AP42 Section: 13.2.6 Abrasive Blasting

Title: Comments and Correspondance for 1997 supplement

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To: Brian Shrager  
From: Dave Reeves  
Date: March 25, 1997

Re: Comments on Abrasive Blasting AP-42, Section 13.2.6

My overall comments on this document center around the fact that I think we missed the targeted industries using abrasive blasting and the use of sand as the abrasive media tested in the wind tunnel represents old, out-of-date technology.

Abrasive blasting in the shipbuilding industry rarely involves sand because of the breakdown of the sand (silica) particles and the serious worker exposure concerns involving silicosis. Most of the shipyards I am familiar with have evaluated several types of materials for blasting applications and Black Beauty or Black Diamond (smelter slags) are most popular (especially on the East coast). These slag materials contain many trace metals, many of which are HAP, and there are several studies and product data sheets that provide typical particulate HAP metal concentrations. Non-silica minerals such as garnet and synthetic materials such as Dupont's "Starblast" were becoming increasingly popular on the West coast (at least at shipyards).

The report mentions that the automotive and painting industries are the major users of abrasives. I am not familiar with any automotive process that involves large scale abrasive blasting, much less any uncontrolled outdoor blasting.

The "industry characterization" also states that the aircraft industry is the largest user of more expensive abrasives. From my involvement on the aerospace NESHAP/CTG project, I only know of two facilities that use or have tried to use plastic media blasting systems. Most large-scale aerospace facilities have small (contained) systems for cleaning(depainting various components of the aircraft. However, the aerospace BID (relevant section attached) states that "many military facilities are currently using plastic media blasting" and the emission factor for plastic media blasting is 0.021 pounds of PM10 emissions per pound of media used.

I would have thought most commercial applications would involve bridges, water tanks/towers, or buildings. Did anyone review trade journals such as Journal of Protective Coatings & Linings or contact the Steel Structures Painting Council?

I did not understand equation 2-1 (taken from SCAQMD document); how do you get Da and Ds?

When you are talking about materials that can be recycled and reused in the process, the cost issue is "relative". Stating that one abrasive is more expensive than other can be misleading if you do not qualify relative amounts needed and life cycle costs. I was corrected on this early on by the suppliers.
I was expecting some discussion of State regulations involving abrasive blasting and the correlation to opacity limits, types of systems and media, enclosures, etc. I have articles that summarize existing State requirements if you are interested.

One of the 1992 articles does state that sand is the most commonly used abrasive blasting material because of its relatively low cost and local availability. Because of the potential silicosis liability, sand blasting is banned by many countries and U.S. companies (including the U.S. Navy).

In summary, I think there are several references that should have been reviewed to better describe the targeted industries and processes. I do not think there is any additional "real" test data available, but the data used in some of the articles would serve as good supporting information. Is it appropriate to provide some guidance regarding the relative emissions of alternate media - particularly those that are non- or low-dust generating? What about the big issue of outdoor uncontrolled blasting versus blasting done indoors or in an enclosure?

I have attached several related articles from my project work. I noticed that Valerie references the MRI '89 report in her 1992 memo on Control of PM10 and Abrasive Blasting Regulations in the Shipbuilding and Ship Repair Industry.
B. DEPAINTING INORGANIC HAP EMISSIONS

The MACT floor level of control specifies that inorganic HAP particulate emissions be controlled by 99 percent. This can be achieved through the use of particulate filters such as panel filters or baghouses. This analysis examines the conversion from low efficiency particulate filters to high efficiency particulate filters that meet the MACT floor level of control.

It is not reasonable to assume that all commercial and military rework facilities (a total of 2,026 facilities) depaint the outer surface of aerospace vehicles. Therefore, it was assumed that only 5 percent of the small and medium facilities and all of the large facilities perform outer surface depainting (see Table 10).

**TABLE 10**

**NUMBER OF DEPAINTING FACILITIES BY MODEL PLANT SIZE**

<table>
<thead>
<tr>
<th>Model Plant Size</th>
<th>Number of Facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>27</td>
</tr>
<tr>
<td>Medium</td>
<td>73</td>
</tr>
<tr>
<td>Large</td>
<td>5</td>
</tr>
</tbody>
</table>

**Baseline**

Baseline has been defined as depainting fully painted aircraft with plastic media blasting and using particulate filters with a control efficiency of 95 percent. Many military facilities are currently using plastic media blasting. Therefore, for the purpose of this option, data from military facilities will be used for both baseline and MACT.

From vendor information, approximately 50 percent of the blasting particulates fall to the ground and 50 percent are airborne. The emission factor for plastic media blasting is 0.021 pounds of emissions per pound of media used. Based on data from a medium,
military rework facility, a typical flow rate of media during blasting is 2,700 pounds per hour. Using the above data, uncontrolled PM10 emissions are:

Average = 2,700 lb media/hr x 0.5 x 0.021 lb emissions/lb media = 28 lb emissions/hr

A medium, military rework facility also stated that it takes 0.03 hours to strip 1 square foot of aircraft outer surface area. From the environmental impacts memo for depainting, the total outer surface area of aircraft reworked annually for each military model plant is:

Small model plant: 137,900 ft²/yr
Medium model plant: 190,500 ft²/yr
Large model plant: 1,032,000 ft²/yr

The time it takes to strip this area by model plant is calculated using the 0.03 hr/ft² stripping rate. The total time for depainting by model plant is:

Small model plant: 137,900 ft²/yr x 0.03 hr/ft² = 4,140 hr/yr
Medium model plant: 190,500 ft²/yr x 0.03 hr/ft² = 5,710 hr/yr
Large model plant: 1,032,000 ft²/yr x 0.03 hr/ft² = 30,960 hr/yr

Using the emission rate of 28 lb/hr for each of the model plants, uncontrolled emissions are:

Small model plant: 4,140 hr/yr x 28 lb/hr = 115,920 lb/yr
Medium model plant: 5,710 hr/yr x 28 lb/hr = 159,880 lb/yr
Large model plant: 30,960 hr/yr x 28 lb/hr = 866,880 lb/yr

Baseline emissions per model plant, using a control efficiency of 95 percent, are:

Small model plant: (115,920 lb/yr x (1 - 0.95)) = 5,800 lb/yr
Medium model plant: (159,880 lb/yr x (1 - 0.95)) = 7,990 lb/yr
Large model plant: (866,880 lb/yr x (1 - 0.95)) = 43,340 lb/yr
Using the number of facilities that perform depainting operations as listed in Table 10, nationwide baseline emission are:

Small model plant: \(5,800 \text{ lb/yr} \times 27 \text{ rework facilities} = 156,600 \text{ lb/yr}\)

Medium model plant: \(7,990 \text{ lb/yr} \times 73 \text{ rework facilities} = 583,270 \text{ lb/yr}\)

Large model plant: \(43,340 \text{ lb/yr} \times 5 \text{ rework facilities} = 216,700 \text{ lb/yr}\)

**MACT Floor**

The MACT floor can be achieved by installing particulate filters with a minimum control efficiency of 99 percent. For the purpose of the impact analysis, it was assumed that each facility performs the blasting operation within a hangar and that a ventilation system is in place.

**Primary Air Emissions**

Assuming that MACT floor has a minimum control efficiency of 99 percent, MACT emissions by model plant are:

Small model plant: \(115,920 \text{ lb/yr} \times (1 - 0.99) = 1,160 \text{ lb/yr}\)

Medium model plant: \(159,880 \text{ lb/yr} \times (1 - 0.99) = 1,600 \text{ lb/yr}\)

Large model plant: \(866,880 \text{ lb/yr} \times (1 - 0.99) = 8,670 \text{ lb/yr}\)

Again using the number of depainting facilities from Table 10, nationwide MACT emission are:

Small model plant: \(1,160 \text{ lb/yr} \times 27 \text{ rework facilities} = 31,320 \text{ lb/yr}\)

Medium model plant: \(1,600 \text{ lb/yr} \times 73 \text{ rework facilities} = 116,800 \text{ lb/yr}\)

Large model plant: \(8,670 \text{ lb/yr} \times 5 \text{ rework facilities} = 43,350 \text{ lb/yr}\)

The total nationwide primary air impact of implementing the MACT standard is equal to the total nationwide baseline primary air impact emissions minus the total nationwide MACT primary air emissions.
Small model plant: 156,600 lb/yr - 31,320 lb/yr = 125,280 lb/yr

Medium model plant: 583,270 lb/yr - 116,800 lb/yr = 466,470 lb/yr

Large model plant: 216,700 lb/yr - 43,350 lb/yr = 173,350 lb/yr

Secondary Air Emissions

Secondary air impacts are generated by the operation of certain control systems. For example, incineration may produce amounts of nitrogen oxides (NO,) and carbon monoxide (CO) from the combustion of hydrocarbons. Additionally, secondary air impacts are generated by the use of products that contain different or additional HAP's from the baseline products. The use of particulate filters does not require incineration or product substitutions. Therefore, no additional secondary air impacts are expected.

Wastewater Generation

No water impacts are expected since there is no water used in conjunction with particulate filters, either for baseline or MACT.

Energy Consumption

While the fans and ventilation systems consume energy to operate, it is assumed that they will have a negligible effect on the overall energy consumption of the model plants. Additionally, ventilation systems will not have to change from baseline to MACT. Consequently, energy impacts will be negligible.

Solid Waste Generation

The only solid waste generated during this process is the spent particulate filters. It is not anticipated that the amount of spent filters generated under the MACT floor level of control will vary significantly with the baseline level of control.

C. WASTEWATER

MACT floor is no control; therefore, no impact incurred.

D. STORAGE TANKS

MACT floor is no control; therefore, no impact incurred.
E. WASTE

100 percent of the reporting facilities are performing housekeeping measures; therefore, no impacts will be incurred.

References


5. References 1, 2, 3, and 4.

6. Section 114 Questionnaire Response from Lockheed Aircraft Service Company in Palmdale, California.

7. Section 114 Questionnaire Response from The Boeing Company in Wichita, Kansas.

8. Section 114 Questionnaire Response from Douglas Aircraft Company in Long Beach, California.

9. Section 114 Questionnaire Response from Naval Aviation Depot in Cherry Point, North Carolina.

10. Section 114 Questionnaire Response from The Boeing Company in Renton, Washington.

11. Section 114 Questionnaire Response from The Boeing Company in Auburn, Washington.


17. Reference 16.

18. Reference 16.

19. Section 114 Questionnaire Response from Lockheed Aircraft Services Ontario Facility in Ontario, California.


21. Section 114 Questionnaire Response from Tinker Air Force Base, Oklahoma.
Control of Suspended Particulate Matter (PM-10) and Abrasive Blasting Regulations In the Shipbuilding and Ship Repair Industry

DRAFT REPORT

EPA Contract No. 68-D1-0115
Work Assignment 9
ESD Project No. 91/53A
MRI Project No. 6500-09

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January 1992
1.0 INTRODUCTION

The purpose of this report is to present information gathered on control of suspended particulate matter (PM-10)* emissions and abrasive blasting regulations in the shipbuilding and ship repair industry. Specifically, this report: (1) provides background information on PM-10; (2) gives details of a literature search and provides sources for additional information gathering; (3) gives detailed information on abrasive blasting methods; (4) gives limited test data on PM-10 emissions; (5) provides options and alternatives for controlling PM-10 emissions; and (6) provides conclusions and recommendations on the information gathered to date.

2.0 BACKGROUND INFORMATION

Several ongoing Federal and State regulatory activities potentially affect PM-10 emissions. Most recently, the Federal Clean Air Act Amendments (CAAA) of 1990 require that guidance on reducing PM-10 emissions be promulgated. Also, on July 1, 1987, EPA promulgated a National Ambient Air Quality Standard (NAAQS) for PM-10 which initiated requirements for State implementation plans (SIP’s). As a result, several State and local agencies expressed concern about industries that use outdoor abrasive blasting and the contribution of these operations to PM-10 emissions. In addition, Section 39611 of the California Clean Air Act of 1988 requires that the California Air Resources Board (CARB) address the prospects for attaining standards for several pollutants, including PM-10. The State of California is particularly concerned about PM-10 because nearly all California areas are designated as nonattainment for PM-10 and because ambient PM-10 concentrations exceed the standards in most California areas on more than 50 percent of the days.

Within the shipbuilding and ship repair industry, outdoor abrasive blasting can occur several times a day for extended

*PM-10 refers to particles with diameters equal to or smaller than about 10 microns.
periods of time on very large surfaces. The PM-10 is a complex mixture of substances that may include carbon, lead, and nickel; compounds such as nitrates, organics, and sulfates; and mixtures such as diesel exhaust and soil.  

3.0 LITERATURE SEARCH

The purpose of the literature search was to obtain information on PM-10 emissions and their control methods in the shipbuilding and ship repair industry. Since very little information was found that specifically related to PM-10, it was decided to present general information on particulate matter emissions on the assumption that PM-10 emissions are at least partially related to total suspended particulate emissions.

To collect suitable documents for analysis, a computerized literature search was performed. The data bases examined were NTIS, Compendex Plus, Pollution Abstracts, Pascal, and Enviroline. For this search, only three individual documents were identified to contain specific information on particulate matter produced from abrasive blasting in the shipbuilding and ship repair industry. One of these documents is almost 20 years old, but few developments have occurred since this time. A technical support document containing PM-10 information was received from CARB also. The technical support document does not address the PM-10 issue in the shipbuilding and ship repair industry but does give general information on controlling PM-10.

To supplement the above gathered documents, several calls were made to industry representatives to obtain viable information on PM-10 relative to the shipbuilding and ship repair industry. The overall response to the request for PM-10 information was favorable; however, to date, the information requested has not been received. Additional sources that will be contacted for PM-10 information include other State agency and Navy personnel.
4.0 ABRASIVE BLASTING OF SHIP'S HULLS

Abrasive blasting is performed primarily upon Naval ships and service craft at Naval Shipyards, Naval Ship Repair Facilities at a number of commercial shipyards under contract to the U.S. Navy, and to a lesser extent in floating drydocks at several other Naval facilities. It is estimated that about 80 percent of the work conducted at all U.S. shipyards is Navy related. Two-thirds of Naval ship repair takes place in Naval shipyards and about one-third in commercial shipyards. The remainder of this section presents general information on where abrasive blasting activities occur in shipyards, types of abrasives that may be used, and abrasive blasting systems.

4.1 GENERAL

To minimize corrosion of ship hulls, the surfaces are prepared by abrasive blasting and coated with protective coatings. After the initial coating is applied, weathered coatings must be removed periodically to maintain this corrosion protection. The abrasive blasting process:

1. Removes marine growth, algae, and barnacles attached to the hull that reduce ship speed, increase fuel consumption, and increase noise as the ship travels;
2. Removes the antifouling paint residue which has lost its effectiveness by the leaching of the incorporated active ingredient used against marine growth;
3. Removes rust and other deteriorated coatings; and
4. Cleans and prepares the surface to ensure adhesion and performance of a new anticorrosive and antifouling coating system.

Surface preparation is the greatest single factor affecting performance of the coating system.

