

INDUSTRIAL HEALTH AND SAFETY CRITERIA FOR
ABRASIVE BLAST CLEANING OPERATIONS

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I. SUMMARY

A. PURPOSE

This report documents a study sponsored by the U.S. Department of Health, Education, and Welfare, Division of Laboratories and Criteria Development, National Institute for Occupational Safety and Health, Cincinnati, Ohio, under Contract HSM 99-72-82.

The purpose of the study was to assess and/or evaluate the existing standards and safety and health conditions in a broad representative scope of abrasive blast cleaning operations within various U.S. industries. The goal of the assessment was to recommend changes or additions to enhance ventilation, safety, and health criteria and to substantially improve personal protective equipment for abrasive blast cleaning operators and other workers who, due to production flow requirements, space restrictions, or other work demands must work in the pressure blast cleaning area.

B. SCOPE

A total of 92 manufacturers were contacted by mail. They were unstinting in providing catalogs, technical information, and operating and maintenance data on their equipment. The survey team visited manufacturing plants and met with design, production, and sales engineers until all team members were fully indoctrinated into past, present, and future abrasive blast cleaning techniques. All manufacturers visited gave generously of their time and knowledge and expressed a sincere desire for manufacturing codes and standardization in the industry. Because federal standards, rules, and regulations have been lacking for many years, the manufacturers have borne the burden of fabricating equipment to meet the varying safety and health demands of the individual states that have developed industrial safety and health requirements. U.S. governmental standards would greatly ease manufacturing problems and insure the safe standardization of equipment throughout the abrasive blast cleaning industry.

All industrial trade unions whose members could be involved in pressure blast cleaning were contacted to gain the viewpoints of organized labor. In this area the response was not 100 percent, but the unions that did respond contributed greatly to the survey.

Numerous plant facilities were visited. Only one major manufacturer refused to cooperate and permit the survey team to view its blast cleaning operations.

Within the various plants, which included both federal and private industrial facilities, each survey involved the metering of noise level exposure to the blast cleaning equipment operator and nearby workers.

Ventilation change rates within blast cleaning rooms were monitored, and dust counts were taken at various radii from the point of operation to distances as far as 100 feet from the operator. Visual acuity tests were taken within the confines of blast cleaning chambers before, during, and after cessation of cleaning operations.

General safety and health conditions for the operator and nearby workers were carefully evaluated and documented.

The present status of personal protective equipment such as short duration head masks, self-contained breathing helmets (some of which are air conditioned), capes, leggings, chaps, gloves, breathing air purifiers, and safety shoes were also evaluated with respect to their personal protective effectiveness.

C. FINDINGS

1. Dust Exposure

A definite dependence of dust exposures on both equipment type and abrasive material was demonstrated.

- Enclosed, ventilated facilities such as blasting rooms, when in good repair, demonstrated little dust leakage. No hazard from dust exposure to either a protected operator or nearby unprotected workers appeared evident at such installations.
- Enclosed facilities such as blasting rooms, in moderate disrepair with leakage through door seals, and through holes worn in walls, developed only local nuisance dust concentrations.
- Enclosed, ventilated automatic and cabinet blasting machines, when in good repair, developed little dust leakage. There appeared no hazard from dust exposure to either an operator or nearby workers.
- Non-enclosed, portable, hand-operated blasting machines generated extensive dust clouds. Typically, no control was exercised to prevent unrestricted dust spread. Several installations demonstrated hazardous dust exposures to poorly protected blast operators and to nearby workers.
- Where metallic shot or slag was used as an abrasive, dust concentrations around protected blast operators and nearby workers consistently fell below the present OSHA limitations and ACGIH guidelines.
- Where silica sand was used as an abrasive, dust concentrations around protected and unprotected blast operators and nearby workers constantly exceeded the present OSHA limitations and ACGIH guidelines.

2. Ventilation and Dust Removal

Satisfactory dust removal during and after blasting was found in all but three of ten blasting rooms and ventilated enclosures surveyed.

