

RESPIRATORY PROTECTION FOR ABRASIVE BLAST CLEANING

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ABSTRACT

Silicosis arising from abrasive blasting represents a serious potential health hazard. Several approaches for worker protection are discussed. In all cases the blaster needs protection from the recoiling material. In many instances respiratory protection is needed. For heavy use or continuous operation, an air supplied blasting helmet is required. If the amount of blasting to be done is small or the work load *intermittant*, protection could be provided by simple half or quarter face mask respirators worn properly. Intangible factors such as the general working habits of each user, training and the condition of the protective equipment must be considered. Those responsible for abrasive blasting operations must evaluate the amount of work to be done and the time over which it will be carried out and choose respiratory protective equipment accordingly.

INTRODUCTION

Silicosis arising from abrasive blasting represents a serious potential health hazard. Control methods for worker protection include substitution of a less toxic abrasive, respiratory protection or both. The choice of the degree of respiratory protection required will depend on the type of abrasive used as well as on the exposure and the exposure time. Factors influencing this choice are discussed below.

Abrasive blast cleaning, often called sandblasting, was introduced as an industrial process in the late 19th century, and is used for many types of industrial cleaning problems, from cleaning sand castings in the foundry to paint removal and glass etching. It has become an indispensable process in many industries, including the metal finishing industry (Plaster, 1972).

In the blast cleaning process, finely sized abrasives are propelled at high speed in dry air against a surface, with the result that cleaning of the surface occurs. With extremely high pressures the stream of abrasive can be made to cut metal or rock, materials which may in themselves be harder than the materials making up the abrasive.

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ABRASIVES USED

When the process was **originated**, sand was the only abrasive available - hence the term "**sandblasting**". Many abrasives can be used in blast cleaning. Typical examples are listed in Table 1. Of the materials listed, sand is still most widely used in both the United States and abroad. It is the least expensive material, and since it is usually provided locally, shipping costs are low. Estimates of annual usage of sand for sand blasting range from 2,000,000 tons to 20,000,000 tons (Johnson, 1980). Examples of sand, a loose accumulation of rounded grains of quartz, include beach, grain and quarry sands that may be washed, dried and graded. The sand may contain fine particles or may fracture into small particles during use.

The extremely hazardous nature of abrasive blasting, when using sand as an abrasive, has been known for almost as long as the process has been used. The finely divided silica dust can produce a rapidly developing form of silicosis within periods as short as a year or so when exposure concentrations are high (Rice, 1983).

In 1936, Merewether published a summary of an inquiry made in Great Britain into the risks associated with sandblasting (Merewether, 1936). This work also focussed on determining situations where substitutes for silica could be used. From a review of mortality data from a number of British silicosis producing industries, he concluded that sandblasting is essentially an extremely dangerous occupation, and went on to say that,

"**while** it may be possible with particular equipment, precautions, and constant supervision, to make it safe for the time, a breakdown in one direction or another is more liable to occur than in many of the dangerous trades, and the results of such a breakdown, even if only of a temporary nature, are more serious."

He concluded that the risk of silicosis could only be reduced significantly by eliminating the source, i.e., by finding a substitute for sand as an abrasive.

In England the use of sand in the workshop as an abrasive has been prohibited since 1949 (Hunter, 1969). Sand is still used in connection with outside work, despite the availability of more acceptable media (Plaster, 1972).

Typical sand substitutes which have been used in the United States are slags such as copper slag sold under trade names as "**Apache**," "**Green Diamond**," "**Kleen Blast**," "**Blast Off**," and "**Diamond K**," boiler slag such as "**Black Beauty**" and other materials such as aluminum oxide or silicon carbide, "**MCA-1360**", "**Dynablast**," "**Arrowblast**," and "**Stoneblast**." These sand substitutes are about four to ten times

more expensive than common sand but are claimed to clean faster than **sand**. Even with the substitute material, some respiratory protection may be necessary because of SiO_2 on the object being cleaned or because of total dust exposure.

In addition to potential health hazards from using sand as an abrasive, the material being cleaned can in itself be rendered into a **hazardous form**. For example, abrasive blasting for paint removal can produce high concentrations of finely divided lead oxide if a **lead-based** paint is being removed.

EARLY RESPIRATOR STUDIES

Respiratory protective equipment for sandblasters was introduced in the early part of the 20th century when it was clear that some protection was needed. In 1920, Winslow, Greenburg and Reeves (1920) published the results of tests on a number of respiratory protective devices and concluded that dust concentrations in sand blasting were significantly greater than those measured at other industrial processes. They observed that the dust seemed to be comprised primarily of particles of crystalline silica. They also found that when using respirators and sandblasting hoods without supplied air, there was substantial removal of the finer dust particles, but the exposure concentration was still high. However, when positive air pressure was introduced into the helmet (2-3 cfm) there was a marked decrease in exposure concentrations. Positive air pressure (2-3 cfm) combined with respirators provided the greatest degree of protection.