Blast cleaning is the most effective and the preferred method of preparing metallic surfaces for painting. Abrasive blasting is very critical to the Navy to ensure availability between drydock schedules and to meet the current Naval requirement of increasing drydock schedules from 3 to 5 years.
The Navy feels that using wire brushes, sanders, or other mechanical means of surface preparation as an alternative to abrasive blasting often results in reduced coating performance and often does not provide the surface profile required. Deterioration of coatings applied to surfaces prepared by the former method is observed in approximately 1 year, and yearly drydockings often result. This is based on commercial ship experience where abrasive blasting is conducted under less stringent requirements and annual drydockings are required. The Navy therefore considers these procedures unacceptable in meeting its operational commitments.

Location of blasting is important when relating abrasive blasting and air pollution. Abrasive blasting of hulls is performed in graving docks, in floating drydocks, and on marine railways. The percentage distribution among the three are not known, but the preponderance of drydockings takes place in graving docks. Graving docks are recessed from the surface level, out of the wind, and tend to contain less fallout of particulate matter during abrasive blasting. Marine railways are, in general, the most exposed locations. Sometimes, depending on drydocking schedules and the ship repair work loading of a given shipyard, a very large deep drydock may be used to drydock several smaller ships. For example, four destroyers might be simultaneously docked in a very large, deep graving dock built to accommodate an aircraft carrier. Since this situation combines the blasting operations that may have been performed in several locations, it minimizes dispersion of particulate emissions to the atmosphere, which results in higher local concentrations of blast particulates.  

4.2 TYPES OF ABRASIVES

Abrasive materials are generally classified as: sand, metallic shot or grit, or other. The cost and properties associated with the abrasive material dictate its application. The following discusses the general classes of common abrasives.
Sand is the least expensive abrasive material. It is commonly used where reclaiming is not feasible such as in unconfined abrasive blasting operations. Sand has a rather high breakdown rate, which can generate substantial dust. For this reason, its use in most shipyards is limited. Synthetic abrasives, such as silicon carbide and aluminum oxide, are becoming popular substitutes for sand. Although the cost of synthetic abrasives is three to four times that of silica sand, they are more durable and have a lower tendency to create dust. Synthetic materials are predominantly used in blasting enclosures and in some unconfined blasting operations where abrasive reclaiming is employed.

Metallic abrasives are made from cast iron and steel. Cast iron shot is hard and brittle and is made by spraying molten cast iron into a water bath. Cast iron grit is produced by crushing the oversized and irregular particles formed in manufacturing cast iron shot. Steel shot is produced by blowing molten steel through air. Steel shot is not as hard as cast iron shot but is much more durable. Due to the higher costs associated with metallic abrasives, they are predominantly used in abrasive enclosures with reclaiming equipment.

Glass beads, crushed glass, cut plastics, and nutshells are included in the "other" category. As with synthetic and metallic abrasive materials, they are generally used in operations where the material is reclaimed.

The type of abrasive used in a particular application is usually specific to the blasting method. Dry abrasive blasting is usually done with sand, aluminum oxide, silicon carbide, metallic grit, or shot. Wet blasting is usually done with sand, glass beads, or any materials that will remain suspended in water. Table 1 lists common abrasive materials and their applications. The choice of abrasive also is influenced by considerations of abrasive cost at the blasting site, labor plus material cost for cleaning a unit area of hull, costs of cleanup.
TABLE 1. MEDIA COMMONLY USED IN ABRASIVE BLASTING

<table>
<thead>
<tr>
<th>Type of medium</th>
<th>Sizes normally available</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass beads</td>
<td>8 to 10 sizes from 30- to 440-mesh; also many special gradations</td>
<td>Decorative blending; light deburring; peening; general cleaning; texturing; noncontaminating applications</td>
</tr>
<tr>
<td>Aluminum oxide</td>
<td>10 to 12 sizes from 24- to 325-mesh</td>
<td>Fast cutting; matte finishes; descaling and cleaning of coarse and sharp textures</td>
</tr>
<tr>
<td>Garnet</td>
<td>6 to 8 sizes (wide-band screening) from 16- to 325-mesh</td>
<td>Noncritical cleaning and cutting; texturing; noncontaminating for brazing steel and stainless steel</td>
</tr>
<tr>
<td>Crushed glass</td>
<td>5 sizes (wide-band screening) from 30- to 400-mesh</td>
<td>Fast cutting; low cost; short life; abrasive; noncontaminating applications</td>
</tr>
<tr>
<td>Steel shot</td>
<td>12 or more sizes (close gradation) from 8- to 200-mesh</td>
<td>General-purpose rough cleaning (foundry operation, etc.); peening</td>
</tr>
<tr>
<td>Steel grit</td>
<td>12 or more sizes (close gradation) from 10- to 325-mesh</td>
<td>Rough cleaning; coarse textures; foundry welding applications; some texturing</td>
</tr>
<tr>
<td>Cut plastic</td>
<td>3 sizes (fine, medium, coarse); definite-size particles</td>
<td>Deflashing of thermoset plastics; cleaning; light deburring</td>
</tr>
<tr>
<td>Crushed nutshell</td>
<td>6 sizes (wide-band screening)</td>
<td>Deflashing of plastics; cleaning; very light deburring; fragile parts</td>
</tr>
</tbody>
</table>

There is no discussion here as in text of coal slag or copper slag which are the main blast media used in shipyards. Also should mention the sodium bicarbonate sprayed dry w/ water spray as seen at Metro Machine.
and disposal of a particular abrasive, and properties of metal surface finish for painting. Table 2 provides the compositions of some commonly used blast media.  

4.3 ABRASIVE BLASTING SYSTEMS

Typically, all abrasive blasting systems include three basic components: an abrasive container (i.e., blasting pot), a propelling device, and an abrasive blasting nozzle(s). The exact equipment used depends on the application.

The three propelling methods used in abrasive blasting systems are centrifugal wheels, air pressure, and water pressure. Centrifugal wheel systems use centrifugal and inertial forces to mechanically propel the abrasive media. Air blast systems use compressed air to propel the abrasive to the surface being cleaned. Finally, the water blast method uses either compressed air or high-pressure water. The most popular systems use either air pressure or water pressure to propel the abrasive material. Therefore, only these methods will be described.

The compressed air suction, the compressed air pressure, and the wet abrasive blasting systems utilize the air blast method. Hydraulic blasting systems utilize the water blast method.

In compressed air suction systems, two rubber hoses are connected to a blasting gun. One hose is connected to the compressed-air supply and the other is connected to the bottom of the abrasive supply tank or "pot."

The gun (Figure 1a) consists of an air nozzle that discharges into a larger nozzle. The high-velocity air jet (expanding into the larger nozzle) creates a partial vacuum in the chamber. This vacuum draws the abrasive into the outer nozzle and expels it through the discharge opening. Figure 1b shows a typical suction-type blasting machine.

The compressed air pressure system consists of a pressure tank (pot) in which the abrasive is contained. The pressure in the tank forces abrasive through the blast hose rather than siphoning it as described above. The compressed air line is connected to both the top and bottom of the pressure tank. This
<table>
<thead>
<tr>
<th>Trade or common name</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural sand</td>
<td>Essentially pure silicon dioxide</td>
</tr>
<tr>
<td>Green Diamond</td>
<td>Copper slag containing residues of free silica, lead, nickel, and chromium</td>
</tr>
<tr>
<td>Polygrit</td>
<td>Cuprous slag</td>
</tr>
<tr>
<td>Boiler slag</td>
<td>Silica containing iron oxide, alumina, and traces of magnesium, calcium, copper, lead, tin, antimony, and arsenic oxides</td>
</tr>
<tr>
<td>Docite Porphyry</td>
<td>Igneous crushed rock</td>
</tr>
<tr>
<td>Black Diamond</td>
<td>Iron slag containing silica, iron, aluminum, calcium, magnesium and titanium oxides, sulfates, phosphorus, manganese and carin</td>
</tr>
</tbody>
</table>
Figure 1a. Suction blast nozzle assembly.

Figure 1b. Suction-type blasting machine.

Source: Reference 2.
allows the abrasive to flow by gravity into the discharge hose without loss of pressure (see Figure 2).

Finally, wet abrasive blasting systems (Figure 3a) use a specially designed pressure tank. The mixture of abrasive and water is propelled by compressed air. An alternate method uses a pressure tank and a modified abrasive blasting nozzle. This modified abrasive blasting nozzle is shown in Figure 3b.

Hydraulic blasting incorporates a nozzle similar to that described above for air suction systems with the exception that high-pressure water is used instead of compressed air as the propelling media. A diagram of this type of nozzle is shown in Figure 4.

Pressure blast systems generally give a faster, more uniform finish than suction blast systems. They also produce high-abrasive velocities with less air consumption than suction systems. Pressure blast systems can operate at as low as 1 pound per square inch (psig) to blast delicate parts and up to 125 psig to handle the most demanding cleaning and finishing operations.¹

Suction blast systems are generally selected for light to medium production requirements, limited space, and moderate budgets. However, suction blast systems can blast continuously without stopping for abrasive changes and refills.² ¹ ²

5.0 EMISSIONS

Table 3 summarizes the test data available on PM-10 and respirable particulate matter (RP) emissions from the abrasive blasting of ship hulls and other structures. Although measurable levels of RP were documented from blasting of ship hulls, there was insufficient information to support the relationship between the amount of PM-10 found, the type of abrasive used to blast clean, and the type of docking facility tested. Furthermore, a comparison of emissions data gathered for abrasive blasting of ship hulls versus other structures appear to have no similarities. For this reason, it is believed that data gathered for non-similar applications cannot be used to estimate emissions from blasting operations at shipyards. The limited amount of
Figure 2. Pressure-type blasting machine.

Source: Reference 2.
Water-Choke relief valve
Equal air pressure above and below abrasive

Figure 3a. Wet blasting machine.

Air supply valve

Figure 3b. Adapter nozzle covering a dry blasting unit to a wet blasting unit.

Source: Reference 2.
Figure 4. Hydraulic blasting nozzle.
Source: Reference 2.
<table>
<thead>
<tr>
<th>Reference document</th>
<th>Test of operation tested</th>
<th>Type of abrasive</th>
<th>Sampler location</th>
<th>Particle size fraction, (μm)(^a)</th>
<th>Time weighted average concentration, mg/m(^3)</th>
<th>Data quality rating</th>
<th>Emission factor (mass/source extent)</th>
<th>Emission factor rating</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samini et al., 1974</td>
<td>Abrasive cleaning of ship hull</td>
<td>Stan-blast</td>
<td>4.6 m (&lt;5 yd) from source</td>
<td>TP</td>
<td>10.2</td>
<td>A</td>
<td>N/A(^b)</td>
<td>N/A</td>
<td>Sampling time = 185 min; Blasting time = 180 min; no process data</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sandblaster’s chest</td>
<td>88.8</td>
<td>RP</td>
<td>N/A</td>
<td>A</td>
<td>N/A</td>
<td>N/A</td>
<td>Sampling time = 181 min; Blasting time = 150 min; no process data</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>9.1 m (&lt;10 yd) from source</td>
<td>RP</td>
<td>2.36-9.08</td>
<td>A</td>
<td>N/A</td>
<td>N/A</td>
<td>No process data available</td>
</tr>
<tr>
<td>Landrigan et al., 1980</td>
<td>Abrasive bridge cleaning of lead-based paint</td>
<td>Grit (Black Beauty)</td>
<td>27 m downwind of bridge</td>
<td>TSP (Pb)</td>
<td>0.0129</td>
<td>E</td>
<td>N/A</td>
<td>N/A</td>
<td>Data for a 6.1 hr sampling period during which canvas shroud was not in place for a 2 hr period; Pb contributions from paint chips, vehicle exhaust, and grit; no process data available</td>
</tr>
<tr>
<td>Bareford and Record, 1982</td>
<td>Abrasive bridge cleaning of lead-based paint</td>
<td>Sand</td>
<td>Center of plume exiting sandblasting bay</td>
<td>TP</td>
<td>N/A</td>
<td>N/A</td>
<td>57-455 lb/hr abrasive blaster</td>
<td>D</td>
<td>2.5% Pb for particles &lt;2.4 μm; sand usage 700 lb/hr/blaster (no exact throughput available)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TP (Pb)</td>
<td>N/A</td>
<td>N/A</td>
<td>1.5-4.8 lb/hr abrasive blaster</td>
<td>D</td>
<td>&lt;1% Pb for particles &gt;75 μm; sand usage 700 lb/hr/blaster (no exact throughput available)</td>
</tr>
<tr>
<td>Department of Navy, 1973</td>
<td>Abrasive blasting of submarine hull in drydock</td>
<td>Green Diamond slag</td>
<td>50 ft from source</td>
<td>TSP</td>
<td>1 to 6.5 million particles per ft(^3)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Sand usage 700 lb/hr/blaster (no exact throughput available)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Green Diamond slag</td>
<td>In vicinity of sand loader</td>
<td>TP</td>
<td>165 million particles per ft(^3)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Sand usage 700 lb/hr/blaster (no exact throughput available)</td>
</tr>
</tbody>
</table>

\(^a\)TP = Total particulate matter.  
\(^b\)RP = Respirable particulate matter (<3.5 μm) as determined using a 10 mm nylon cyclone followed by a 37 mm filter cassette.  
TSP = Total suspended particulate (<30-50 μm) as determined by a high volume air sampler.  
N/A = Not available or not applicable.
data indicates that follow-up testing is necessary to assess PM-10 emissions in the shipbuilding and ship repair industry. The remaining discussion focuses on the quality of the reported data.

The first three data sets were evaluated using the criteria and rating system developed by EPA's Office of Air Quality Planning and Standards (OAQPS) for developing AP-42 emission factors. The source of the fourth data set's evaluation criteria is undetermined at this time.

Using the EPA system, the test data sets were rated based on the following standards:

1. **A**--Tests performed by a sound methodology and reported in enough detail for adequate validation. These tests are not necessarily EPA reference method tests, although such reference methods were used as a guide;

2. **B**--Tests that are performed by a generally sound methodology but lack enough detail for adequate validation;

3. **C**--Tests that are based on an untested or new methodology or that lack a significant amount of background data; and

4. **D**--Tests that are based on a generally unacceptable method but may provide an order-of-magnitude value for the source.

An A-rated test may be a source test, results of personnel sampling or ambient monitoring, or some other methodology, as long as it is generally accepted as a sound method.

In those cases where emission factors were presented in the reference document, the reliability of these emission factors was indicated by an overall rating ranging from A (excellent) to E (unacceptable). These ratings took into account the type and amount of data from which the factors were derived, as follows:

1. **A**--Excellent. Developed only from A-rated test data taken from many randomly chosen operations in the industry population. The source category is specific enough to minimize variability within the source category population;
2. B--Above average. Developed only from A-rated test data from a reasonable number of operations. Although no specific bias is evident, it is not clear if the operations tested represented a random sample of the industry. As in the A rating, the source category is specific enough to minimize variability within the source category population;

3. C--Average. Developed from A- and B-rated test data from a reasonable number of operations. Although no specific bias is evident, it is not clear if the operations tested represent a random sample of the industry. As in the A rating, the source category is specific enough to minimize variability within the source category population;

4. D--Below average. Developed only from A- and B-rated test data from a small number of operations; there may be reason to suspect that these operations do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of the emission factor were footnoted; and

5. E--Unacceptable. Developed from C- and D-rated test data; there may be reason to suspect that the operations tested do not represent a random sample of the industry. There may be evidence of variability within the source category population. Limitations on the use of these factors were footnoted.

