (29 CFR 1910.244). The device (control handle) that activates remote control valves must be located at the nozzle and must be used correctly by the blaster. Using blast machines without remote controls is a dangerous and unacceptable practice that may result in serious injury to blasters and other personnel in the immediate vicinity.

In addition to obvious safety features, there are other benefits to utilizing remote controls. Quick start and stop response offered by remote control systems avoids substantial waste of abrasive. If a nozzle has to be pointed in the air while waiting for someone else to shut off the machine or while the blaster is repositioning on
scaffolding, good abrasive is being squandered. Another labor-saving advantage is eliminating the necessity of a helper who tends the blast machine.

**BLAST HOSE**

Hose and hose fittings are victims of rapid wear and tear by the very nature of their exposure in an abrasive blasting system. Hose, in particular, is especially vulnerable due to the cutting action of high-velocity abrasive on the inside. On hose fittings, wear is seldom a problem, but rough handling shortens their useful life through breakage and deformation. Procuring appropriately sized, top-quality blast hose and fittings and installing them properly is the most advantageous approach to keeping costs in line and production at a high level.

Hose must be specifically manufactured for abrasive blasting. It should have thickwalled internal rubber tube supported by fabric, protected by a durable outer cover, and rated at an appropriate working pressure. Rubber tubes must be treated with static-dissipating compound for the comfort and safety of the operator. Typical wall thickness of blast hose tube is 1/4 in. (6.3 mm). Thin-walled hose tubes only 3/16 in. (4.7 mm) thick are often found in super flexible blast hose where customers prefer more elastic hose movement.

The sole purpose of blast hose is to convey air-driven abrasive from the blast machine to the nozzle. Hose should have a sufficient inner diameter to allow unrestricted particle movement. It should be no longer than necessary to carry abrasive from the machine to the nozzle.

There is a very simple formula to use when selecting blast hose. It starts with the size of the nozzle orifice and continues back to the machine piping. The formula is: **Blast hose inner diameter should be three to four times the size of the nozzle orifice.** Where possible, choose the four times number.

**COUPLINGS AND HOSE ENDS**

Blast hose couplings and hose ends are available in a variety of materials and configurations. Much like blast hose, couplings and hose ends must be designed and manufactured to withstand the rigors of rough service.

Generally, hose couplings are manufactured from brass alloy, aluminum alloy, or nylon materials. Each material serves a particular purpose, although there is an overlap of purpose based on job applications. Brass is ideal for rough and tough usage. Aluminum is lightweight but less durable than the other two materials. Nylon offers the lightweight feature of aluminum and durability of brass, in addition to precise dimensional advantages.

For the most part, there is an industry standard on the method of interconnecting hose couplings. Locking lugs (two) on every coupling are identically formed to allow any two couplings to be firmly connected and, with a quarter of a turn, locked into place. Universal-designed locking lugs are produced on couplings for blast hoses ranging from 1/2 in. to 1-1/2 in (13 - 38 mm) inside diameter. Standardized lugs are convenient in that variously sized hose can be coupled together without the necessity of an assortment of couplings.

Every coupling is supplied with a rubber gasket to seal against air and abrasive leakage. When two couplings are placed together for connection, gaskets in each coupling align and compress as the couplings are twisted into the locked position. Specially designed safety cables for blast hose are available to prevent injury in the event two hoses disengage. A second safety feature for hose couplings is safety pins, which eliminate accidental twisting from a locked position.

**BLAST NOZZLES**

Performance at the blast nozzle reveals whether or not all of the previous requirements for air and abrasive flow have been correctly followed. The objective of everything installed between the air compressor and the nozzle has been to convey a steady supply of abrasive at adequate pressure to the nozzle.

Nozzles are versatile in performance. They can convert air-driven abrasive into a highly accelerated cutting force that can tackle the toughest application. They can also decelerate abrasive into a low-flow process that can gently strip paint away from soft surfaces. Choice of size, type, and shape of nozzles becomes an important decision due to the effect on production speed and desired appearance of the end product.