During the period 1929-31, a study of abrasive blasting operations in the United States was made by the U.S. Public Health Service (PHS) in cooperation with the National Safety Council to determine the concentration and quartz content of dust in the atmosphere associated with abrasive blasting operations. These data were then to be used to determine the best method of worker protection. The results of the study were reported in a paper by Bloomfield and Greenburg (1933). They found that in a foundry using sand alone as an abrasive, the quartz content of the air varied from 42 to 98 percent, depending on the cleanliness of the castings being blasted. Exposure concentrations were of sufficient magnitude to definitely constitute a hazard to the worker. For indoor exposure, the average room **concentration** was determined to be 969 million particles per cubic foot (mppcf) when sand was used as an **abrasive**. The average exposure dust concentration which the worker breathed ranged from 241 mppcf for workers wearing only helmets to **4.7** mppcf when positive pressure hoods were worn.

Based on these and other findings, the authors concluded that a positive air supply of 6 cubic feet of dust free air per minute would protect the worker under the operating conditions then in practice. Since the accepted limit for exposure to silica

dust (assuming 25-35% quartz) was thought at that time to be about 10 mppcf (or for SiO₂ dust with >50% free silica, 5 mppcf according to the ACGIH in 1946) it was concluded that sandblasting, although hazardous, could be safely carried out with adequate respiratory protection. This study has formed the basis for most recommended standards for respiratory protection for sand blasting in the United States since the 1930's.

CURRENT PRACTICE - "SAFE* LIMITS

The current threshold limit value for silica dust exposure as recommended by the American Conference of **Governmental Industrial Hygienists** (ACGIH) is given either in terms of millions of particles per cubic foot (mppcf), milligrams of respirable dust per cubic meter or total dust per cubic meter (Anon., 1980). Recommended current practice suggests sampling techniques which give results in milligrams of respirable dust per cubic meter.

Recently Miller (1982) studied various equivalencies between respirable dust samples reported in mg/m³ and total mppcf and found fairly good agreement with previous work (Table 2). From this table an approximate conversion relationship can be established:

$$\text{mppcf} = \frac{\text{mg/m}^3}{0.09}$$

In addition to particle concentration, the potential for silicosis depends on the quartz or free silica content of the respirable dust. The threshold limit value is varied to reflect this point. The particle count limits have remained virtually unchanged since the 1930's [Lanza in 1938 recommended a "safe" level for 100% quartz of 5 mppcf (1983)].

For nuisance dusts a higher TLV is permitted. Nuisance particles are those which do not contain free silica or other toxic material, and hence present no risk of silicosis, but in high concentrations represent a definite impediment to the **worker**. Examples of nuisance dusts as given by the ACGIH are silicon carbide and aluminum oxide, both used as abrasives in blast cleaning.

LIMITATION OF EXPOSURE

If an adequate substitute for silica sand cannot be found, then respiratory protection must be used, the type of protection depending on the exposure concentration, free silica content of the sand and duration of exposure.

Exposure concentration is highly variable since it depends on whether the blaster is upwind or downwind of the dust cloud, **whether** he is working in a confined or open area, his own work **practices**, the degree of fracturing of the abrasive, and the type of material being cleaned. Table 3 shows summarized data from a Tulane University School of Medicine study (Hammad, 1976) indicating typical average exposure levels for blasters and helpers and the compressed air line feeding air to the **blaster's** hood. These data are typical for exposures to sandblasters.

Data from the Winslow et al. (1920) study and from Bloomfield and Greenburg (1933) are also listed to show a typical exposure concentration expressed in millions of particles per cubic foot. The rough agreement between these data collected almost 40 years apart with two entirely different sampling techniques helps to establish the level of protection necessary to prevent silicosis. The higher levels measured in the Bloomfield work are probably due to measurements being made inside a room where exposure concentrations were higher compared to the other **mesurements** which were made out of doors.

By comparing the average exposure concentrations for sandblasting to the current TLV and PEL for silica dust it is possible to estimate protection factors required in order to have safe working conditions. How can these factors be achieved? There are three possible approaches. Some type of dust control system can be installed. Respiratory protection can be provided which will reduce the dust concentration breathed. Or the worker can be permitted to work only long enough so that his time weighted average exposure is maintained below the threshold limit value. This latter approach is not practical for many cases since very little time would then be available for sandblasting. On the other hand, if sandblasting is only being carried out very occasionally, this approach might be the most practical.