Based on the criteria and rating system developed by OAQPS, both sets of emission factors reported in Table 3 were below average in quality and thus given a D rating.²

6.0 CONTROL TECHNIQUES

A variety of techniques have been used to contain and recover the debris generated during abrasive cleaning operations and to reduce particulate matter emissions. These techniques may be categorized into the following: blast enclosures and drydock covers, vacuum blasters, water curtains, wet blasters, centrifugal blasters, improved abrasives, underwater cleaning, and chemical cleaners. Brief descriptions of each are provided below.
6.1 BLAST ENCLOSURES AND DRYDOCK COVERS

Blast enclosures are designed to completely enclose one or more abrasive blast operators, thereby confining the blast debris. The enclosure floor is usually equipped with funnels to divert the captured debris into adjacent trucks. In one design, a ventilation system removes the airborne dust from the enclosure by using a wet scrubber to remove the particles from the effluent airstream air. The enclosures are moved as the work progresses.

Blast enclosures can be very effective in containing and recovering abrasive blast debris. However, they are specifically designed for a particular application, are relatively expensive, and tend to slow down the overall cleaning rate due to the time required to move the enclosure as the work progresses.

Some leakage of abrasive and paint debris can also occur at the joints between the blast enclosure and the structure being cleaned. Although attempts have been made to seal the joints with canvas, this is usually not very effective, particularly when the blast is directed into these areas. A better method to minimize leakage from enclosure joints is to fasten a flexible seal made of rubber, plastic, or thin metal to the inside edges of the enclosure walls. The end of the flexible seal rests on the structure being cleaned, thus reducing the escape of airborne dust.

Several schemes that use some form of drydock cover have been evaluated by the Navy. Lean-to enclosures placed directly against the ship's hull, small portable enclosures, bellows-type attached to three-level roller staging, and canvas placed from the deck of the ship to the top of the graving or floating drydock offer the opportunity for some suppression of airborne particulates within the shipyard. Because of the additional time required to construct, move, and remove these enclosures (i.e., for hull preparation), Long Beach Naval Shipyard studies have concluded that this approach is clumsy and costly. Tents placed around the blasting operation also offer some dust
control, but the Navy considers these to be uneconomical because of the investment and handling costs and lack of durability.

Puget Sound Naval Shipyard completely roofs the drydock during abrasive blasting of submarines with apparently complete containment of blast particulates. Because the submarine stands below the top of the drydock, roofing is simplified. However, for surface ships the Navy believes that a complete cover may be an impractical approach. An alternative approach under consideration for development by the Navy is encapsulation by air-supported, bubble-like structures, which may also work for bigger ships.4

6.2 VACUUM BLASTERS

Vacuum blasters are designed to remove paint and other surface coatings by abrasive blasting and simultaneously collect and recover the spent abrasive and paint debris with a capture and collection system surrounding the blast nozzle (Figure 5).7 In this type of system, the abrasive is automatically reclaimed and reused as work progresses. Vacuum blasters are made in a variety of sizes, but even the smaller units are comparatively heavy and awkward to use.2 Boston Naval Shipyard has been using a vacuum unit capable of picking up abrasive grit, wet sand, or slurry.4 The vacuum unit is equipped with a moisturizer to trap dust from dry debris after collection.

6.3 WATER CURTAINS

In this technique, a water header with a series of nozzles is installed along the edges of the structure being blasted. The water spray from the nozzles is directed downward, creating a water curtain to collect debris from abrasive blasting performed below the header, which is subsequently washed down to the ground.12 This technique is relatively inexpensive and does reduce the amount of airborne dust. However, one disadvantage is that the debris-laden water spills onto the ground, creating additional contamination and clean-up problems.

One method used to solve the spillage problem associated with water curtains involves placing troughs under the spray
Figure 5. Schematic of vacuum blaster head.

Source: Reference 2.
pattern to catch the water/abrasive mixture and divert it to an appropriate container (e.g., tank truck) for disposal. For low structures, the troughs can be placed on the ground. For high structures, the troughs can be supported from the structure itself.

6.4 WET BLASTING

Wet blasting techniques include wet abrasive blasting and high-pressure water blasting. The type of wet blasting method used depends on the application.

Wet abrasive blasting is accomplished by adding water to conventional abrasive blasting nozzles as shown in Figure 6. High-pressure water blast systems include an engine-driven, high-pressure pump, a high-pressure hose, and a gun equipped with a spray nozzle. If abrasives are introduced to this type of system, high-pressure water and abrasive blasting is provided. Finally, in air and water abrasive blasting systems, each of the three materials can be varied over a wide range, making three systems very versatile. As compared to dry blasting, all wet blasting techniques produce substantially lower dust emissions.

While wet or slurry blasting eliminates much of the fugitive airborne emissions, it leaves a more difficult debris to clean up satisfactorily, which raises the risk of water pollution during drydock floating. Because wet blasting requires the use of rust inhibitors and sometimes antifreeze additives to prevent freezing in cold weather, the extent of water pollution is increased when wet blasting debris is discharged into adjacent waters.

Most wet abrasive blasters mix the water with the abrasive prior to impact on the surface. This interaction can cause the rate of surface cleaning to be lower than with dry abrasive blasting. Other disadvantages include the need for touch-up abrasive steps and the need to include rust inhibitors and in some cases antifreeze solutions in the slurry. Wet abrasive blasting evaluated at Long Beach Naval Shipyard resulted in a 100 percent increase in the docking period normally allotted for an aluminum hulled ship. Similar results were achieved at Mare
Figure 6. Nozzle for air abrasive wet blast.

Source: Reference 2.
Island with productive rates reduced 50 to 75 percent. Experiments at Charleston Naval Shipyard indicated that wet blasting reduces suspended particulate matter by a factor of two.4

A retrofit device (designed to minimize premixing of the water with the abrasive blast) has been developed to fit over the end of conventional abrasive blast nozzles. This device is shown in Figure 7.12 The two principal parts of the device are a swirl chamber and an exit nozzle. The swirl chamber is equipped with a tangential water inlet. The incoming water swirls around the inside of the chamber and then out the exit nozzle. Centrifugal force causes the water to form a hollow cone pattern around the abrasive blast stream. The angle of the water cone is controlled principally by the shape of the exit nozzle and centrifugal forces.

This device is expected to be an improvement over traditional wet abrasive blasting. The modified water nozzle design provides a water curtain around the abrasive/airstream. Thus, the cleaning effectiveness of the abrasive/airstream should not be substantially affected. The device is simple to install and operate with conventional abrasive blasting equipment.

Long Beach Naval Shipyard studies show that enveloping the abrasive blast streams with a cone of water reduced the particulate generation by about 80 percent. However, this method can cause a problem with removing the saturated abrasive from the drydock floor.4

High-pressure water blasting using a pressurized stream of water is a technique that was evaluated at Pearl Harbor Naval Shipyard but was not fully accepted because of its operational slowness, the fact that water promotes corrosion of bare metal, the requirement that a rust inhibitor be included in the jet stream (rust inhibitors may be pollutants), the high initial cost of equipment, and the fact that the operation will not blast to white metal. In Northern shipyards antifreeze additives would have to be added, and these additives may be water pollutants.
Figure 7. Water envelopment device for abrasive blast nozzle.

Source: Reference 2.
The advantage of high-pressure water blasting is that it reduces air pollution.4

6.5 CENTRIFUGAL BLASTERS

Centrifugal blasters use high-speed rotating blades to propel the abrasive against the surface to be cleaned. These blasters also retrieve and recycle the abrasive by using a capture and collection system that allows little abrasive or paint debris to escape. Present centrifugal blasters are designed primarily for large, flat, horizontal surfaces such as ship decks. Some have been designed for use on large vertical surfaces such as ship hulls and storage tanks.2 Closed-cycle blasting machines, portable and self-propelled, using recycled steel shot have been used by the Navy for blasting of ships’ hulls. These machines are a promising alternative to open dry blasting. They have certain advantages in that they minimize air pollution through the closed-cycle abrasive handling, they have a high cleaning rate, they contain debris, they use less abrasive because it is recycled, they have a low abrasive breakdown, and fewer crew members are required to operate them.

Disadvantages include the high initial equipment costs, the increased equipment maintenance, and the fact the steel abrasive must be kept dry. However, these devices appear to be a promising alternative to exterior preparation of the ships’ hulls.4

6.6 IMPROVED ABRASIVES

Sand pulverizes easily and generates environmental problems. For this reason, current practice is to avoid its use. There is an on-going study at all Naval shipyards to find better abrasives. Hunters Point Naval Shipyard has changed to commercial Green Diamond™ in order to reduce the dust problem; however, complete elimination of dust is improbable. The friability, or disintegration tendency, of abrasive grit can be selected to minimize particulate emissions and to make reclamation economical; however, friability must be traded off
with costs and effectiveness and with the hardness of the grit chosen to prevent metal surface damage.

6.7 UNDERWATER CLEANING

A relatively foul-free hull helps reduce significantly the amount of blasting required for repainting and also reduces air pollution problems. Underwater cleaning of a waterborne hull is normally carried out by mechanically brushing the marine growth from the hull surface, but it is only partially effective. This operation is not meant to remove paint. Although there is no air pollution involved, there is associated minor contamination of the berthing area waters with marine growth and some paint residues that may be removed in the process.

6.8 CHEMICAL CLEANERS

Chemical cleaning of ships' hulls is possible; however, the volatility and toxicity of paint-stripping chemicals raise concerns about health and flammability. In addition, waste disposal is difficult. Chemical cleaning techniques are highly impractical because of handling problems, vapor emission, water contamination, and structural damage. Chemical stripping vinyl coatings with chlorinated hydrocarbon solvents introduces these potentially harmful solvents and polymers into the environment. Usually this type of chemical stripping must be followed by some form of abrasive blasting. Also, chemical stripping does not materially solve the corrosion removal problem, and abrasive blasting would still be required to adequately clean the metal surfaces.

7.0 CALIFORNIA'S OUTDOOR ABRASIVE BLASTING REGULATIONS

The most stringent abrasive blasting regulation adopted to date in the U.S. is in the State of California. The last major revision to the regulation was made in November 1990. A summary of the regulation guidelines is provided in Figure 8.

The regulation states that abrasive blasting can be conducted either inside or outside of a permanent building. Indoor abrasive blasting must meet a Ringelmann 1 (20 percent opacity) visibility emission standard, regardless of the abrasive
Figure 8. California’s blasting regulation.

Source: Reference 3.
or the abrasive blasting method used. All outdoor abrasive blasting is required to meet a Ringelman 2 (40 percent opacity) visibility emission standard. To conduct abrasive blasting outside, (1) steel or iron shot/grit must be used exclusively, (2) the blasting item must exceed 8 feet in any dimension, or (3) the item being blasted must be at, or close to its permanent location. If Options 2 and 3 are met, then wet abrasive blasting, hydroblasting, vacuum blasting, or dry blasting with a certified abrasive must be used. According to the regulation, abrasives are certified biannually and have a "cut-point for fineness" criterion. Abrasives are certified to restrict the types of abrasives used in dry unconfined blasting for the purpose of reducing the amount of fine particles generated. The "cut-point for fineness" criterion allows abrasives to be reused only when they can be reconditioned to their original cut-point for fineness. The outdoor blasting regulations were based on data collected during abrasive blasting of buildings and it is not known whether such regulations are applicable to the blasting of ships.

8.0 CONCLUSIONS AND RECOMMENDATIONS

A very limited amount of information was found on PM-10 emissions and control methods in the shipbuilding and ship repair industry. Insufficient data were available to relate PM-10 emissions to the abrasive-blasting practices of ships. Also, one of the key references for this report is almost 20 years old but few developments have occurred since this time. To supplement and update the information gathered, additional information needs to be obtained from other State agencies and Navy personnel, and commercial shipyards through site visits and telephone contacts. Also, testing for PM-10 from outdoor abrasive blasting of ships needs to be conducted. Non-confidential information from these sources will be used to revise this report.

Several schemes have been evaluated to control fugitive particulate emissions from this industry. The most promising
approaches are: (1) using some form of drydock cover either placed against the ship's hull or placed from the deck of ship to the top of the drydock to suppress airborne particulates within the shipyard; (2) wet abrasive blasting with a retrofit device (designed to minimize premixing of the water with the abrasive blast) that fits over the end of conventional abrasive blast nozzles; (3) using centrifugal blast cleaners designed specifically for use on ship hulls; and (4) using abrasives that can reduce the formation of particulate matter emissions. Although each of these options has some drawbacks, these options are considered to be the most feasible technologies at this time for controlling PM-10 emissions in the shipbuilding and ship repair industry.

9.0 REFERENCES


Ms. Laurel Driver  
U. S. ENVIRONMENTAL PROTECTION AGENCY  
411 Chappel Hill St.  
Durham, NC 27701

Dear Ms. Driver:

I enjoyed the chance to talk with you this afternoon, and I’d be most happy to assist in any way possible as the EPA develops the guidelines we discussed. While I have to keep my company’s economic interest in mind, I think I can also take a more universal view of some of the problems and be of real help to you.

Enclosed are the Navy specification and some of our technical data sheets. "GMA Garnet" is a trade name for an Australian almandite garnet we import to the states. It is noted for very low dusting levels and for low consumption rates. As I said on the phone, it is in our interest to see that varying levels of quality are recognized in any new guidelines.

The problems facing U.S. shipyards are not unique. Pollution control and elimination of noxious dust are common goals in our foreign markets as well as here at home. We look forward to discussing these complex issues with you and with your contractor at any time.

Please give me a call if you have any questions on the enclosures.

Yours very truly,  
BARTON MINES CORPORATION  
[Signature]

James D. Hansink  
General Manager

cc: Mr. J. L. Nash; President; Barton Mines Corporation
October 28, 1991

To: Attendees: The American Waterways Shipyard Conference  
October 23, 1991; Pecido Beach, Alabama

From: J. D. Hansink; Barton Mines Corporation  
1658 Cole Blvd.  
Golden, CO. 80401  (303) 233-1145

Dear AWO Attendees:

I would like to personally thank all of you and the people from the AWO for the opportunity to share some of my thoughts and ideas concerning blast cleaning and environmental challenges at the recent conference in Alabama. No single event or meeting will clarify these issues for American industry, yet we are faced with growing internal and external competitive pressures that dictate rapid and flexible response to this changing environment.

Reproduced below and on the following exhibits is a summary of my comments. If you have any questions, suggestions, or comments, I would be glad to hear from you. I firmly believe that our domestic ship building and repair industry can be competitive with its foreign counterparts. To do so will require the use of innovative tools and techniques, and the application of the best in modern management methods and tools.

It is much too late to look at the trees.... We have now to focus on the forest and to solve the larger problems of competitive performance in a complex and changing and challenging global environment. We at Barton Mines hope we can help you meet these challenges.