**NOZZLE MATERIALS**

There are various types of nozzle materials that primarily affect wear life. Wear life, however, is not simply a matter of how long a nozzle will last; it is a critical element affecting air flow. The nozzle orifice is the determining factor for air volume usage; that is, a certain-sized orifice will pass a certain volume of air. As the orifice wears, it will require increases in air volume to maintain 100 psi (689 kPa). For example, a nozzle with a 3/8 in (9.5 mm) orifice operating at 100 psi requires air volume of 196 cfm (5.5 m³/min). When the nozzle orifice enlarges by 1/16 in. (1.5 mm), the air volume required to maintain 100 psi is 254 cfm (7.2 m³/min). A tiny 1/16th of an inch (1/2 millimeter wear) on the nozzle orifice increases the air volume requirement by 30%! All the more reason to choose nozzle materials that provide the best possible wear resistance for prolonged productive results.

Available nozzle materials are cast iron, ceramic, tungsten carbide, silicon carbide and boron carbide. Cast iron is rarely used today because of its rapid wear, which is typically 6-8 hours. Ceramic is commonly used with small, light duty equipment and with blast cabinets where nonaggressive abrasive is used. Carbide-type nozzles are the most popular choice on the great majority of blasting applications due to their long life characteristics.

**NOZZLE SHAPE**

Since the advent of abrasive blasting, the shape of nozzles incorporated a tapered entrance leading into a straight barrel of various lengths. With straight barreled nozzles, the center of the blast pattern is hit with excessively heavy concentrations of abrasive while the outer perimeter gets only a spattering of abrasive coverage. Straight barreled nozzles continue to be used, but generally only on low-production machines or in blast cabinets where the distance between parts and nozzles is very close.
A more effective nozzle shape is the venturi design. In the venturi configuration, an engineered converge-diverge concept is calculated to accelerate abrasive particles to their maximum velocity. The length and diameter of the cone-shaped entrance are mathematically calculated to correspond to the orifice size and to the flared length and diameter of the exit end. Each size of nozzle has its own shape dimensions - no two sizes are the same. Abrasive enters the converging end of the nozzle, tunnels through the orifice, and rapidly expands into a high-powered stream through the diverging exit end of the nozzle. At 100 psi (689 kPa) nozzle pressure, the velocity at the end of the nozzle reaches 660 feet per second (200 meters per second) - nearly the speed of sound. By comparison, a straight barreled nozzle velocity is 318 ft/sec (97 m/sec), which is less than half of the venturi's velocity.

**NOZZLE ORIFICE**

Nozzle orifices dictate the amount of compressed air required for blast machine assemblies. The larger the orifice, the higher the production. Naturally, the largest possible nozzle should be used as long as the air compressor can support it. The second major consideration with nozzle sizing, similar to hose and pipe, is comprehending the area of a circle and how alteration of a circle changes a blasting systems performance. When orifices wear or when nozzles of different orifice sizes are interchanged, there is a dramatic change in air requirements and abrasive consumption. Table I illustrates the effect of nozzle orifice selection or the effect of wearing an original orifice 1/16 in. (1.5 mm) larger.

<table>
<thead>
<tr>
<th>Nozzle No.</th>
<th>Orifice, in (mm)</th>
<th>Area, in.² (mm²)</th>
<th>Area Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>1/4 (6.5)</td>
<td>0.05 (3.2)</td>
<td>—</td>
</tr>
<tr>
<td>5</td>
<td>5/16 (8.0)</td>
<td>0.08 (5.2)</td>
<td>60% larger than #4</td>
</tr>
<tr>
<td>6</td>
<td>3/8 (9.5)</td>
<td>0.11 (7.1)</td>
<td>38% larger than #5</td>
</tr>
<tr>
<td>7</td>
<td>7/16 (11.0)</td>
<td>0.15 (9.7)</td>
<td>36% larger than #6</td>
</tr>
<tr>
<td>8</td>
<td>1/2 (12.5)</td>
<td>0.20 (12.9)</td>
<td>33% larger than #7</td>
</tr>
</tbody>
</table>

Translating the figures in Table I into compressed air and abrasive usage, when a number 4 nozzle wears by 1/16 in. (1.5 mm), it will use 60% more air and abrasive than it did originally. Referring to a nozzle consumption chart (see Table II on page 21), the percentages shown in Table I are proven to be reasonable accurate in the abrasive and air usage figures. It is easy to see how a blast system that has been equipped with an air compressor with no reserve supply of air will start to show a reduction in production as the nozzle begins to wear.