Protection factors provided by various types of respiratory protective equipment depend not only on equipment type and fit, but also on such intangible factors as the general working habits of each user and the condition of the equipment. Suggested protection factors are listed in Table 4 for several types of respirators. This table was adapted from OSHA Program Directive No. 300-9 (Olishifski, 1979). It is often possible to get much greater protection factors than those listed above if great care is taken to get a well-fitting respirator. However, the values given in Table 4 will be assumed in subsequent discussions to be the maximum achievable.

To protect a blast cleaner, it is necessary in insure that his time-weighted exposure to dust produced by the cleaning operation does not exceed recommended TLV levels (assuming that the TLV levels currently in use are adequate). For someone spending full time blast cleaning, it is impossible to meet TWA concentrations without isolating the worker from the dust exposure, either through the use of

containment or air supplied blast helmets. With shorter exposure times, however, less protection may be acceptable. For example, blast cleaning for only 15 minutes a month would not require the elaborate protection required for full-time blast cleaning.

If it is assumed that a typical breathing rate for a blaster is 32 liters per minute, equivalent to a moderate work rate according to Silverman (1951), then over the course of 8 hours a worker will inhale 1.54 milligrams of silica dust if working in the TLV concentration of 0.1 mg/m^3 . Using this value as the allowable daily intake gives a three month allowable intake of $1.54 \times 5 \times 13 = 99.84 \text{ mg}$ or say 100 milligrams (based on 13 weeks, 5 days worked per week). There is some basis for considering cumulative exposure. Trice and Eason (1938) showed in 1938 that there was a sharp increase in lung pathology of workers when plotted against cumulative exposure and concluded that cumulative exposure was most important in assessing the potential for disease. The nature of silica dust is such that its cumulative effect, rather than its instantaneous effect, seems to be more important in causing disease, although peak exposure may in some cases also be important. Cumulative exposure has been applied to diseases resulting from chronic exposures (Rice, 1983).

The computed quarterly intake could be reached with a much higher exposure of shorter duration. If the exposure concentration is equal to the average reported previously for blasting, 12.47 mg/m^3 , then the permissible exposure time would be only 250 minutes for the entire quarter. Exposures beyond this time would very likely significantly increase the risk of disease. If a half or quarter face mask air purifying respirator was used, the permissible exposure time could be increased by a factor of 10 to about 40 hours per quarter.

The same approach can be made using particle count data. With a TLV concentration of 3 mppcf (assuming 100% quartz) and a breathing rate of 32 lpm, a quarterly "safe" intake of 1.06×10^{11} particles is implied. Considering blasting exposure levels of 969 mppcf gives a permissible unprotected exposure time of about 100 minutes per quarter, and with a respirator this would increase to about 16 hours per quarter.

These numbers can be used as rough guides for respiratory protection in blasting as shown in Table 5 which sets forth a suggested protocol for respirator use. Naturally, for these values to be applicable the respiratory protective devices must be well-maintained, properly worn and properly fitted.

SUMMARY

Abrasive blasting, or as it is more commonly known, sandblasting, is by its very nature a hazardous occupation. The blaster is being continually pummeled by the fine grains of abrasive and in addition has the potential for exposure to toxic dusts. To protect the worker, several approaches are possible. In all cases the blaster needs protection from the recoiling material. For this reason a blast helmet of some sort should be used. The helmet is not designed to provide protection from fine dust, but only to protect against rebounding grains of abrasive.

For protection against inhalable dusts, there are several approaches. Dust control using an enclosure or some sort of ventilation is possible. In many instances respiratory protection is required. This could be provided with the use of simple half or quarter face mask respirators when the amount of blasting to be done is small or the work load intermittent. Also such intangible factors as the general working habits of each user and the condition of the protective equipment must be considered. For heavy use or continuous operation, an air supplied blasting helmet is required. Those responsible for abrasive blasting operations must evaluate the amount of work to be done and the time over which it will be carried out and choose respiratory protective equipment accordingly.