Yours very truly,

James D. Hansink
BARTON MINES CORPORATION
1. Notes on Federal Regulation

Five key federal regulatory acts or laws affect the small business concern.

State and local regulations may be more strict than the federal statutes. Be Aware. Get good information and use it.

2. Slides

<table>
<thead>
<tr>
<th>Abrasive</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica Sand</td>
<td>2.5 m t/yr.</td>
</tr>
<tr>
<td>Coal Slag</td>
<td>1.0</td>
</tr>
<tr>
<td>Smelter slag</td>
<td>.5</td>
</tr>
<tr>
<td>Other</td>
<td>.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>4.5 m t/yr</td>
</tr>
</tbody>
</table>

About 4 million tons of abrasives are used domestically every year. Most of it is sand or slag, and much of it is defined as a "hazardous" waste upon disposal because of paint contamination or because of the chemical nature of the abrasive itself. The user has choices that can reduce or eliminate environmental risk and cost.

**Blasting costs - $/ton** (and other American myths)

- all blasting media are the same
- all handling costs are the same
- all media create the same levels of dust
- all media are equally costly upon disposal
- SOME REINDEER CAN FLY

The reliance on $/ton is a short-sighted and dangerous method of measuring the cost of abrasives for blast cleaning. The cost of abrasives, while easy to measure, may be an insignificant part of the total cost. The user should take a close look at all of the issues.

**Waste Management Disposal**

"fixed" costs include - sampling, analysis, handling, storage, insurance, supervision, etc.
"variable" cost is the cost per ton for commercial disposal.
Full Cost = material + labor + equipment + other production

\[ \frac{(AxB)}{X} + C + D + E \]

A = $/ton for delivered abrasive
B = tons/hr consumed per nozzle
C = labor cost plus fringes per hour/nozzle
D = equipment cost per hour per nozzle
X = productivity, Sq. Ft./Hr./Nozzle
E = Any other identifiable cost such as dust control or disposal, expressed as $/sq.ft.

Blasting costs generally run from $1.00 to $1.50/sq.ft. The cost of the abrasive (A) is only a small part of the equation.

OSHA Compliance

Environmental compliance implies compliance with health and safety requirements - OSHA! Chances are, if it is an environmental hazard, it is also an industrial hygiene problem.
Silica sands and mineral slags contain elements identified by OSHA as hazardous. The graph show the relationship of arsenic and lead (two regulated elements out of 423 listed in the federal regulations). Slags high in arsenic and lead used at Puget Sound Naval Shipyard exceeded the exposure limits for these metals at low levels of dusting (between 1 and 10 mg/m³ of contained dust.)

At common dust levels of 200 g/m³, most limits are exceeded.
The user has several choices in abrasives:


Slag Abrasives - Common substitutes for silica sand. Slags contain varying levels of trace metals (arsenic, lead, beryllium, etc.) and radiation. Dust in use creates a separate set of risks and potential liabilities. Serious OSHA fines recently levied for violation of Personnel Exposure Levels for contained metals.

Mineral Abrasives - Non-silica minerals (garnet, olivine, and staurolite) that are often used as safer and more environmentally acceptable media in standard blasting and with recycling systems. Higher cost is usually off-set by other advantages.

Manufactured abrasives (steel shot and grit) - These materials are often used in conjunction with mechanical systems that allow multiple use and cleaning on the media. In the marine environment care must be taken to assure that the media is kept dry and thoroughly cleaned between cycles. The advantage lies in the reduction in wastes to be disposed of.

SUMMARY:

The user of modern abrasives is offered a wide choice of tools to accomplish his task. Regulations make more complex the old simple decisions about selection of the "cheapest" abrasive. The penalties for incorrect or inappropriate decisions far outweigh the cost of the blast media. Today, users must evaluate the entire process, incorporating the evaluation of air quality, water and land pollution, and worker safety into their purchase decision.

The cost of failure can be catastrophic.
NOTES ON FEDERAL REGULATIONS

- WATER POLLUTION CONTROL ACT
  as amended by the CLEAN WATER ACT OF 1987 - CWA 40CFR
  ...
  to eliminate pollution of navigable waters
  ...
  creates standards, test procedures, pretreatment regulations, and effluent guidelines.
  ...
  includes bio-toxicity tests in some states
  ...
  regulates storm run-off permits.

- RESOURCE CONSERVATION AND RECOVERY ACT - 1980/84 40CFR "RCRA"
  Cradle to Grave program to protect human health and the environment from the improper management of Hazardous Waste.
  Identify and list haz. wastes. Set Stds for:
  Generator definition
  transport regulations
  treatment and disposal
  land disposal restrictions
  permit requirements
  Goal is to eliminate all land disposal of hazardous wastes
  Operator must:
  Identify waste streams and establish his size status
  Store wastes less than 90 days
  Develop a management plan; ie. training, logs, etc.
  File EPA reports
  Has numerous amendments: ie. solvents, "Land Ban", Calif.
  List, waste water treatment of sludge. May '90 - 3/3

- CLEAN AIR ACT - AMENDED 1990
  Sets standards of 6 critical pollutants including lead
  States must file "SIP's", many of which go beyond EPA
  Covers VOC's, smoke, smog, etc. - Issue of Boiler slag

- COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION & LIABILITY ACT
  CERCLA = "Superfund"
  Addresses past problems and legal or financial liabilities
  Requires operators to list and notify states of haz. Mat.
  in use, and to report spills.

- OCCUPATIONAL SAFETY AND HEALTH ACT - OSHA 29CFR 1900......
  Requirements for safety in the workplace
  Sets legal standards in numerous areas: ie.
  Hazardous communication - 29CFR1910.1200 MSDS's/plan
  Respiratory protection - 29CFR1910.134
  Noise exposure - 29CFR1910.95(c)
  Air contaminants - 29CFR1910.Part(%)silica/metals
  OTHERS
Determining Exposure Levels During Blasting
By James Hansink,
Barton Mines

The growing awareness of the health and financial risk associated with the removal of lead-based paints and the growing number of citations issued for violation of metal exposure while blasting with mineral slag abrasives point to the need for a clear understanding of the regulations and how exposures are determined. This Maintenance Tip addresses both issues.

The Role of OSHA
The U.S. Department of Labor, through the Occupational Safety and Health Administration (OSHA), is responsible for the enforcement of safety regulations in the workplace. OSHA enforces regulations limiting the exposure of the work force to a large number of chemicals and elements. These limits and associated administrative requirements (e.g., medical surveillance, training programs, wash room facilities, record keeping, etc.) are detailed in the Department of Labor Code of Regulations 29 CFR 1910 for General Industry and 29 CFR 1926 for the Construction Industry.

It is incumbent on all industrial contractors and plant owners to be well-informed about these regulations and how they might affect operations.

In the area of worker exposure to lead, the standard for general industry is more strict than the Construction Industry Standard—at least for the present. The General Industry Standard is expected to be the model for a new Construction Industry Standard on lead (see May 1991 JPCL, p. 24). Therefore, this article will address the general industry requirements.

The section of the Code of interest here is CFR 1910.1000 (and 1018 and 1025, which apply to arsenic and lead, respectively). In a series of tables, this section lays out the allowable exposure levels for over 400 substances. Table 1 shows the exposure limits of a few substances of interest to those involved in blast cleaning. A blast cleaning operation that exceeds the metal levels in Table 1 could be judged to be in violation of OSHA standards if proper protective and administrative programs are not in place.

continued

\[
M = \frac{m \times D \times 1,000 \text{ micrograms (ug)}}{100 \text{ milligram (mg)}}
\]

Note: 1 milligram = 1,000 micrograms

where:
- \( M \) = the amount of metal present in the air, in micrograms/cubic meter, the basis on which OSHA standards are applied
- \( m \) = the amount of metal present in the abrasive media, expressed as a percent
- \( D \) = the amount of dust present in the work area, a number obtained by air sample monitoring. Levels depend on abrasive type, number of nozzles in use, ventilation, etc.

examples of dust levels are:
- <1 mg/cu m fresh air
- 15 mg/cu m OSHA nuisance dust level
- 30-50 mg/cu m typical blasting
- 300 mg/cu m very dusty blasting

Fig. 1
Proposed formula for calculating lead dust
Maintenance Tips

Operator Responsibility

The fundamental responsibility of the operator is to protect worker health. This requires controlling dust and establishing other work practices to assure that worker exposures are kept below the OSHA limits or to provide respiratory protection and other support programs. What is needed then is a mechanism to assess the risk of violation prior to blasting.

In the removal of lead-based coatings, the probability of creating high levels of lead in the air is high enough that the need for special protective measures can be assumed. Exposure risks brought about by the chemical nature of the coating being removed are beyond the scope of this Maintenance Tip, and operators are advised to design their programs with the nature of the coating in mind.

When mineral/slag abrasives (such as smelter slag) that carry varying amounts of trace metals are to be used, an initial estimate of the potential risk should be made. For this assessment to be made, the following information is needed:

- nature of the surface to be blasted (i.e., if lead-based paint is present, special precautions will be required);
- chemical composition of the abrasive to be employed; and

continued
likely levels of dust to be generated. (See Note on Dust Levels at the end of this Maintenance Tip.)

With this information in hand, it is possible to estimate the amount of airborne metal or other contaminants that will be present when the blast cleaning operation begins.

Abrasive suppliers should be able to provide accurate measurements of the amount of metals in their products. This information is normally a standard part of the material safety data sheet (MSDS) supplied with the media.

Next, a simple mathematical model must be developed that relates dust levels in the workplace and the amount of metal (or other substance of interest) present in the dust. This formula will assume that all metals present in the dust during blasting will be generated by the breakdown of the abrasive media. This assumption is valid for most metals and other substances of concern. Metals that may be present in the coating system (e.g., lead or tin) will be additive to the results obtained and should be taken into account when planning the project. The formula in Fig. 1 is proposed for calculating metallic dust.

Figure 2 gives an example of how the model might work in practice. A project will employ a slag media with 40 parts per million (ppm) arsenic and 6,000 ppm lead. Ventilation will be excellent, and dust levels should not be higher than 15 mg/m³. Should the contractor expect a possible OSHA compliance problem, based only on the blasting abrasive? As Fig. 2 indicates, there may be cause for concern.

Figure 3 uses the formula to summarize the situation and may be used to estimate the "risk" of exceeding various limits if the metal content is known. The vertical axis shows the amount of metal present in the air and ranges from zero to 50 micrograms. The axis could be extended to higher levels.

The horizontal axis shows dust levels ranging from zero to over 60 milligrams/m³ of air. Also shown are the "limits" for arsenic and lead and the nuisance dust level. Limits for other substances can be plotted as needed.

The graph in Fig. 3 also shows data plots for 5 levels of metal content (0.0001 percent to 0.50 percent) in the blast media. Not surprisingly, media with higher metal content, such as 0.50 percent, will hit a "limit" at much lower dust levels than will media with lower metal content. Note, however, that all abrasives will ultimately lead to a violation if dust levels are allowed to build to very high levels.

As regulations tighten and as enforcement procedures are broadened, both the contractor and the owner need to be aware of the possible risks. Each needs to consider the true cost of material selection for abrasive blast cleaning, the cost of implementing required engineering control measures, and the requirements for administrative procedures.

Note on Dust Levels
Estimates of the expected level of dust generation may be derived from prior

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Manager

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To learn what, contact your local Hubbell Safety Products Representative.
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**Maintenance Tips**

continued

<table>
<thead>
<tr>
<th>General Industry Exposure Limits for Heavy Metals and Other</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Table 1: Substances in Air</strong></td>
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<tr>
<td>Substance</td>
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<td>-----------</td>
</tr>
<tr>
<td>Arsenic</td>
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<tr>
<td>Beryllium</td>
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<tr>
<td>Chromium</td>
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<tr>
<td>Copper</td>
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<tr>
<td>Lead</td>
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<tr>
<td>Nickel</td>
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<tr>
<td>Tin (organic)</td>
</tr>
<tr>
<td>Uranium (insoluble)</td>
</tr>
<tr>
<td>Zinc oxide (fume)</td>
</tr>
<tr>
<td>Fibrous minerals</td>
</tr>
<tr>
<td>Nuisance dust</td>
</tr>
</tbody>
</table>

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experience, measurement, published data from similar projects, or merely conservative assumption. Care must be taken to differentiate between total and respirable dust. Many high volume air samplers do not make this distinction. Most regulations will be applied based on the total amount of dust present.

Respirable dust (less than 5 microns) in the workplace generally makes up about 30 percent of the total dust loading.

Table 1 is based on data published by Samimi et al. in the Archives of Environmental Health, August 1974.
assignment as plant manager for the Ervin Product Development Center in Tecumseh, MI. The facility was recently completed and will provide technical support to the AMASTEEL Division. Bates has been with the company for 22 years.

Jim Lemon has been promoted to plant manager of the Adrian, MI AMASTEEL plant. He has been in the company’s manufacturing division for 14 years and replaces Ralph Wurster, who retired after 39 years of service.

Dean Davies has joined the Division’s sales department. For the past 16 years, he has worked in manufacturing at the Adrian plant. With his new assignment, he will be located at the company headquarters.

Ervin Industries is a Patron Member of SSPC.

Diablo Group Merges with Nies Eggert Waterproofing

The Diablo Group, Inc. is now doing business under the name of Nies Eggert Waterproofing Co., Inc. The name change was effective January 1, 1992. All assets and liabilities of Diablo Group have been merged with Nies Eggert Waterproofing. All warranties issued under Diablo Group will be honored by Nies Eggert Waterproofing, the company says.

Nies Eggert Waterproofing is a union shop specializing in masonry restoration, sealants and waterproofing, firestopping, epoxy injection, and concrete restoration. Diablo Group specialized in seamless flooring, chemical-resistant floorings and linings, tank linings, epoxy injection, and concrete restoration.

The staff and work force of both companies have been retained.

CHMR Schedules Courses for 1992

The Center for Hazardous Materials Research (CHMR; Pittsburgh, PA) has announced several occupational safety and health courses to be held in the following months.

The names and dates of the courses follow.

- "8-Hour Environmental Air Monitoring Devices": May 19, July 21, and October 12
- "8-Hour Environmental Air Sampling": May 20, July 22, and October 13
- "16-Hour Environmental Field Sampling": May 21-22, July 23-24, and October 14-15
- "8-Hour Confined Space Entry": April 20, June 25, August 18, October 26, and December 16

Courses can be conducted in-house or at CHMR’s training facility, which features simulations of actual emergency and industrial scenarios. The courses are said to meet or continued
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This Month’s Question:
Some states are beginning to specify the use of recycled steel abrasives for lead paint removal projects. What are the advantages and disadvantages of this approach?

From David H. Dorrow, Reed Minerals, a Division of Harsco Corporation, Highland, IN:

With changes in regulations and advances in technology affecting the surface preparation and painting industries, no one can claim to know the best way of abrasive blasting, whether it be with recyclable steel abrasives or disposable abrasives.

If states specify the use of recyclable steel abrasives only, it will impede the industry’s progression toward other viable, economical, and environmentally safe methods of surface preparation.