- Downdraft and crossdraft blasting rooms, using steel shot and slag abrasives, provided good working visibility in all cases where the air flow rate was at or above 18 CFM/FT².
- Two blasting rooms using steel shot demonstrated sluggish dust clearance and impaired visibility at air flow rates of 11 and 15 CFM/FT².
- A large hood, with ceiling exhausted air flow, provided very poor silica sand dust removal which in turn reduced visibility. The air flow in this case was determined to be 49 CFM/FT².
- Two additional facilities demonstrated satisfactory dust removal during blasting. An open-faced shed with crossdraft ventilation was adequately cleared of silica sand dust at 140 CFM/FT². A shipboard tank, ventilated at 57 CFM/FT², adequately cleared slag abrasive dust during pressure blast cleaning of the internal surfaces of the tank.
- All facilities demonstrated rapid dust removal at blasting cessation so as not to create a dust exposure hazard for the blast operator after helmet removal. Air rates as low as 1.2 - 1.3 changes/minute were found to be satisfactory.
- All facilities demonstrated adequate air inlet baffling and inlet air velocity so as to prevent unrestricted dust escape. Inlet air velocities were found to be as low as 250 LFM.

3. Sound Level Exposure

Out of 22 separate abrasive blasting facilities visited, only 5 produced sound levels that would allow a normal eight-hour working day without exceeding the present OSHA regulations. At one installation the operator could use his equipment only five minutes working time per day if federal sound limits were observed. (He did use ear plugs, however.) Hearing damage was subjectively observed at some facilities, and the use of personal hearing protection was not a prevalent practice.

4. General Safety

The manufacture of abrasive blast cleaning equipment is a price-competitive business. To meet pricing competition, most machines are sold on a basic or "stripped" basis. Numerous safety items and automatic controls are available from the manufacturers, but they are sold as optional equipment being added to the basic machine only when specified

by the purchaser. If provided as standard equipment, such items as dust collectors, negative pressure interlock/sensing control valves, pneumatic remote control valves, compressed air purifiers, moisture separators, and air-supplied helmets would greatly reduce the developed health and accident exposures.

The greatest single adverse factor observed at most locations involved poor maintenance of the blast cleaning equipment. Rarely are the manufacturers' preventive maintenance procedures followed. Poor maintenance procedures developed unsafe conditions that:

- affect the workers' life support system
- permit the escape of abrasive from blasting chambers
- create a dirty and dusty environment in the immediate and nearby work areas
- permit the operator to work from unsafe footing
- prevent observation of the operator from the exterior of a cleaning booth, room, or chamber
- distract from the operating efficiency of dust collection systems
- contribute to the development of excessive noise levels
- result in sudden and accidental abrasive hose failure
- restrict the workers' vision

From an engineering design standpoint, certain machines may have superior or built-in safety and health protection; however, each machine type does have the same basic features. It cannot be stressed enough that the greatest number of undesirable conditions are developed from poor maintenance and service of the available equipment.

D. CONCLUSIONS

1. Dust Exposure

a. Blast operators using hand-held nozzles are continually exposed to very high dust levels regardless of abrasive material or facility type, i.e., open air or enclosures. These operators must therefore be protected by well-maintained, respirated helmets.

b. Non-enclosed, portable blasting machines are not generally provided with means of restricting dust spread. Where a health hazard from dust exposure exists in the blasting vicinity, such as with silica sand, workers should be prohibited from the area until the blasting operations have been completed. Where only a nuisance hazard exists from dust exposure in the blasting vicinity, as with nontoxic abrasives such as steel shot, workers should be required to use respiratory protection, such as dust masks and/or hoods, while blasting operations are in progress.

c. Silica sand is an extremely toxic material and a difficult abrasive to control. Where silica sand is in use with hand-held blasting nozzles, blast operators must be protected with well-maintained, respirated helmets. Where silica sand is in use with non-enclosed, hand-held blasting nozzles, excessive dust concentrations are often generated up to one hundred feet from the blasting operation. If nearby workers must be present, they must have adequate respiratory protection.

d. The most effective safety measure would be to prohibit the use of silica sand abrasives in the abrasive blast cleaning industry.

e. Nonsilica abrasives such as slag or steel shot are the safest materials for use as they are typically nontoxic and do not cause excessive dust exposure hazards. Nearby workers are often exposed to such dust; however, it is primarily only a nuisance and an irritant.