**OPERATOR SAFETY EQUIPMENT**

Anyone working with a powerful stream of sharp particles containing some degree of foreign materials, and removing surface contaminants that may contain toxic substances, needs personal protection equipment of the highest caliber of safety and quality. Personal safety equipment for blast operators and any personnel in the blast room is an absolute necessity to prevent a variety of injuries that will occur without proper protection.

Translated from the figures in Table I, compressed air and abrasive usage, when a number 4 nozzle wears by 1/16 in. (1.5 mm), it will use 60% more air and abrasive than it did originally. Referring to a nozzle consumption chart (see Table II on page 21), the percentages shown in Table I are proven to be reasonable accurate in the abrasive and air usage figures. It is easy to see how a blast system that has been equipped with an air compressor with no reserve supply of air will start to show a reduction in production as the nozzle begins to wear.

**HELMET AIR SUPPLY**

Air furnished to helmets and hoods MUST be clean, dry, contamination free and at NIOSH prescribed pressure and volume. Simple logic dictates the need for good, clean air because it is used for breathing air, but more than that, breathing air quality is heavily regulated to precise specifications. Special attention must be paid to the source and composition of air and its required filtration system. Carefully read all instructional materials on all equipment employed in the breathing air producing and conveying system.

There are several sources for breathing air ranging from small air cylinders to large, oil-lubricated air compressors. No matter how or where air is furnished, it must comply with strict standards for high-quality breathing air. Never attach a breathing air hose to plant or any stationary fittings without first testing the quality of air in the line. Breathing air quality must meet at least the requirements describe in the Compressed Gas Association Commodity Specifications ANSI/CGA G-7.1 as specified by OSHA regulations 30 CFR, Part 11, Subpart J, Paragraph 11.121 (Grade D or higher quality).

**BREATHEING AIR FILTERS**

Air supplied to helmets and hoods must be cleansed through efficient filtering systems. It is not only a good idea to clean the air, but it is also an OSHA regulation (29 CFR, Subpart I, 1910.134). OSHA demands that filters comply with some of the requirements for Grade D quality breathing air. The filter’s role in Grade D is to remove oil mists, water vapor, and particulate larger than 0.5 micron. Filters that do not meet these specifications should not be used for breathing air.

There is a vast selection of filters on the market. Unfortunately, many users choose small, inadequate filters because of price rather than performance. Choosing ineffective filters is false economy, in addition to violating the OSHA regulations. Dust, dirt, and other foreign matter mixed with oil and water mists clog air passageways and sound deadening materials inside respirators. Air flow become restricted, required pressure diminishes, and operators experience unpleasant odors. The same problems occur if filters are too small to handle continuous volume and pressure of air. Poorly chosen filters result in frequent and costly maintenance of respirators, as well as reducing safety levels for operators.
High capacity, super efficient filters should be installed in breathing air systems. These filters should be designed with filter cartridges that can be quickly replaced. Filter bodies should be engineered to handle air volume and pressure by allowing inlet air to expand, cool, and slow down the velocity prior to entering filtering media. Filters must be equipped with pressure regulators and gauges, not only to set required air pressure, but also to use the gauge to indicate when cartridges need replacement. Gauges, installed on the clean air side of filters, will show declining readings when cartridges begin to saturate with liquid and solid matter. As an extra precaution, pressure relief valves are mounted on filters to prevent any change of excessive pressure.

CARBON MONOXIDE ALARMS AND CONVERTERS

The greater danger associated with lubricated air compressors for breathing air is carbon monoxide. Very simply, carbon monoxide is produced by overheated compressors, which burn lubricating oil to the point where carbon monoxide gas is formed in the compressor compartment and fed into the air line.

Carbon monoxide kills; therefore, safety steps must be implemented to prevent exposure to this deadly gas. First, air compressors must be serviced at the manufacturer’s recommended intervals. Second, compressors must be equipped with overheating shut-off devices and/or carbon monoxide alarms. If only an overheating alarm is used, the air must be frequently tested for carbon monoxide.