There are several advantages and disadvantages of using either recyclable steel abrasives or disposable abrasives. One must consider the functional, economical, and environmental impacts. However, there are many unanswered questions regarding the use of recyclable steel abrasives to remove lead-based paints because of the experimental technologies employed and the lack of sufficient data to emphatically claim that this method is “the best.”

In recent years, interest has focused on surface contaminants, such as chlorides, sulfates, oil, and grease, and the detrimental effects they may have on paint systems if not properly removed from the surface. Limits have been set in recent abrasive specifications to ensure that these contaminants are not present on the virgin abrasives. On bridge jobs where the states specify recyclable steel abrasives, these contaminants are present in varying degrees from de-icing salts, heavy traffic, and the surrounding environment. It is questionable whether these contaminants can be cleaned from the recycled steel abrasives with the current technology in abrasive “cleaning stations” or whether they are reintroduced onto the surface as the product is reused. It is my understanding that the manufacturers of current steel abrasive recycling equipment cannot guarantee that they can remove all the hazardous lead from the recycled steel abrasives. This creates unanswered questions with regard to worker safety. With disposable abrasives, this question does not need to be addressed because they are used only once.

The economics of using recycled steel abrasives versus disposable abrasives has been debated for years. There is a large initial capital expenditure required that may limit the number of contractors capable of bidding with only recyclable steel abrasives. Economic considerations include the cost for equipment that removes moisture from the air to prevent steel abrasives from rusting and clumping, which renders them unusable.

States that specify only recyclable steel abrasives limit competitive bidding, and this may not be the most economical means of doing a project. The contractor should be allowed to decide which method of surface preparation is the most economical way to blast clean a surface.

Another important issue is the protection of the workers. In particular, does one product result in more lead exposure than another, or is there a reduction in lead exposure by using one product versus another? The present information suggests that there are not enough data to answer this question. The SSPC should request funding for testing to provide information whereby logical, constructive decisions can be made. Contractors and owners are charged with the responsibility of protecting their workers and the environment. Contractors recognize these responsibilities and willfully use the best available technology to economically meet these requirements.

Using recyclable steel abrasives may reduce hazardous waste; however, there are also new technological advances in treating disposable abrasives to render them non-hazardous. Some products can be added to the abrasives prior to blasting and are claimed to eliminate the problems associated with hazardous waste disposal.

By using disposable coal slag abrasives, contractors are not adding waste to landfills. Coal slag abrasives are a by-product of the electric power industry, which are already destined for a landfill. By using these abrasive products, contractors are actually recycling a waste product and creating a beneficial use for it in the blasting industry.

In answering this question, I have generated several more unanswered questions. Recyclable and disposable abrasives are viable options. When states specify one method over another...
exclusively, they eliminate any opportunity for the contractor and the state to realize that there may be viable alternatives when considering all functional, economic, and environmental impacts.

This is not the time to shut down the marketplace but rather to open it up for investment in technology. No one can predict the outcome of a free market and technological innovation, but we can all predict failure or exceptional cost when the marketplace is not allowed to be open. To say that new methods, products, or technologies are experimental is a valid and important statement because the entire premise of capitalism, product development, and future benefit is derived from this free market environment.

There are numerous products today that show promise; however, it would be a disservice to predict their future. The specification for abrasives, without question, will eventually turn to issues of economy, safety, and performance.

In summary, my company feels that there are advantages and disadvantages to recyclable steel abrasives and disposable abrasives. Neither type of abrasive should be eliminated through specifications to allow the marketplace to remain open to competitive material and methods.

From H. William Hitzrot, Chesapeake Specialty Products, Baltimore, MD:

Blast cleaning a steel bridge surface requires an abrasive particle and a means to propel that particle with sufficient force to effectively “blast off” the surface contaminant. Over the years, many abrasive media and methods of propulsion have been tried with varying degrees of success.

However, one abrasive medium, steel abrasive, has proved to be the most consistent, efficient, and environmentally sound cleaning medium at a reasonable cost.

These key aspects of efficiency and cost-effectiveness are what make steel the preferred abrasive medium for lead paint removal, and they have resulted in states specifying steel abrasive. The following outlines some of the major advantages that have made steel the preferred abrasive.

- High density: Steel abrasives are 2 to 3 times more dense than sand, slag, garnet, or other mineral-type abrasives. Higher density means that each particle has more kinetic energy or impact energy than comparable mineral-type abrasives. More energy means more cleaning power. High density is also important when recycling. The heavy steel particles fall through an air wash while dust and fine paint chips are easily swept away, leaving a clean steel abrasive for recycling.

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**Problem Solving Forum**

continued

* Durability: Because steel abrasives do not break down on impact, steel can be recycled hundreds of times. This translates into major savings in disposal costs and material handling at the job site.

The recycling of steel abrasives also achieves the Environmental Protection Agency's (EPA) primary goal, waste minimization. A typical bridge job that may generate 3,000 tons (2,700 tonnes) of residual waste using garnet or coal slag would produce less than 30 tons (27 tonnes) of waste using steel.

* Non-dusting property: Steel abrasives break down very slowly—less than 1 lb (0.5 kg) per 100 sq ft (9 sq m) of blast-cleaned surface. This slow degradation means that little or no dust comes from the abrasive, and a better working environment is achieved for the blaster.

* No abrasive residue: Because steel abrasives do not break down on impact, they do not leave an abrasive residue on the blast-cleaned surface. Non-metallic abrasives leave a substantial amount of residue on the blasted surface, which can ultimately cause premature coating failure.

* Magnetic separation: Using magnetic separation makes it easy to separate the steel abrasive particles from the non-magnetic paint chips and trash. This is a simple way to achieve a paint chip-free recycled abrasive.

Because of the higher density of the steel, substantially finer steel abrasive particles will produce surface cleaning equal to that of a coarser, non-metallic abrasive. When a finer steel abrasive is used, more particles will hit the surface, resulting in better coverage and faster cleaning.

The durability of steel allows blasting at considerably higher nozzle pressures—up to 120 to 130 psi (830 to 900 kPa). Combining higher nozzle pressures with finer steel abrasives can produce a major improvement in blast cleaning production rates.

Steel abrasives are equally effective in removing paint and mill scale. Most mineral abrasives, however, are effective in removing coatings but are slow in removing mill scale.

Because most lead paint systems were applied over mill scale, steel abrasive will remove the paint and the mill scale quickly. Additionally, the steel abrasive will create a profile that is necessary for an effective bonding system.

Steel abrasive will rust if exposed to moisture for extended periods, which is perhaps steel's only disadvantage.

Steel, like any other abrasive product, must be kept dry to be an effective abrasive medium. Steel abrasives also require an effective recycling system to assure that a clean, dry abrasive product is being returned to the blast pot. The incremental investment re-
quired for steel abrasive recycling is not as significant as is claimed by the suppliers of competitive, non-metallic abrasive. Once the commitment is made to containment, which is required for any lead paint removal job, the capital cost of recycling is less than $200,000. This cost can be spread over several projects, making recycling cost very minimal on a cost per sq ft (sq m) basis.

If the blast cleaning industry is serious about meeting the EPA goal of waste minimization, then steel abrasive meets this goal better than any other abrasive product.

From Stavro N. Semanderes, Odyssey Contracting Corp., Houston, PA:

The only advantages of steel grit are that it does not break down easily and it can be recycled many times. These advantages, however, can be realized only in a shop operation and present no benefit in the field, where the abrasive may be lost in a few cycles in the collection scheme or from moisture exposure.

The claim that hazardous waste is minimized is not true because waste generated by other blasting abrasives can be rendered non-hazardous through treatment and disposed. The claim that steel grit produces less dust makes little sense because the use of negative air containment to protect people inside the containment has been proven to work well with other abrasives, such as slag. The benefit of having better visibility inside the containment is not germane. A blaster has to see only 4 to 5 ft (1 to 1.5 m) away from his face. This is achievable with negative air and slag abrasive.

Let us now look at the disadvantages of abrasive blasting with recycled steel grit. The root of the problem in using steel abrasives in the field is their specific gravity or weight. Because the steel grit weighs 3 times more than most other commonly used abrasives, it is very difficult to handle in the field. This difficulty translates into slower production, which increases performance time and costs. Presently, there are technological problems with most steel grit systems that cause higher lead exposure to workers. These problems will undoubtedly be solved with additional research and development, but the weight problem has no solution.

The history of sandblasting in the field shows that the industry started with small sandblast machines with typical capacities of 300 lbs to 600 lbs (135 kg to 270 kg) and then proceeded to build mobile units with capacities of 6 tons, 8 tons, and even 25 tons (5 tonnes, 7 tonnes, and 22.5 tonnes). The move to large mobile units was done to enhance efficiency.
and reduce costs. Now, for steel grit, the industry is going back to square one, working with low capacity equipment. The resulting higher costs and longer performance times could have been predicted by any history major, let alone an engineer or scientist. The weight of steel grit prohibits the manufacture of larger, more efficient mobile units. The largest mobile machine that can be made will hold steel grit equivalent to 8 tons (7 tonnes) of slag. Thus, blasters can never be as efficient as they can with lighter abrasives. Furthermore, the larger the structure to be blast cleaned, the more difficult blasting with recycled steel grit becomes because the blaster has to move further and higher and must handle the extra weight of the abrasive at every step of the operation.

Field experience confirms the increase of performance time. The Pennsylvania Department of Transportation has been trying to paint the Kinzua Bridge for the last 2 years, and only 70 percent of the job has been completed. The Kinzua Bridge is a deck truss that carries 2 lanes of traffic and has a total area of 400,000 sq ft (36,000 sq m). Similar production rates have been experienced on other jobs using steel grit in Louisiana. Conversely, using negative air and slag abrasives, one of our crews completed about 700,000 sq ft (63,000 sq m) of a four-lane bridge in one season. The bridge consisted of deck trusses and through trusses over a large river.

In conclusion, I would like to state that steel grit has no future in field operations, and specifiers should leave their projects open to other methods of surface preparation.

From Louis G. Lyras, Corcon, Inc., Lowellville, OH:

Environmental problems with landfills and the Environmental Protection Agency's (EPA) goals to reduce the production of waste have made conventional abrasive blasting of bridges costly and difficult at a time when our bridges are in great need of repair and rehabilitation. Abrasive blasting with recycled steel is a viable and cost-effective alternative to conventional blasting. But what are the advantages and disadvantages of this system? The most obvious and valuable advantage of using recycled steel abrasives is that it offers a way of greatly reducing large volumes of hazardous waste and still permits abrasive blasting to remove lead-contaminated coatings from bridges. This factor alone warrants specifying abrasive blasting with recyclable steel. Yet, there are many who often mention the disadvantages of abrasive

Continued
blasting with recycled steel. Perhaps it would be appropriate to counter these disadvantages in order to explain the advantages of abrasive blasting with recycled steel.

One so-called disadvantage is that abrasive blasting with recycled steel is an experimental method, and the machines are not reliable. All machines begin as experiments. However, abrasive blasting with recycled steel has been successfully used for decades in shop application. The enormous need to minimize abrasive blast waste propelled the development of machines for field applications.

Most of these recycling machines for field use have been developed within the last 5 years. Some work better than others, but, as we all know, complex machines can break down. Anyone who owns a car can attest to this fact. Abrasive blast recycling machines, which may vary in sophistication and function, are no different. As for reliability, the mobile classifying station used by my company was put in service in the spring of 1991 and worked through the painting season without a breakdown.

Another frequently mentioned disadvantage is the reintroduction of lead-laden chips and dust through the blast nozzle due to static charge adherence and faulty cleaning, which causes higher air-borne lead levels in containment structures. Abrasive blasting in a contained area with any abrasive—steel, sand, or mineral—increases the level of lead. But when steel abrasive is properly cleaned, there is no difference between recycling or conventional methods of abrasive blasting. Older, and some newer, machines have been guilty of reintroducing lead into the containment area due to over-simplified and ineffective cleaning methods. Certain new recycling machines, however, utilize more advanced methods to remove nearly all lead chips and dust from the recycled steel. The lead dust that adheres to the recycled steel by static charge proved to be more of a problem when discovered, but a process used by one manufacturer of recycling machines eliminates this problem, assuring cleaner recycled steel.

The issue of the lead “plating” to the recycled steel has been occasionally but inappropriately referred to as a disadvantage. The “plating” effect is a chemical property of lead and steel when subjected to the leaching test conditions used in laboratories to determine whether the waste will be classified as hazardous or non-hazardous prior to disposal. This effect has nothing to do with recycling machines and the classification of spent steel; hence, it is not a disadvantage to abrasive blasting with recycled steel.
Another so-called disadvantage is that painters are being contaminated with lead and exhibit elevated blood lead levels more often with recycled abrasive blasting than with conventional abrasive blasting. Painters have been contaminated with lead for as long as they have been using abrasive blasting, but 2 years ago, virtually no contractors were testing for blood lead levels. Now, with more and more painters being tested for blood lead levels, the extent of this contamination is revealed.

While older recycling machines had been ineffective in removing the lead from steel, new machines are far superior. However, the best ways to protect workers from lead exposure are to use reliable machines, to have a good understanding of containment enclosure and ventilation, and to maintain proper hygiene.

An often mentioned disadvantage of using recycled steel is that recyclable abrasive blasting is far more expensive than conventional blasting. In reality, abrasive blasting—recycled or conventional—is more expensive today than a few years ago. Whatever the system, abrasive blasting may require containment platforms, air draft fans, bag houses, and vacuum truck loaders. Recycled abrasive blasting merely requires the addition of a cleaning station or recycling blast unit. Initially, the cost of this equipment may be high, but just as there are differences between a paper mask filter and a good respirator, there are major differences in machines that can be used over and over again at no additional cost to contractor or owner. With good equipment, abrasive blasting with recycled steel is much less expensive than with non-recyclable abrasive when waste disposal is considered with the total cost.

Can special products be added to conventional abrasive blast residue to render the waste non-hazardous and less costly to dispose of, thus making recycling with steel abrasive disadvantageous? These additives have to be mixed uniformly and in proper amounts for all the blast waste to test as non-hazardous. Furthermore, the amount of lead in the containment still has not changed; therefore, workers still have to be protected. Additionally, in direct conflict with the Resource Conservation and Recovery Act, large volumes of blast waste are generated and must be disposed of. Do these additives bind with chromium and other heavy metals present in old paint? The questions of landfill acceptance of waste treated in this way and of potential liability arising from a chemical breakdown of this residue in the landfill have not yet been properly addressed. Either way, it is more advantageous to recycle.

It is obvious that there are no real disadvantages to abrasive blasting with recycled steel, but only small obstacles that can be solved and that have been solved. There are some very important advantages to recycled abrasive blasting other than the minimization of waste.

Recycled steel removes mill scale far better and faster than mineral abrasives because of the steel’s weight and density. Recycled steel can be reused many times more than any other abrasive medium. Recycled steel resists fracturing more than all other abrasives and does not easily become imbedded in the blasted surfaces. Finally, when abrasive blasting with recycled steel is specified, a strong economic incentive is introduced for proper containment.

Twenty years ago, our country was faced with the threat of oil shortages and pollution. American automobile manufacturers were challenged to build smaller, cleaner, fuel-efficient cars. Goals were established, and manufacturers complained that they were unrealistic and too costly. They resisted the change. Foreign manufacturers quickly adapted to global needs and produced cars that met and exceeded those goals. The rest is history.