2. Ventilation and Dust Removal

a. Enclosure crossdraft and, preferably, downdraft ventilation systems should be designed to provide adequate dust clearance for visibility with a minimum air flow rate of ~ 20 CFM/FT² past the blast operator while using nonsilica abrasives.

b. Updraft ventilation, counteracting the natural tendency of dust to settle, provides very poor dust removal unless unrealistic air velocities, such as are found within exhaust ducting, are designed into the ventilation system.

c. Interior blast cleaning operations, such as in tanks and cabinets, should be exhaust ventilated to allow worker visibility.

d. Enclosure crossdraft and downdraft ventilation systems at greater than 1.2 air changes per minute provide for satisfactory dust removal at blasting cessation so as to prevent dust exposure hazards with nonsilica abrasives in use. A blast operator typically takes 15-30 seconds to remove a helmet; this is an adequate time for heaviest dust to be removed.

3. Sound Level Exposure

a. Little attention has been given to reducing noise levels at the blast cleaning equipment manufacturer's level, although some attention has been given to hearing conservation at the user's level.

b. There appears to be little concern for hearing protection on the part of the user and the individual operator himself.

c. Noise reduction should be an active concern of the manufacturers of the abrasive blasting equipment, but significant noise reduction would be a difficult task.

d. Because abrasive blasting does not require a high degree of manual skill, it seems that little penalty would be incurred in frequent rotation of operating crews in order to reduce the noise exposure time.

e. Noise reduction in automatic or cabinet installations is more easily accomplished than in portable units and in blasting rooms where the operator is physically located at the noise source.

4. General Safety

a. Maintenance conditions within blast cleaning rooms and on automatic type machines is generally poor.

b. Personal safety devices and automatic controls are readily available for use on all types of abrasive blast cleaning machines; however, many installations lack such devices or the machine operator by-passes them.

c. State-of-the-art personal protective equipment (masks and hoods that lack breathing air, breathing-air purifiers, protective clothing, and metal air-supply helmets) needs upgrading to provide greater protection for the worker. In addition, suitable cabinets should be provided for the protection and clean storage of personal protective equipment when not in actual use.

d. Abrasive blast cleaning machines (all types) are frequently positioned in densely populated work areas where nearby workers are exposed to dust and noise levels that could be injurious to their health.

e. There are varying designs of "deadman" abrasive flow shut-off controls. They range from spring levers, to continuous push button, to pinch hose controls. Some designs do not develop a positive shut-off of the abrasive discharge and can be operated by the weight of the hose and nozzle when dropped to the ground. Other units can develop an abrasive discharge when driven over by a truck or when the control hose is otherwise depressed.

f. The pressure vessels or "pots" on portable and blast cleaning room machines generally conform to the requirements of the 1971 ASME Pressure Vessel Code, Section VIII which defines design, materials, and construction criteria for unfired pressure vessels. Although most vessels viewed were of code construction, a number of "home made" units were viewed in actual operation during the various surveys. A total of 40 of the 50 states have accepted the ASME Code. Most, if not all, of the 40 states require that unfired pressure vessels be internally examined on a bi-annual basis by a competent state or deputized insurance inspector. Since the blast cleaning vessels are generally hidden by location, or are portable units, few of the vessels viewed had been internally inspected during the entire period of the operation life, and some even lack inspection openings.

E. RECOMMENDED CRITERIA

1. Dust Exposure

- Abrasive Blast Operator

a. All abrasive blasting operators using hand-held blast nozzles in open-air portable or fixed facilities in blast cleaning rooms or booths, or in any other enclosures should be protected by air-respirated, nonleaking helmets, regardless of abrasive material used.

b. All abrasive blasting equipment operators using automatic or hand-operated cabinet machines should be protected from nuisance-type dust leakage by suitable respirator masks and safety glasses.

c. Maximum respiratory protection should be mandatory when silica sand is used as an abrasive, regardless of blasting equipment type.

d. Respiratory protection equipment should be inspected daily and replaced or repaired when any leakage is detected.

- Nearby Workers

a. When open air abrasive blasting or any other abrasive blasting operation is performed so as to allow generated dust to spread to nearby workers, suitable measures should be taken to protect those workers:

(1) Respirator masks and safety glasses should be used to protect against nuisance-type dusts.