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**Table II. Nozzle Chart Giving Compressor Air and Abrasive Consumption**

<table>
<thead>
<tr>
<th>Nozzle Orifice</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
<th>125</th>
<th>Air (cfm)</th>
<th>Abrasive (ft³/hr and lb/hr)</th>
<th>Compressor hp</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 2</td>
<td>11</td>
<td>13</td>
<td>15</td>
<td>17</td>
<td>18.5</td>
<td>20</td>
<td>25</td>
<td>Air (cfm)</td>
<td>Abrasive (ft³/hr and lb/hr)</td>
<td>Compressor hp</td>
</tr>
<tr>
<td>(1/8 in.)</td>
<td>0.67</td>
<td>0.77</td>
<td>0.88</td>
<td>1.01</td>
<td>1.12</td>
<td>1.23</td>
<td>1.52</td>
<td>Air (cfm)</td>
<td>Abrasive (ft³/hr and lb/hr)</td>
<td>Compressor hp</td>
</tr>
<tr>
<td>No. 3</td>
<td>26</td>
<td>30</td>
<td>33</td>
<td>38</td>
<td>41</td>
<td>45</td>
<td>55</td>
<td>Air (cfm)</td>
<td>Abrasive (ft³/hr and lb/hr)</td>
<td>Compressor hp</td>
</tr>
<tr>
<td>(3/16 in.)</td>
<td>1.50</td>
<td>1.71</td>
<td>1.96</td>
<td>2.16</td>
<td>2.38</td>
<td>2.64</td>
<td>3.19</td>
<td>Air (cfm)</td>
<td>Abrasive (ft³/hr and lb/hr)</td>
<td>Compressor hp</td>
</tr>
<tr>
<td>No. 4</td>
<td>268</td>
<td>312</td>
<td>354</td>
<td>408</td>
<td>448</td>
<td>494</td>
<td>608</td>
<td>Air (cfm)</td>
<td>Abrasive (ft³/hr and lb/hr)</td>
<td>Compressor hp</td>
</tr>
<tr>
<td>(1/4 in.)</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>12</td>
<td>Air (cfm)</td>
<td>Abrasive (ft³/hr and lb/hr)</td>
<td>Compressor hp</td>
</tr>
<tr>
<td>No. 5</td>
<td>77</td>
<td>89</td>
<td>101</td>
<td>113</td>
<td>126</td>
<td>137</td>
<td>168</td>
<td>Air (cfm)</td>
<td>Abrasive (ft³/hr and lb/hr)</td>
<td>Compressor hp</td>
</tr>
<tr>
<td>(5.16 in.)</td>
<td>4.68</td>
<td>5.34</td>
<td>6.04</td>
<td>6.72</td>
<td>7.40</td>
<td>8.12</td>
<td>9.82</td>
<td>Air (cfm)</td>
<td>Abrasive (ft³/hr and lb/hr)</td>
<td>Compressor hp</td>
</tr>
<tr>
<td>No. 6</td>
<td>108</td>
<td>126</td>
<td>143</td>
<td>161</td>
<td>173</td>
<td>196</td>
<td>237</td>
<td>Air (cfm)</td>
<td>Abrasive (ft³/hr and lb/hr)</td>
<td>Compressor hp</td>
</tr>
<tr>
<td>(3/8 in.)</td>
<td>6.68</td>
<td>7.64</td>
<td>8.64</td>
<td>9.60</td>
<td>10.52</td>
<td>11.52</td>
<td>13.93</td>
<td>Air (cfm)</td>
<td>Abrasive (ft³/hr and lb/hr)</td>
<td>Compressor hp</td>
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<tr>
<td>No. 7</td>
<td>147</td>
<td>170</td>
<td>194</td>
<td>217</td>
<td>240</td>
<td>254</td>
<td>314</td>
<td>Air (cfm)</td>
<td>Abrasive (ft³/hr and lb/hr)</td>
<td>Compressor hp</td>
</tr>
<tr>
<td>(7/16 in.)</td>
<td>8.96</td>
<td>10.32</td>
<td>11.76</td>
<td>13.12</td>
<td>14.48</td>
<td>15.84</td>
<td>19.51</td>
<td>Air (cfm)</td>
<td>Abrasive (ft³/hr and lb/hr)</td>
<td>Compressor hp</td>
</tr>
<tr>
<td>No. 8</td>
<td>24</td>
<td>28</td>
<td>32</td>
<td>36</td>
<td>39</td>
<td>44</td>
<td>52</td>
<td>Air (cfm)</td>
<td>Abrasive (ft³/hr and lb/hr)</td>
<td>Compressor hp</td>
</tr>
<tr>
<td>(1/2 in.)</td>
<td>11.60</td>
<td>13.36</td>
<td>15.12</td>
<td>16.80</td>
<td>18.56</td>
<td>20.24</td>
<td>24.59</td>
<td>Air (cfm)</td>
<td>Abrasive (ft³/hr and lb/hr)</td>
<td>Compressor hp</td>
</tr>
</tbody>
</table>

This table provides calculated consumption rates of air and abrasive for new nozzles. When selecting a compressor, add 50% to these figures to allow for normal nozzle and friction loss.