Today in our industry, we have been challenged to rehabilitate our bridges and reduce waste. Abrasive blasting with recycled steel is the most advantageous method of surface preparation currently available when abrasive blasting is required. Still, as before, many are resisting the change. Let us confront the challenge and not repeat the past.
Problem Solving Forum
continued

Reader Response

On Measuring Coating Thickness over a Rough Surface
From Aivars Freidenfelds,
Elektro-Physik USA,
Arlington Heights, IL:

My response addresses the “Problem Solving Forum” question on determining the dry film thickness of thin-film primers applied to a roughened surface (April 1992). When conducting a coating thickness evaluation, one must be aware of the factors that can influence the values obtained. One such factor is surface roughness. Surface roughness is an important condition because it influences the measurement of coating thickness. The rougher the surface, the more the actual coating thickness will be exaggerated.

To understand the influence of surface roughness, one must consider the principle of magnetic induction. With magnetic induction, magnetic flux lines are generated from the tip of the coating thickness probe to the substrate. Typically, thickness gauges that operate on the magnetic induction principle require that a zero reference measurement be made. The purpose for this reference measurement is to establish the characteristics of the fluxlines to the substrate. Any change, then, in the length of the fluxlines is an indication of a barrier existing between the probe and the substrate. The barrier here is considered a coating.

Figure 1a illustrates a coated, smooth surface, while Fig. 1b shows a rough surface with what appears to be the same amount of coating. Note that the fluxlines in Fig. 1b are longer than those in Fig. 1a. Figure 2a depicts a reading on an uncoated surface. Figure 2b shows a reading on a coated surface. The length of the fluxlines
continued
Problem Solving Forum

continued

in Fig. 2b is longer because the substrate is coated.

Because the length of the fluxlines increases over a rough surface, the rough surface acts like a coating. Thus, the gauge registers a thickness value when no coating is present. When a coating is present over a rough surface, the gauge overstates the true thickness of the coating.

Fortunately, the influence of surface roughness can be offset in most cases by deriving a correction value. However, the correction value pertains only to a specific surface roughness. Any increase or decrease in the degree of surface roughness requires a new evaluation. Surface roughness is categorized: therefore, a correction value derived for a specific surface roughness can be used for subsequent applications where a comparable surface roughness is present. But it is always best not to assume. For the most reliable results, it is recommended that the evaluation of surface roughness and the computation of a correction value be made on each application.

The surface roughness correction value is derived using the formula in Fig. 3. The procedure for deriving the surface roughness correction value is as follows. First, the electronic thickness gauge must be calibrated according to the manufacturer’s instructions over an even surface with a shape and substrate composition identical to the roughened sample.

Second, the influence of surface roughness must be determined by measuring an uncoated area of the rough surface. It is important to remember that surface roughness acts like a coating even when no coating is present. This step determines the mean value of the influence of surface roughness (x₀) and then its standard deviation (S₀). At least 6 to 10 readings should be taken to develop the mean value.

Third, the mean value of the coating (Xₘ) must be determined. This value will include the influence of surface roughness. Again, 6 to 10 readings should be taken before computing the mean value.

Fourth, the measuring uncertainty of the gauge (Uₘ) should be determined. This value is usually stated in the operation instructions or can be obtained from the manufacturer. Some manufacturers of coating thickness gauges indicate the measuring uncertainty of the gauge in the form of a percentage range (e.g., 1 percent to 3 percent of the reading) and require the gauge to be calibrated following a specific procedure to obtain a certain degree of accuracy. If those instructions are not followed properly, the final analysis will not be correct.

Fifth, the values should be plugged into the equation to determine the true value of the coating thickness adjusted for surface roughness. An example of this calculation is shown in Fig. 4.

In this calculation, the average sur-
Problem Solving Forum
continued

Figure 4
Sample of a calculation to determine the true value of the coating thickness adjusted for surface roughness.

Figure 5
Equation for deriving the influence of surface roughness on coating thickness measurement.

\[
\bar{X}_o = 0.78 \text{ mils, } S_o = 0.28 \text{ mils,}
\]
\[
\bar{X}_m = 5.3 \text{ mils, } U_m = 3 \text{ percent}
\]
\[
X_{eff} = (X_m - X_o) \pm S_o \pm 3 \text{ percent}
\]
\[
X_{eff} = (5.5 \text{ mils} - 0.78 \text{ mils}) \pm 0.28 \text{ mils} \pm 3 \text{ percent}
\]
\[
X_{eff} = (4.72 \text{ mils}) \pm 0.28 \text{ mils} \pm 3 \text{ percent}
\]
\[
X_{eff} = (4.72 \text{ mils}) \pm 0.28 \text{ mils} \pm 0.16
\]
\[
X_{eff} = 4.72 \text{ mils} \pm 0.43 \text{ mils}
\]

\[
(\bar{X}_o) \pm S_o \pm U_m
\]
\[
= 0.78 \pm 0.28 \pm 3 \text{ percent}
\]

Surface roughness influence is found to be 0.78 mils (19.5 microns), and the standard deviation is 0.28 mils (7.5 microns). The average coating thickness, including the surface roughness, is 5.5 mils (137.5 microns). The gauge manufacturer states that the measuring uncertainty is \(\pm 3\) percent. Therefore, we can conclude that the true coating thickness is 4.72 mils (118 microns) + 0.43 mils (10.75 microns). The surface roughness, in this case, influenced the thickness value by 0.78 mils (19.5 microns) + 0.43 mils (10.75 microns). The actual influence of the surface roughness itself is 0.78 mils (19.5 microns) + 0.30 mils (7.5 microns), as derived from the equation in Fig. 5.

The surface roughness value is constant over comparable surfaces with the same degree of surface roughness. But this value is of little use without considering the thickness of the coating because the measuring uncertainty of the coating thickness gauge is an important element in determining the total error factor. Therefore, it is recommended that the procedure described earlier always be reconstructed to ensure the most accurate coating thickness assessment possible.

Finally, it was mentioned that surface roughness can be offset in most cases. However, when the surface roughness is extreme and the coating thickness is thin, the influence of surface roughness becomes unmanageable. For instance, in the earlier example, the mean surface roughness was 0.75 mils (18.75 microns). However, if the true coating thickness was known to be 0.29 mils (7.25 microns), the average measured value including the influence of the surface roughness would be 1.07 mils (26.75 microns).

A problem will be noticed when this value is plugged into the aforementioned equation because the result indicates that there is 0.58 mil (14.5 microns) to zero mil (0 microns) of coating present. When the value of the standard deviation of \(X_o\) is close to or equal to \(X_m - X_o\), the measuring uncertainty is so high that the measured result is questionable.
Particulate Emissions from Abrasive Blasting

<table>
<thead>
<tr>
<th>Source</th>
<th>Percent of Total is Particulate</th>
<th>Reference</th>
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</thead>
<tbody>
<tr>
<td>Repair, Blast Media</td>
<td>PM-10 = 4%</td>
<td>1</td>
</tr>
<tr>
<td>Repair, Paint</td>
<td>PM-10 = 10%</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>PM-10 = 16%</td>
<td>3</td>
</tr>
<tr>
<td>Construction, Blast Media</td>
<td>TSP = 8%</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>PM-10 = 4%</td>
<td>1</td>
</tr>
<tr>
<td>Construction, Paint</td>
<td>PM-10 = 10%</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>PM-10 = 16%</td>
<td>3</td>
</tr>
</tbody>
</table>

1. CARB
DATE: September 11, 1992

TO: Holly Reid
ESD/PAB/PIHS
U. S. Environmental Protection Agency
Research Triangle Park, N. C. 27711

FROM: Dave Reeves

RE: Shipbuilding and Ship Repair NESHAP
Estimated HAP Emissions from Abrasive Blasting and Paint (Solids) Overspray
EPA Contract 68-D1-0115: Work Assignment No. 38
ESD Project No. 91-53B; MRI Project No. 6500-38

The following summary table provides estimated annual worst-case HAP emissions from abrasive blasting operations and paint (solids) overspray. Additional details were provided in separate memos to Laurel Driver dated May 27, 1992 and June 26, 1992.

There are approximately 440 U.S. shipyards and it is estimated that 95 shipyards qualify as major sources. The two shipyards chosen for the HAP emission estimates rank in the top 10 in terms of both paint and abrasive media usage. NORSHIPCO and NASSCO were selected based on the different blast media (coal slag vs. copper slag) and wanting to present worst-case estimates.

Several assumptions were made in estimating HAP emissions from the various shipyard operations. We have tried to make conservative assumptions in each case in order that the combined annual estimated HAP emissions are truly worst-case for comparison with any de minimus values. If any additional explanation or clarification is needed, please give me or Laurel Driver a call.
Estimated Annual Combined HAP Emissions from Blast Media / Abraded Paint and Paint (Solids) Overspray

NORSHIPCO in Norfolk, Virginia used 7011 tons of (coal slag) abrasive media and 120,148 gallons of paint in 1990. HAP emissions were estimated as:

<table>
<thead>
<tr>
<th>HAP</th>
<th>Blast Media/ Abraded Paint</th>
<th>Paint (Solids) Overspray</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lb / yr</td>
<td>lb / yr</td>
<td>lb / yr</td>
</tr>
<tr>
<td>chromium VI</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>chromium III</td>
<td>29</td>
<td>1.1</td>
<td>30.1</td>
</tr>
<tr>
<td>lead</td>
<td>22</td>
<td>17.8*</td>
<td>39.8</td>
</tr>
<tr>
<td>antimony</td>
<td>70</td>
<td>-</td>
<td>70</td>
</tr>
<tr>
<td>arsenic</td>
<td>6</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>beryllium</td>
<td>7</td>
<td>-</td>
<td>7</td>
</tr>
<tr>
<td>cadmium</td>
<td>14</td>
<td>-</td>
<td>14</td>
</tr>
<tr>
<td>cobalt</td>
<td>14</td>
<td>-</td>
<td>14</td>
</tr>
<tr>
<td>mercury</td>
<td>0.1</td>
<td>-</td>
<td>0.1</td>
</tr>
<tr>
<td>nickel</td>
<td>14</td>
<td>-</td>
<td>14</td>
</tr>
<tr>
<td>selenium</td>
<td>0.6</td>
<td>-</td>
<td>0.6</td>
</tr>
<tr>
<td>other</td>
<td>6.3</td>
<td>-</td>
<td>6.3</td>
</tr>
<tr>
<td>TOTAL HAP's</td>
<td>184</td>
<td>18.9</td>
<td>203.9</td>
</tr>
</tbody>
</table>

NASSCO in San Diego, California used 2330 tons of (copper slag) abrasive media and 58,357 gallons of paint in 1990. HAP emissions were estimated as:

<table>
<thead>
<tr>
<th>HAP</th>
<th>Blast Media/ Abraded Paint</th>
<th>Paint (Solids) Overspray</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lb / yr</td>
<td>lb / yr</td>
<td>lb / yr</td>
</tr>
<tr>
<td>chromium VI</td>
<td>ND</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>chromium III</td>
<td>48</td>
<td>4</td>
<td>52</td>
</tr>
<tr>
<td>lead</td>
<td>18</td>
<td>63*</td>
<td>81</td>
</tr>
<tr>
<td>antimony</td>
<td>ND</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>arsenic</td>
<td>3</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>beryllium</td>
<td>ND</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>cadmium</td>
<td>ND</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>cobalt</td>
<td>14</td>
<td>-</td>
<td>14</td>
</tr>
<tr>
<td>mercury</td>
<td>7</td>
<td>-</td>
<td>7</td>
</tr>
<tr>
<td>nickel</td>
<td>4</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>selenium</td>
<td>ND</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>other</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TOTAL HAP's</td>
<td>94</td>
<td>67</td>
<td>161</td>
</tr>
</tbody>
</table>

* Most lead containing paints are being replaced with paints using synthetic (non-HAP) pigments.
Date: May 27, 1992

To: Laurel Driver
ESD/CPB/CAS (MD - 13)
U.S. Environmental Protection Agency
Research Triangle Park, N.C. 27711

From: Dave Reeves

Re: Shipbuilding and Ship Repair NESHAP Abrasive Blasting Operations and HAP Emissions
EPA Contract 68-D1-0115 : Work Assignment No. 25
ESD Project No. 91/53B ; MRI Project No. 6500-25

This memo provides a preliminary estimate of the magnitude of (potential) HAP emissions from abrasive blasting operations. The information on abrasive blasting has been compiled from the CTG Section 114 information requests, site visit questionnaires, available literature, and phone conversations with industry representatives.

Model shipyards from the East and West Coasts (NORSHIPCO and NASSCO, respectively) were chosen for HAP emission comparisons. Total HAP emissions (element-specific and combined) are calculated and presented for each of the model shipyards. NORSHIPCO's Berkley facility and NASSCO were chosen based on the amount of blasting and painting done, as well as the availability of HAP "solids" data on the paints applied. Both facilities represent large shipyards with 3000 - 4000 employees and major painting operations. Actual data from the CTG 114 responses were used for HAP emission calculations.

Both the abrasive media and the paint from the surface being abraded may emit HAP's. Some marine paints contain small amounts of heavy metals such as lead and chromium as pigment or as a trace contaminant with other metals like zinc. For purposes of this memo, each of the HAP emission sources (blast media and abraded paint) is discussed separately. Combined HAP emission estimates were calculated for each facility, and a summary of the inputs and results of the analysis is provided in Table 1. Example calculations are provided with each of the assumptions used in making emission estimates.
GMA Garnet is a natural mixture of almandite garnet and contains no HAP materials. It is considered a low free silica blast media and the sales literature states that it performs 3 times better (reduces usage) than coal slag. The cost used in GMA's cost model is $340 per ton.

An area of great uncertainty is how much of the media actually becomes airborne as a result of the surface blasting. Some small percentage of the media is expected to become airborne dust particulate. Since we have heard 90 to 95 percent of the used media is typically recovered at the shipyards, we decided to use 10 percent for our emission calculations. This is believed to be a conservative estimate based on most comments on what is thought to become airborne and actually carried beyond the drydock or fenceline boundary of the shipyard.

<table>
<thead>
<tr>
<th>Facility</th>
<th>NORSHIPCO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>(Berkley yard) Norfolk, Va.</td>
</tr>
<tr>
<td>Abrasive Media</td>
<td>Black Blast™ (coal slag) GMA Garnet (coal slag)</td>
</tr>
<tr>
<td>Media Cost ($/ton)</td>
<td>$58 $340</td>
</tr>
<tr>
<td>Annual Usage (tons)</td>
<td>7011 2337*</td>
</tr>
<tr>
<td>Total Media Cost</td>
<td>$406638 $794580</td>
</tr>
<tr>
<td>HAP Content of Media (lbs/ton)</td>
<td>0.25 0.00</td>
</tr>
<tr>
<td>Total HAP content of Media</td>
<td>1753 # 0 #</td>
</tr>
<tr>
<td>Annual HAP Emissions from Media (using 10% emission factor)</td>
<td>175 # (0.0875 tons) 0 # (0 tons)</td>
</tr>
</tbody>
</table>

Cost Effectiveness: \[ \frac{\$794580 - \$406638}{0.0875\text{ tons}} = \frac{\$4,433,623}{\text{ton of HAP's reduced}} \]

* Assuming performance is 3 times better than coal slags.
The other control option used for cost comparison in reducing HAP emissions was vacuum blasting. Several industry representatives have commented that existing vacuum blasting systems are too slow for shipyard applications. The time a ship is in drydock is expensive for the ship owner and for the shipyard. Servicing as many ships as possible in as short amount of time as possible is vital to most shipyards.