(2) When dust levels are sufficiently heavy to cause marked discomfort, distraction from work, or a health hazard (according to the best available guide such as ACGIH TLV's), workers should be required to use respirated hoods or change working location until blasting has ceased.

b. Workers associated with automatic and other blasting machines requiring performance of an operation such as airblowing excess abrasive or dust from the cleaned object, should be protected from nuisance-type dust by suitable respirator masks and safety glasses.

c. Maximum respiratory protection should be mandatory when silica sand is used as an abrasive regardless of blasting equipment type.

d. Respiratory protection equipment should be inspected daily and replaced or repaired when any leakage is detected,

- Equipment Maintenance

a. All blast cleaning equipment, especially blasting rooms, booths, cabinet type and automatic machines should be well maintained to prevent development of dust leaks. This applies to any dust escape, whether simply nuisance or in sufficient quantity or size to cause a health hazard by impact or inhalation.

2. Ventilation and Dust Removal

a. A downdraft or crossdraft exhaust-type ventilation system should be designed into abrasive blasting enclosures to provide effective dust removal. The enclosures should be designed and well maintained to prevent air leakage through seals, holes, or other openings which would interfere with a uniform downdraft or crossdraft flow pattern.

b. Downdraft ventilation should be preferentially used in totally enclosed abrasive blasting facilities. Dust removal by air flow is thereby augmented by the natural tendency of dust to settle by gravity.

c. For adequate dust clearance, a minimum air flow rate of approximately 20 CFM/FT² should be used with nonsilica abrasives. Higher minimum rates should be used with low density or toxic abrasives that exhibit a tendency to fracture extensively. For example, past experience has shown 80 CFM/FT² to be effective for the control of silica sand dust.

d. Crossdraft ventilation is effective both in totally enclosed abrasive blasting facilities and in semi-enclosed abrasive blasting facilities. Air flow rates should be in the same range (preferably higher) but no lower than those for downdraft systems designed for identical operating conditions.

e. Upflow ventilation should not be used in abrasive blasting enclosures.

f. All required openings on abrasive blasting enclosures should be designed with baffling to prevent unrestricted dust leakage. Also minimum inlet air velocities of 250-300 LFM through such baffled openings should be developed to prevent dust leakage.

g. Abrasive blasting enclosures should be designed with uniform downdraft and crossdraft air flow patterns to insure the most prompt clearance. Turbulence by leakage or poor flow distribution slows dust clearance rates and should be eliminated.

h. Uniform air rates greater than 1.2 changes per minute, combined with velocities sufficient to provide good visibility during blasting, should be provided to quickly reduce dust concentrations and alleviate any potentially dangerous dust exposures.

3. Sound Level Exposure

The most up-to-date criterion which has received the most thoughtful consideration is the OSHA Regulation Section 1926.52 reproduced here (Figure 14) from the Federal Register of December 16, 1972. Further reductions of the levels by 5 dB are presently being discussed. It is not likely that state or local municipalities would have criteria better established or justified than the above.

It is recommended that these OSHA regulations for occupational noise exposure also apply for abrasive blast operators. It should be understood that measured levels at the operator's ear must be modified by the known attenuation characteristics of any ear protection devices used.

4. General Safety

- Hand-Operated Portable and Room Type Blast Cleaning Machines

- a. Mechanical

(1) All units should be equipped with a positive fast-acting abrasive shut-off control that must be depressed by the operator to commence blasting operations. The design should be such that the machine cannot be operated by the weight of the hose and nozzle if the nozzle is dropped, or by other means of "on ground" depression, cutting, or pinching by pedestrian, vehicular, or other traffic.

(2) Hose lines which are exposed to internal deterioration from abrasive action should be subjected to regular nondestructive integrity testing on an elapsed time basis. The initial test after use can be of a greater time span than the subsequent tests which should be conducted more frequently depending on age. The elapsed time between testing should be determined by the hose manufacturers based on the types of hose construction and on the type of abrasives for which the hose has been designed or will be used. The user should maintain test records

and make them available to the OSHA Compliance Officers or any other designated safety inspectors.

(3) On a time-use basis, all metal pipe lines, joints, bends, valves, connectors, and nozzles should be subjected to regular internal inspection to detect deterioration from internal abrasion. Defective parts should be replaced promptly to avoid sudden and accidental failure. The time test period should be established by the user on the basis of previous failure and/or past replacement time procedures. The user should maintain and make them available for examination by OSHA Compliance Officers and other designated safety inspectors.