Carbon monoxide detection equipment is available to perform two different functions. One method is to monitor supply air and set off an alarm if carbon monoxide reaches an unacceptable level. The other method is a sophisticated system that is designed to convert carbon monoxide to carbon dioxide, a less dangerous gas.

**PROTECTIVE CLOTHING**

Abrasive moving at high velocity can inflict serious injury upon unprotected operators performing blasting jobs; therefore, it is essential to furnish them with protective clothing. OSHA regulation 29 CFR, Subpart I, 1910.94 and 1910.134 states that operators should wear heavy duty clothing, canvas or leather gloves, and safety shoes. Lightweight clothing simply will not provide sufficient protection. Heavy duty clothing is effective against ricocheting abrasive and it will afford adequate protection from momentary direct blasts of high-speed sharp abrasive.

**OPERATOR TRAINING**

Without question, the most important element of a manually operated blasting system is the blaster. The finest equipment on the market will not perform to its greatest potential without blasters who are fully trained on equipment and totally knowledgeable on concepts. Just as critical to production output is the safety factor. Blasting is a powerful cleaning method, which requires mandatory attention to safety procedures for operators and job site personnel.

Although abrasive blasting is not a highly technical vocation, a considerable level of operator skill is absolutely necessary to achieve the best results. Using spray painting as a comparative scenario, no one would consider taking people off the street, handing them spray guns, and telling them to start painting a bridge. They would not know how to set up the paint spray equipment with the proper amount of air and paint, or how to apply paint in an even layer over the entire surface without excessive overlapping and missed spots, or how to clean and maintain the equipment to prevent costly repairs. The consequence would be a devastating failure of the paint job and profit-robbing rework.

The same scenario would be true with abrasive blasting, with the addition of a far greater chance for personal injury. Ill-trained blasters will not accomplish satisfactory results on production rates or achieve required surface finishes, if they do not know how to utilize the equipment to its full potential. More importantly, they could seriously injure themselves if they are not properly educated on blasting processes, and they are not instructed on mandated safety procedures. Many painting and coating jobs have to be redone at great expense due to poor blasting work. It simply makes no sense to jeopardize any job or subject anyone to possible injury by using unprepared personnel. Conversely, workers who have attained a high degree of expertise in the blasting process will produce predictable profits under safe working environments, and will ultimately contribute to the overall success of their companies.

A thorough training program is not simply how to use the equipment. In order for operators to become truly skillful with their job, they must know the purpose of the job, their objectives, and how their performance will be measured. They must learn about surfaces they will be blasting and what results are required. They must learn about abrasive, air pressure, air volume, and how these interrelate to meet specifications on surface cleanliness and profile. Above all, they must be totally familiar with the equipment and how to maintain it in top condition for maximum efficiency and safety.

**STUFF AND NONSENSE**

- Back Up My Hard Drive? How do I put it in Reverse? :)
- I just got lost in thought. It was unfamiliar territory.
- Everyone has a photographic memory. Some don’t have film.
- Seen it all, done it all, can’t remember most of it.
- You have the right to remain silent. Anything you say will be misquoted, then used against you.
- I wonder how much deeper would the ocean be without sponges.
- Honk if you love peace and quiet.
- Pardon my driving, I am reloading.
- Despite the cost of living, have you noticed how it remains so popular?
- Nothing is foolproof to a sufficiently talented fool.
- Diplomacy is saying “nice doggy” until you find a rock.
- A day without sunshine is like, you know, night.
- Change is inevitable. Except from a vending machine.
- Those who live by the sword get shot by those who don’t.

We will start with Blasting Abrasive in the next issue of Abrasive Blast Cleaning News.