Since service time is such a key factor, the following assumptions were made for our preliminary cost calculations:

1. a large industrial vacuum blast unit can achieve an equivalent rate of surface preparation as an operator using coal slag abrasive media,
2. cost of such a unit, LTC-2000, is $75,000 (price quoted from LTC International, Inc. on 10/28/92),
3. disregard operational costs, and
4. capital costs annualized over 10 year period.

Using the NORSHIPCO test set-up as a basis, 32 blasters using coal slag abrasive worked simultaneously and averaged 58.3 sq. ft per hour during the 12 hour test. The LTC sales representative quoted rates of 60 to 110 sq. ft per hour with one man (nozzle) per unit. The initial capital investment would be $2,400,000., which would reduce 0.0875 tons of total HAP's. To reduce 1 ton of total HAP emissions, the cost would be:

\[
\frac{\$2,400,000}{0.0875 \text{ tons}} = \$27,428,571 \text{ per ton of HAP's reduced}
\]

Disregarding operational costs and annualizing the capital costs over a 10 year period, the cost effectiveness is still greater than $2.7 million per ton of HAP's reduced.
Abrasive blasting is an operation with a great diversity of occupational hazards. A jet of abrasives can cut flesh like a knife. The noise of air jets added to the din of abrasive shot against metal could cause hearing loss without proper protection. The full extent of the problem is not realized, however, until one considers that operators are also exposed to all types of toxic hazards. Both the abrasives and surfaces abraded may emit a broad array of dangerous substances. For small industrial applications, the abrasives and parts can be placed inside a sealed cabinet but, for large outdoor construction operations, controlling these hazards becomes a much more difficult challenge.

Protective Clothing

Airtight blasting enclosures can protect workers from all types of health hazards. When this form of engineering control is not feasible, full-body protective clothing is required (Figure 1). Coveralls can protect against fine abrasives but metal shot may require heavy padded suits, even in hot, muggy environments. The resulting discomfort generates stress, fatigue and reduced alertness. These factors constitute hazards for workers on scaffholdings cluttered with air hoses, enveloped in dust and with slippery shot underfoot. Add the limited visibility afforded by protective visors and you have all the ingredients for nasty falls and injuries that constitute the primary hazard to which abrasive blasters are exposed.

Toxic Hazards

Materials used as blasting abrasives include natural and synthetic organic and inorganic media. Examples include rice hulls, plastic particles, sands, slags and metal shot. Silica sand is an excellent abrasive but the crystalline silica dust causes silicosis, the most prevalent occupational disease of abrasive blasters. Rice hulls, it has been reported, also contain crystalline silica and may be hazardous. Avoidance of silicosis was one motive for introducing media with low silica contents such as metal and coal slags. However, subsequent studies of the metal slags revealed the presence of toxic contaminants, such as 6 to 180 parts per million (ppm) of beryllium and 2 to 1,450 ppm of arsenic, one a severe fibrogenic agent and the other a cancer-causing agent.1,2 An analysis of a dozen coal slags with low silica contents also revealed carcinogens.3 Media without any silicosis or cancer hazard include natural zircon Barton 'sands' and synthetic olivine Olimag sands. However, a broad array of toxic substances may still be emitted from the surfaces blasted. For example, leaded paint is a major problem in ship, tank and bridge repair work.

In certain cases a vacuum nozzle consisting of an enclosure hood under negative pressure that seals against the surface by means of a sponge gasket may be used (Figure 2). The vacuum exhaust air from the system is filtered prior to discharge. Regrettably, a lower quality of work is obtained, often preventing more wide-spread acceptance of this type of control device.

Respirators

The use of a supplied-air respiratory protector (or respirator), hood style, type CE is generally recommended (Figure 3). Type CE supplied-air hood or helmet style respirators help protect the wearer by providing a fixed flow of breathable air to the respirator at all times. This air flow creates a slight positive
pressure condition inside the respirator to help prevent the inward migration of contaminants to the respirator. Additionally, the protective capes attached to the helmet are manufactured with a tight-fitting neck cuff that serves as a physical barrier to contaminants. The laminar flow of air combined with the physical barrier of the helmet and cape help provide the respiratory protection needed by the abrasive blaster. This offers some protection against dust, abrasive rebound and noise. Supplied-air respirator systems may also provide personal cooling by means of vortex tubes, which use the expansion energy of the compressed air to cool the inside of the suit. Grade D or better breathing air in compliance with the Compressed Gas Association specifications must be used.

In addition to protecting the workers directly involved in abrasive blasting, it is necessary to protect other workers at the same site, such as shipyard personnel who may be exposed to these same hazards in varying degrees. Although it would be ideal if all exposed workers were as completely protected as the blasters, in practice, much better respiratory protection is achieved if the respective job classifications are analyzed individually. Properly enforced respiratory protection takes into account the nature of the hazards, the degree to which the permissible exposure limits are exceeded and the duration and the frequency of exposure.

As minor as these secondary operations may seem, it is suspected that much of the respiratory illness that befalls abrasive blasters begins long before these workers are promoted to blaster positions at the worksite. Better respiratory protection of pot-tenders, clean-up workers, welders and other workers at abrasive blasting sites would greatly improve the overall health of workers in these
occupations. By the time a worker is promoted to a blaster position and is given a supplied-air respirator to wear, he may already have contracted silicosis although it may take years to manifest itself into notable medical symptoms.

Respirator selection may be based on the National Institute of Occupational Safety and Health (NIOSH) respirator decision logic. This takes into account the possibilities of oxygen deficient atmospheres, permissible exposure limits, warning properties (hydrogen chloride gas warns, but not carbon monoxide), eye irritants and toxins absorbed through the skin. Protection factors for respirators vary widely and these are shown in the following table.

| NIOSH PROTECTION FACTORS |
|---------------------------|-------------------|
| Respirator Type           | Factor            |
| SCBA (self-contained breathing apparatus) pressure demand mode | 10,000+ |
| Supplied air respirator, full-face air line | 2,000 |
| SCBA Demand mode | 50 |
| Full-face respirator, negative pressure | 50 |
| Supplied air respirator with hood or helmet | 25 |
| 1/2 Face respirator | 10 |
| 1/4 Face respirator | 5 |
| Disposable respirator | 5 |

The above factors are based upon the NIOSH logic published in May 1987 which drastically downgrades the Minimum Assigned Protection Factor of supplied-air hood or helmet style respirators from 2,000 (previously published by NIOSH in 1976) to a factor of 25. This presents a severe compromise to what had become a standard industry practice regarding worker protection.

This also gives us a prime example of one of the goals of ASTM Committee E-34 on Occupational Health and Safety—to bridge the awareness gap between industry and regulators. By bringing together manufacturers, users and regulators in a constructive setting, unnecessary upsets to the regulated community can be avoided. The consensus process requires that all points of view be given a fair and open hearing.

Manufacturers of supplied air type CE respirators with hoods are ensuring customers that they may rely on their products to provide a protection factor of at least 1,000, which is consistent with the latest logic from other nationally recognized standards for respiratory protection. Reportedly, the U.S. Mine Safety Health Administration (MSHA) which jointly shares with NIOSH the role of testing and certifying respirators in the United States, is about to publish new regulations which adopt the higher protection factor values.

There is a great deal of controversy and differing opinions about protection factor ratings of respirators. Given this confusion, interested parties make their own best judgments on respirator selection based upon information from regulatory agencies, standards-setting organizations, and the respirator manufacturers themselves. ASTM Subcommittee E34.60 on Abrasive Blasting intends to be a key player in eliminating that confusion and in bringing sound guidance to that industry.

In the United States, federal regulations require a written respirator program covering the following items:
- Respirator selection surveillance and assessment of hazards;
- Respirator training, fit testing, inspection, disinfection, cleaning, maintenance and storage; and
- Monitoring of hazards, supplied air quality and medical fitness.

Whether we are talking about the abrasive blaster engulfed in dust or one of the support personnel briefly entering the work area wearing a half-mask respirator, they must be checked as to their medical fitness for wearing a respirator. In addition, they must be trained in the use and maintenance of their equipment prior to assignment in the hazardous area. The entire respiratory protection effort must be reviewed periodically by qualified individuals to ensure program effectiveness.
Conclusion

In view of the variety of hazards associated with abrasive blasting, awareness of all the hazards and the degree of exposure to each are indispensable in taking adequate protective measures. There is never any substitute for sound judgment, but a well-articulated safety program, rigorously enforced, can be a good starting point. Personal protective equipment is the primary defense against the hazards of large scale abrasive blasting operations. A soundly applied respiratory protection program is essential to protecting workers from toxic airborne hazards throughout the work area.

Acknowledgement

Permission was obtained from the author to borrow extensively from Reference 6 for this article.

References

Date: October 28, 1992

To: Laurel Driver  
ESD/CPB/CAS (MD - 13)  
U.S. Environmental Protection Agency  
Research Triangle Park, N.C. 27711

From: Dave Reeves

Re: Shipbuilding and Ship Repair NESHAP  
Cost Effectiveness of Reducing HAP Emissions from Abrasive Blasting Operations at Shipyards  
EPA Contract 68-D1-0115 : Work Assignment No. 50  
ESD Project No. 91/53B ; MRI Project No. 6501-50

This memo provides a preliminary estimate of the cost effectiveness of reducing HAP emissions from abrasive blasting operations used in the shipbuilding and ship repair industry. The two control options evaluated for this cost comparison are alternative blast media (containing no HAP material) and vacuum blasting (where the blasting dust is captured at point of use and therefore not emitted to the air). In the initial analysis, both the abrasive media and the surface being abraded were thought to emit HAP's. Based on the testing done at NORSHIPCO earlier this year, it is now believed that only a small (insignificant for purposes of this memo) amount of the abraded marine paints becomes airborne and would be considered HAP material.

A model shipyard from the East Coast (NORSHIPCO) was chosen for HAP emission/cost effectiveness comparisons. NORSHIPCO's Berkley facility was chosen based on the amount of blasting and painting done, as well as the availability of HAP contents data on the abrasive media used. This facility was also the site of the Ambient Monitoring Test for Total Suspended and PM10 Particulate Emissions During a Ship Sandblasting Operation conducted on July 14 and 15, 1992.

BLAST MEDIA

Black Beauty™ seems to be the medium of choice for several large shipyards, especially those on the East Coast. Black Beauty™ consists of crushed slag from coal-fired utility boilers and is relatively cheap (around $35-$58 per ton) compared to other media. It is usually recovered on-site and then landfilled as a non-hazardous waste. Total HAP contents were calculated to be 0.25 lbs per ton.
GMA Garnet is a natural mixture of almandite garnet and contains no HAP materials. It is considered a low free silica blast media and the sales literature states that it performs 3 times better (reduces usage) than coal slag. The cost used in GMA's cost model is $340 per ton.

An area of great uncertainty is how much of the media actually becomes airborne as a result of the surface blasting. Some small percentage of the media is expected to become airborne dust particulate. Since we have heard 90 to 95 percent of the used media is typically recovered at the shipyards, we decided to use 10 percent for our emission calculations. This is believed to be a conservative estimate based on most comments on what is thought to become airborne and actually carried beyond the drydock or fenceline boundary of the shipyard.

COST COMPARISON OF REDUCING ANNUAL HAP EMISSIONS FROM ABRASIVE BLASTING OPERATIONS

<table>
<thead>
<tr>
<th>Facility</th>
<th>NORSHIPCO (Berkley yard) Norfolk, Va.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Black Blast™ (coal slag)</td>
</tr>
<tr>
<td>Abrasive Media (type)</td>
<td>GMA Garnet (coal slag)</td>
</tr>
<tr>
<td>Media Cost ($/ton)</td>
<td>$58</td>
</tr>
<tr>
<td>Annual Usage (tons)</td>
<td>7011</td>
</tr>
<tr>
<td>Total Media Cost</td>
<td>$406638</td>
</tr>
<tr>
<td>HAP Content of Media (lbs/ton)</td>
<td>0.25</td>
</tr>
<tr>
<td>Total HAP content of Media</td>
<td>1753 #</td>
</tr>
<tr>
<td>Annual HAP Emissions from Media (using 10% emission factor)</td>
<td>175 #</td>
</tr>
</tbody>
</table>

| Cost Effectiveness | $794580 - $406638 = $4,433,623/0.0875 tons of HAP's reduced |

* Assuming performance is 3 times better than coal slags.
VACUUM BLASTING

The other control option used for cost comparison in reducing HAP emissions was vacuum blasting. Several industry representatives have commented that existing vacuum blasting systems are too slow for shipyard applications. The time a ship is in drydock is expensive for the ship owner and for the shipyard. Servicing as many ships as possible in as short amount of time as possible is vital to most shipyards.

Since service time is such a key factor, the following assumptions were made for our preliminary cost calculations:

(1) a large industrial vacuum blast unit can achieve an equivalent rate of surface preparation as an operator using coal slag abrasive media,

(2) cost of such a unit, LTC-2000, is $75,000 (price quoted from LTC International, Inc. on 10/28/92),

(3) disregard operational costs, and

(4) capital costs annualized over 10 year period.

Using the NORSHIPCO test set-up as a basis, 32 blasters using coal slag abrasive worked simultaneously and averaged 58.3 sq. ft per hour during the 12 hour test. The LTC sales representative quoted rates of 60 to 110 sq. ft per hour with one man (nozzle) per unit. The initial capital investment would be 32 * $75,000. = $2,400,000., which would reduce 0.0875 tons of total HAP's. To reduce 1 ton of total HAP emissions, the cost would be:

$$\frac{2,400,000}{0.0875 \text{ tons}} = \frac{27,428.571}{\text{ton of HAP's reduced}}$$

Disregarding operational costs and annualizing the capital costs over a 10 year period, the cost effectiveness is still greater than $2.7 million per ton of HAP's reduced.
<table>
<thead>
<tr>
<th>FACILITY</th>
<th>ANNUAL USAGE</th>
<th>ANNUAL Cr EMISSIONS*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TONS</td>
<td>MILLION LBS</td>
</tr>
<tr>
<td>NORSHIPCO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Berkley)</td>
<td>7011</td>
<td>14.0</td>
</tr>
<tr>
<td>(Brambleton)</td>
<td>2239</td>
<td>4.5</td>
</tr>
<tr>
<td>Peterson Bldrs.</td>
<td>27</td>
<td>0.05</td>
</tr>
<tr>
<td>Gen. Dynamics</td>
<td></td>
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</tr>
<tr>
<td>(Conneticut)</td>
<td>1968</td>
<td>3.9</td>
</tr>
<tr>
<td>(S. Carolina)</td>
<td>1386</td>
<td>2.8</td>
</tr>
<tr>
<td>Ingalls</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Louisiana)</td>
<td>3530</td>
<td>7.1</td>
</tr>
<tr>
<td>Newport News</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Virginia)</td>
<td>2075</td>
<td>4.2</td>
</tr>
<tr>
<td>Southwest Mar.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(San Fran., Ca)</td>
<td>8000</td>
<td>16.0</td>
</tr>
<tr>
<td>Northwest Mar.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Portland, Or)</td>
<td>3525</td>
<td>7.1</td>
</tr>
<tr>
<td>Average of</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 facilities</td>
<td>3307</td>
<td>6.6</td>
</tr>
</tbody>
</table>

(Facilities in San Diego, Ca. - NASSCO and Southwest Marine, reported using copper mineral slag and were not included.)