(4) Pressure "pots" or vessels used in conjunction with abrasive blast cleaning operations should be examined for internal deterioration on a regular two-year frequency. Following each five years of operation, the "pot" or pressure vessel should be subjected to a hydrostatic test at a pressure of 1-1/2 X designated maximum working pressure. Such inspections and testing should be conducted and/or witnessed by an individual who has attained proven competency in this work such as an ASME/National Board Commissioned Inspector, or a state or deputized insurance company inspector. The use of pressure "pots" or vessels which lack a removable hand-hole plate that permits internal examination should be prohibited. All "pots" or vessels should be constructed in accordance with ASME pressure vessel code requirements.

(5) Pop-up valves used to pressurize the "pot" or pressure vessels should not be fabricated of all rubber construction. Rubber seals may be used as long as the valves have an internal metal core of greater diameter than the opening in the tank top. Rubber-covered valves and tank top seals should be checked frequently for deterioration, and defective parts should be promptly replaced.

(6) Pressure "pots" or vessels should be designed in a manner that will permit free and easy entry of the abrasive, reduce spilling, and generally aid in the prevention of strains and sprains when the "pot" is being filled manually. In this respect it is preferable that the upper fill head be of concave design.

(7) The interior floors, ledges, and shelf surfaces (whenever practical the latter two items should be avoided) of blast cleaning rooms should be cleaned of waste abrasive and debris on a regular daily basis whenever the facility is used. The person or persons conducting such cleaning operations should be supplied with and instructed to wear suitable respiratory protection during such cleaning operations. In addition, all floor surfaces within the room or chamber should be continually examined for abrasive deterioration and distortion and prompt repairs should be made to provide an even floor surface that will not contribute to slipping and falling accidents.

(8) Blast cleaning rooms should be inspected on a regular weekly basis to detect holes, abraded metal enclosure surfaces, and defective door seals that can permit the escape of abrasive material. Such defective sections should be subjected to welding repair or replacement as the extent of deterioration warrants. Whenever practical, the interior of blast cleaning rooms should be rubber lined to reduce operating noise and to protect the metal sidewalls from abrasive deterioration.

(9) In a similar manner to Item 8, split or divided blast cleaning rooms that permit the entry of work on an overhead traveling crane should have the division seals examined, at least weekly, and defective seals should be replaced promptly.

(10) Whenever the blast cleaning process entails the cleaning of heavy or bulky objects, an adequate means of handling such items prior to, during, and after blast cleaning should be provided.

(11) All doors of a blasting enclosure should be kept closed at all times when blasting is being done and should be kept closed for a reasonable time after the blasting has ceased.

(12) All moving mechanical devices, conveyor belts, and other mechanical drives should be mechanically guarded to prevent physical contact with moving machinery. Protection by remoteness is not considered adequate since maintenance personnel can still be injured in the machinery.

(13) Each blast cleaning room should have at least two inspection ports located in such a position that the operators can be clearly viewed from an external source at all times. The internal protective guard or cover for such inspection ports should be maintained to open and close freely and thereby protect the vision glass from abrasive etching.

(14) Doors providing entrance and exit for blast cleaning rooms should operate freely and should not be obstructed or otherwise restrict fast exit. The doors should not be lockable on the inside or in any way prevent the entry of emergency assistance into the blasting enclosure.

(15) Waste abrasives should be cleared from work areas on a regular daily basis and should not be permitted to accumulate or stockpile. The method of disposal should not cause environmental problems.

b. Electrical

(1) All motors used in conjunction with abrasive blast cleaning equipment should be of totally enclosed dust-proof design.

(2) All electrical controls should be confined in dust-tight enclosures meeting the design criteria of The National Electrical Manufacturers Association (NEMA) Spec. 12.

(3) The main abrasive supply hose line should be provided with an efficient means for the discharge of static charges from the blasting nozzle. It is preferable that the grounding system be built into the hose line rather than utilizing a separate grounding cable attached to the outside of the hose since exterior grounding systems are easily damaged and rendered worthless. The grounding system should be subjected to a ground continuity test on a regular weekly basis prior to the commencement of work operations at the beginning of each workweek. Test records should be maintained and be made available for review when requested by federal, state, municipal, or other safety inspectors.

(4) All electrical lighting within the confines of blast cleaning rooms should be 100 percent operative at all times, and the protective glass shades or plates should be promptly changed when the glass becomes etched and restricts light emission. The illumination within every blasting chamber should not at any time be less than twenty foot-candles over all parts of the chamber measured in a horizontal plane at three feet above the floor.

c. Personal Protective and Life Support Equipment

Each operator should be provided with and instructed to wear the following personal protective equipment:

(1) An air-supplied breathing helmet, which bears a distinguishing mark indicating that it has been allotted to an individual operator. Such helmets should not have been previously worn by any other person or should be subjected to a thorough cleansing and disinfecting since last being used by another person.