BIBLIOGRAPHY

- Anon., (1980). 1980 Threshold Limit Values, Am. Conf. Gov. Ind. Hyg., Cincinnati.
- Bloomfield, J.J. and Greenburg, L. (1933). Sand and Metallic Abrasive Blasting as an Industrial Health Hazard, **J. Ind. Hygiene**, 15:184-204.
- Hammad, Y. (1976). Evaluation of Respiratory Protective Practices During Abrasive Blasting, Tulane Univ. School of Medicine, Pulmonary Disease Section, Undated Report.
- Hunter, D. (1969). The Diseases of Occupations, 4th Ed., Little, Brown and Company, Boston, 999.
- Johnson, D. (1980). Personal communication, Research Triangle Institute.
- Lanza, A. J. (1938). Silicosis and Asbestosis, Oxford University Press, New York, 46.
- Merewether, E. R. A. (1936). The Risk of Silicosis in Sand-Blasters, **Tubercle**, 17:385-391.

- Miller, S. (1982). Silica Dust Conversion Factors: A Study of the Mass and Count Relationships of the Siliceous Dusts using the Standard **Impinger**, Midget **Impinger** and **10-mm Nylon Cyclone**, Masters Technical Report, University of North Carolina at Chapel Hill.
- Olishifski, J. B. (1979). , Fundamentals of Industrial Hygiene 2nd Ed., National Safety Council, Chicago, 734.
- Plaster, H. J. (1972). Blast Cleaning and Allied Processes, Vol. 1 and 2, Industrial Newspapers Ltd., London.
- Rice, C. H. (1983). Exposure Reconstruction and Study of Silicosis in North Carolina, Ph.D. Thesis, University of North Carolina at Chapel Hill.
- Rice, C. H. (1983). Personal communication, University of North Carolina.
- Silverman, L., Plotkin, L. T., Sawyers, L. A. and Yancy, A. (1951). Air Flow Measurements on Human Subjects With and Without Respiratory Resistance at Several Work Rates, **Arch. Ind. Hyg.** and Occ. Health, 3:461-478.
- Trice, M. F. and Eason, H. F. (1938). , Report of A Study of the Foundry Industry in North Carolina Division of Industrial Hygiene, N. C. State Board of Health, Raleigh, N. C., 38.
- Winslow, C. E. A., Greenburg, L. and Reeves, E. H. (1920). The Efficiency of Certain Devices Used for the Protection of Sand Blasters Against the dust Hazard, Public Health Reports, 35:518-534.

TABLE 1

Abrasives used in blast cleaning

Almond shell	Oat husks
Aluminum oxide	Olive kernels
Boiler slag	Peach pits
Bronze shot	Polystyrene beads
Chilled iron sheet and grit	Rice hulls
Coconut shell	Rubber slugs
Copper slag	Sand
Corn cobs (crushed)	Silicon-carbide grit
Garnet	Stainless steel shot
Glass Beads	Steel shot and grit
Hardwood saw dust	Walnut shells
Iron slag	Wire pellets
Nail chippings	Zinc wire pellets
Nylon pearls	

TABLE 2

**Relationship between Particle Count Data and Mass
Collected with a Mass-Respirable Cyclone (from Rice, 1983).**

Investigator	Total respirable mass $\text{mg}/\text{m}^3 = 1 \text{ mppcf}$	Particulate sampled
Miller	0.07	pure alpha quartz
	0.08	resuspended foundry dust
Sutton and Reno	0.09	granite shed production
Ayer et al.	0.13	granite shed production

TABLE 3
Typical exposure levels for sand blasting.

Tulane study (Hammad, 1976), exterior

Method	no. samples	Dust Conc.,mg/m ³	%SiO ₂
Blaster	62	12.47	90
Helper	8	0.40	70
Compressed Air Line	2	1.72	12 ,

Winslow et al., (1920), exterior

Method	Dust Conc., mppcf
Air of cabinet (no protection)	243
Respirator alone	18.2
Helmet and respirator	8.19
Helmet, positive air pressure	1.47
Helmet, positive air pressure and respirator	0.62

Bloomfield and Greenburg, (1938), interior

Method	Dust Conc., mppcf	% SiO ₂
Blaster	969	95

TABLE 4
Maximum use concentration for typical well-fitting respirators (Olishifski, 1979)

	Protection Factor
Purifying, quarter face mask	10
Air purifying, half mask	10
Air purifying, full face	50
Continuous-flow, air supplied hood	2000

TABLE 5
Suggested guide for respirator usage in abrasive blasting. (Based on good, well-maintained equipment, properly worn and fitted.)

	Percent Free Silica Content of Dust					
Use per Quarter	0	20	40	60	80	100
100 minutes	a	a	a	a	a	a
100 min-1 day	a	a	b	b	b	b
1 day-1 week	a	b	b	b	b	c
1 week-1 mo.	a	b	c	c	c	c
Steadily	b	c	c	c	c	c
a -	Blast helmet only					
b -	Blast helmet with respirator					
c -	Air-supplied blasting hood					