* Reference analysis for Black Blast™ used for HAP emissions estimate (values in ppm):

- Antimony: ≤50
- Arsenic: 4
- Beryllium: ≤5
- Cadmium: ≤10
- Chromium: 20
- Cobalt: 10
- Lead: 10
- Mercury: 0.1
- Nickel: ≤10
- Selenium: 0.4
ABRASIVE COST MODEL

NORFOLK NAVAL SUPPLY CENTER
1991 CONTRACT PROGRAM

The U.S. Navy is a large consumer of slag and mineral abrasives. Use of these products by Navy personnel and by contractors doing work for the Navy is regulated by State and Federal code and by military specification (MIL-A-22262-SH).

Typically the Navy purchases abrasives from a single source for each shipyard with a contract awarded to the approved supplier offering the lowest cost-per-ton to the government. It is now recognized that the cost per ton basis has at least two serious faults:

1. The basis assumes that all abrasives are the same, and that initial cost is the only decision criteria;

   In fact productivity, dusting, and environmental costs vary considerably among blast media.

2. It ignores the non-material costs associated with blast cleaning, such as labor and clean-up or disposal charges.

To correct these defects and to establish an alternative method for contract awards, the Norfolk Naval Shipyard is conducting an extensive testing program to measure the total cost-per-square-foot cleaned. The test involves blasting a large enough area to obtain meaningful data and the calculation of a FULL COST of service.

The formula for the Navy analysis is shown below. Awards will be bases on the lowest FULL COST of service.

\[
\text{FULL COST} = \text{abrasive used (lbs.) x cost ($/lb.)} \\
\text{area blasted (sq. ft.)} \\
+ \text{time (hr.) x labor rate ($/hr.)} \\
\text{area blasted (sq. ft.)} \\
+ \text{abrasive used (lbs.) x disposal cost ($/lb.)} \\
\text{area blasted (sq. ft.)}
\]

The formula is sensitive to productivity (the area cleaned) of the various blast media, and the importance of the initial cost of the material is limited to one factor. Other factors (i.e. dust control or medical surveillance costs) might also be added.
ABRASIVE COST MODEL

NORFOLK NAVAL SUPPLY CENTER
1991 CONTRACT PROGRAM

---Supplement Numerical Example---

The analysis uses the Navy's abrasive cost model to calculate "Full Cost" figures for surface preparation using actual field derived data for GMA Garnet and for mineral slag.

The data for the GMA Garnet is intentionally selected from very conservative examples, and the data for the slag is more favorable than commonly found in actual practice. In other words, this example strongly favors slag.

**COMMON ASSUMPTIONS**

1,000 sq. ft. cleaned
best case disposal costs of $50.00/ton
labor charges at $60.00/hr

<table>
<thead>
<tr>
<th>SLAG ASSUMPTIONS</th>
<th>GMA GARNET ASSUMPTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$50 per ton ($.025/lb.)</td>
<td>$340 per ton ($.17/lb.)</td>
</tr>
<tr>
<td>9#/sq. ft. (9000 lb. used)</td>
<td>3#/sq. ft. (3000 lb. used)</td>
</tr>
<tr>
<td>125 sq. ft./hr. (8 hrs. needed)</td>
<td>175 sq. ft./hr. (5.7 hrs. needed)</td>
</tr>
</tbody>
</table>

**COST CALCULATIONS**

**SLAG**

\[
\begin{align*}
\text{SLAG} & \rightarrow (9000\# \times \$0.025/\#)/1000 \text{ sq. ft.} \\
& + (8 \text{ hr.} \times \$60/\text{hr.})/1000 \text{ sq. ft.} \\
& + (9000\# \times \$0.025/\#)/1000 \text{ sq. ft.}
\end{align*}
\]

**GMA GARNET**

\[
\begin{align*}
\text{GMA GARNET} & \rightarrow (3000\# \times \$0.17/\#)/1000 \text{ sq. ft.} \\
& + (5.7 \text{ hrs.} \times \$60/\text{hr.})/1000 \text{ sq. ft.} \\
& + (3000\# \times \$0.17/\#)/1000 \text{ sq. ft.}
\end{align*}
\]

**RESULTING COST PER SQUARE FOOT**

\[
\begin{align*}
\text{SLAG} & = \$0.94 \\
\text{GMA} & = \$0.92
\end{align*}
\]
GENERAL FORMULA
for
METAL EXPOSURE IN AIRBORNE DUST
DURING BLAST CLEANING

\[ M = \frac{m \times D \times 1000 \text{ ug}}{100 \text{ mg}} \]

M = The amount of metal present in the air, in mg/m³, the basis on which OSHA standards will be measured.

m = The amount of metal present in the abrasive blast media, expressed as a percent. Example media:

40 ppm Arsenic = 40 mg/kg = 0.0040%, and
6000 ppm Lead = 0.60%.

D = The amount of dust present in the work area, generally a number obtained at the site by air sample monitoring. Dust levels depend on the abrasive in use, the number of nozzles in use, ventilation, pressure, etc.

examples of dust levels:

\(< 1 \text{ mg/m}^3 \) fresh air
15 " nuisance dust level, no respirator
30 " average blasting with sand/slag
200 " very dusty blasting conditions, poor ventilation
1500 " Approx. limit of dust in air

EXAMPLE

There is an OSHA limit for arsenic of 10 mg/m³. At the nuisance dust limit would the media with 40 ppm As exceed the limit?

\[ M = \frac{0.0040 \times 15 \text{ mg/m}^3 \times 1000 \text{ ug/mg}}{100} \]

M = 0.6 ug/m³; well below the limit

Would the lead limit of 30 ug/m³ be exceeded at the nuisance dust level?

\[ M = \frac{0.6 \times 15 \text{ mg/m}^3 \times 1000 \text{ ug/mg}}{100} \]

M = 90 ug/m³; well in excess of the OSHA limits and in violation of the standards

The model assumes that all metal comes from the abrasive.
Overview of Advances
in
Surface
Preparation and Preservation

by
Jimmy W. Fuller Industrial Specialist (Shipbuilding)
Naval Sea Systems Command
Washington, D.C.

ABSTRACT

Surface preparation technology has improved from sand blasting with sand to Laser removal of coatings. Some of the transitional methods include: CO₂ blasting; blasting with water, injected with sodium bicarbonate of soda, garnet, and drilling salt; plastic blast media; and steel grit. Closed cycle blasting equipment is also becoming available.

This paper discusses these changes in technology and how the naval shipyards have adapted and assisted in establishing these changes as industry standards.
Navy ships are made of various materials that require repainting from time to time. The substrates are either steel, aluminum, glass reinforced plastic or wood. The bulk of navy ships are made from steel and aluminum. These metals have a tendency to rust or corrode. The most economical method for surface preparation is open air abrasive blasting. The industry standard uses either a 3/8 or 1/2 inch nozzle attached to a 2 1/2 inch steel reinforced hose. The media is propelled through the hose from a pressurized blasting pot using compressed air. Open air blasting remains the accepted industry standard. Different nozzles of new materials and quick disconnect hoses are the main changes in this technology. The abrasive blast media has changed from silica sand, the most economical and plentiful abrasive for many years, to mineral slags, i.e. coal, copper and nickel. Silica sand was replaced due to health concerns and is no longer permitted to blast naval ships. Garnet is another alternative to silica sand and if the complete life cycle cost (initial purchase price, recycle and disposal) is taken into account, garnet is very cost effective. The Clean Air Act brought the quality of the air to the attention of the country. As a result the environment and the effects of various applications have become more important than in the past.
In 1977 Air Quality and Emission Limitations were added to the environmental laws and regulations. Subsequently, the air quality rules and regulations are constantly being revised and becoming more restrictive. The naval shipyards have become pro-active in the implementation of these rules and have identified alternate methods for accomplishing surface preparations with little or no impact on the environment.

High pressure water blasting is one of the alternate technologies that the shipyards have investigated and implemented. The high pressure water alone will not provide a profile but, if the substrate had an acceptable profile in the beginning, the high pressure water may provide adequate surface preparation. Some high pressure water blasting equipment permits the injection of garnet, bicarbonate of soda, or drilling salts into the water stream. Garnet injection provides the best profile of these three, and is cost effective in removing the coatings. The bicarbonate of soda is more aggressive than water alone but, not as aggressive as garnet or drilling salts, and has little effect on profile. Drilling salts injected into high pressure water is under initial investigation by David Taylor Research Center for the Naval Sea Systems Command (NAVSEA). Additional testing will be conducted if required. Plastic media blasting in the naval shipyards has produced mixed results. The removal rate for plastic is approximately equal to that of walnut.
shell blasting. Puget Sound Naval Shipyard is currently evaluating a new plastic media system with a recycling capability. The shipyard will provide NAVSEA the results in the near future. The recycling of the spent plastic may be a problem, depending on the coatings removed. Another alternative method is CO₂ pellet blasting. Norfolk Naval Shipyard recently conducted a test and found CO₂ blasting to be a good method for removing grease and several types of paints and coatings. NAVSEA will share the final reports with the SNAME (Society of Naval and Marine Engineers) Panel SP-3 on Surface Preparation and Coatings.

Steel grit is the most aggressive and recyclable abrasive that the naval shipyards use. As with any abrasive blasting operation, the variables must be controlled for repeatable performance. The nozzle size, dry air pressure at the nozzle, angle of the grit striking the substrate, consistency of the grit, distance from the blasting pot, adequate lighting, and sufficient volume of dry air are the variables that should be controlled. Additionally when using steel grit in tanks or voids, the relative humidity in the tanks must be controlled to avoid flash rusting of the tank surfaces after blasting, of the spent grit and subsequent contamination of the tank surface where the steel grit resides.

A variation of the standard open air blasting process is under development - an enclosed blasting containment using the
standard blast hose, but hooked up to a recycling system to catch the spent abrasive and contain the generated dust. The blasting media may be mineral slags, steel grit, garnet or aluminum oxide. The size of the cabinet is approximately 4 x 8 x 3 feet, and is attached to the end of a high reacher or cherry picker. This cabinet will permit the application of paints or coatings with essentially no overspray or adverse impact on the environment.

Several companies use a vacuum system in conjunction with their 1/4 or 3/8 inch blast nozzle to contain the blasting media at the point of impact. Each of the three companies mentioned above provides a containment system with near zero effluent to the environment and a recycling capability.

Puget Sound NSY is investigating a Methylene Chloride paint stripper that does not yield a liquid waste. Additional testing will be required prior to Methylene Chloride becoming an acceptable surface preparation method. Initial results are promising. Epoxy paint was successfully removed from a portion of an anchor. Safety precautions must be adhered to when using Methylene Chloride. Methylene Chloride is extremely toxic, an ozone depletor and a suspected carcinogen.

The Naval Air Systems Command has a contract in place for laser paint removal. NAVSEA provided test panels coated with an underwater hull paint system applied, for the vendor to remove using lasers. The demonstration of this technology in an
industrial environment is still two years in the future. When
the laser technology becomes a reality for removing paints and
coatings from naval ships, the material/waste disposal costs
associated with spent abrasive blast media should decrease.

Through the SP-3 panel, NAVSEA supported and continues to
support the recycling of spent abrasive blast media. Bethlehem
Steel, Sparrow’s Point Yard, installed a partially successful
recycling unit for spent abrasive media. The recycled grit
performed as well as virgin material; however, the recycling
equipment did not remove all of the paint chips. In order to use
recycled grit to abrasive blast naval ships the recycled grit
must pass all of the same tests required of virgin material.
Thus, the Sparrows Point recycling plant was only partially
successful.

NAVSEA tested another abrasive blast media recycling system
that the Institute of Gas Technology developed - a sloping grid
calciner. The test successfully removed all paint chips, foreign
material and the recycled media passed all of the required tests.
A pilot scale project, proposed for the West coast, is being
developed that will be large enough to receive the spent abrasive
from three naval shipyards. Several questions remain unanswered
- such as: What are the permitting requirements; Who owns the
plant; Who runs the plant; Who owns or buys the recycled grit; Is
it legal for the government to give away or sell the spent
abrasive then buy the same recycled grit back?
Surface preservation improved over the years from brushes to air atomizing spray guns to airless atomizing now to high volume low pressure spray applications. Research and development is looking at using carbon dioxide as a solvent to permit spraying of high solid paints with standard airless equipment, and using hydrogen gas as the propelling or pressurization gas in aerosol cans.

SUMMARY

Surface preparation and preservation in the naval shipyards has improved over the years, additional improvements in both are on the drawing boards. The interest in our environment, emphasis on cleaning up the world, and economic necessity will enhance and quicken the arrival of these new technologies. Open air abrasive blasting and painting may become extinct like the dinosaurs.
Proceedings
of the Seminars

December 3–7, 1990
Nashville

SSPC 90-10
Table of Contents

Performance Standards for Low-VOC Coatings................................................................. 1
   Bernard R. Appleman
   SSPC

Detection and Significance of Surface Contaminants......................................................... 15
   Simon K. Boocock
   SSPC

The Development of New SSPC Standards......................................................................... 33
   Bernard R. Appleman
   SSPC

Environmentally Acceptable Coatings for Galvanized Steel............................................. 36
   Richard W. Drisko, Jesse R. Neal, and Jeffrey R. Yanez
   Naval Civil Engineering Laboratory

Cold-Weather Curing Coatings: The Canadian Experience.............................................. 47
   John Witter
   Corrosion Service Company Limited

In Search of the Optimum New Welded Steel Tank Coating System.............................. 55
   E. Crone Knoy
   Tank Industry Consultants, Inc.

The Criticality of Sampling and Quality Control for Hazardous Waste Testing............. 65
   Gary Tinklenberg, Corrosion Control Consultants and Labs
   Lloyd Smith, S. G. Pinney & Associates

A Systematic Approach to Lead Paint Removal Operations............................................. 74
   Kenneth A. Trimber
   KTA-Tator, Inc.

Lead-Base Paint Removal, Disposal and Painting for the Chesapeake Bay Bridge Tunnel Project................................................................. 86
   Ronald Olson, Sverdrup Corporation
   Jerry Burbank, Hartman Walsh Painting Company

Consideration for Tanks and Vessels to be Lined for Immersion Service....................... 93
   Pat Connors, Mobay Corporation
   Jeff Theo, Service Painting Company of Texas
   Charles Wyatt, Enviro-Air Control Corporation

Surface, Service and Quality Assurance........................................................................... 100
   Dick McGown
   Mavor-Kelly Company, Inc.