(2) The use of helmets and/or masks lacking a self-contained source of breathing air should be prohibited since they lack an air seal to prevent dust entry into the helmet or mask and are frequently used for periods of time in excess of the designed temporary or short-term use.

(3) The air supplied into self-contained breathing helmets should not be drawn from the main air supply compressor. A separate oil-free compressor should be used to supply breathing air. In addition, the breathing air should be air conditioned and cooled to a temperature in the range of 65°F. It should also be passed through an air purifier before entering the operator's helmet. Each breathing-air supply system should be equipped with an audible alarm that will warn the blast cleaning operator, his helper, or other workers in the vicinity that the breathing supply is contaminated with smoke or carbon monoxide.

(4) Self-contained breathing helmets should be designed to accommodate and permit the use of sound-reducing ear muffs either as built-in protection or to fit over conventional ear muffs. Until sound reduction techniques within self-contained breathing helmets has been applied the use of ear muffs and/or ear plugs should be mandatory to insure that the 90 dB(A) level is not exceeded. This also applies to other workers within the high noise level area.

(5) Vision glasses in self-contained breathing helmets should be replaced promptly when the glass becomes etched from abrasive impact. The condition of such glasses should be checked on a weekly basis by the blast cleaning operator's direct work supervisor. The use of protective mylar films over vision glasses is highly recommended.

(6) Abrasive blast cleaning workers should be provided with and instructed to wear safety boots or toe guards.

(7) Each operator should be provided with and instructed to wear suitable gauntlet gloves and coveralls that will prevent abrasive materials from contacting the skin from entry through breaks in clothing. This requirement is additional to the protection afforded from leather or rubberized capes associated with self-contained breathing helmets and protective leg chaps. The lower leg of such coveralls should be belted and buckled or taped closed around the workers safety boot to prevent the entry of abrasive.

(8) In addition to the stipulated personal protective equipment a suitable, clean locker or container should be provided for each operator to store equipment in a clean condition. Such storage accommodation should be in a dust-free area outside of the blasting area but as close as practical to the area of operations.

(9) Silica sand as an abrasive cleaning agent should be prohibited from use with all hand-held abrasive blast cleaning machines.

(10) No worker that has been involved in extensive (over 4 hours) blast cleaning operations should be assigned to spray paint operations within the same workday.

- Hand-Operated Cabinet Machines
- a. Mechanical

(1) The exhaust fans of cabinet machines should be acoustically engineered to the extent that the resulting noise level does not exceed the federally stipulated 90 dB(A).

(2) All cabinet machines, including small bench-top type units should be equipped with a forced-air type dust collecting system. Gravit;- settling dust collecting systems should be prohibited since they restrict vision and can become overpressured causing leakage of abrasive.

(3) The use of open-front cabinet machines as used in the suede preparation and cleaning industry should be prohibited.

(4) The observation port on all hand-operated cabinet machines should utilize only safety glass. Each vision glass should be designed to visually indicate that safety glass observation ports have been provided.

(5) Door seals on cabinet units should be inspected weekly, and defective seals should be promptly replaced.

(6) All metal surfaces within cabinet machines should be designed to eliminate flat dust-collecting surfaces. Angled surfaces should be provided that will aid in directing the abrasive and debris into the dust-collecting system.

(7) Dust-collecting systems on cabinet machines should be cleared of blockage on at least an hourly operational basis. Dust collection bags should be inspected on a weekly basis and defective bags should be promptly replaced.

(8) Foot-type controls used to activate cabinet machines should be equipped with a stirrup-type guard that will prevent accidental operation of the machine.

(9) The internal surfaces of all cabinet machines should be inspected on a regular weekly basis to determine any thinning of the metal casing from abrasive action. Deteriorated sections discovered during inspection should be promptly repaired or replaced.

b. Electrical

(1) All machines should be provided with an efficient means for the discharge of static electricity from the blasting nozzle. In addition, the cabinet machine operator should be provided with an easily attachable grounding strap that will protect him from static electrical shock.

(2) All cabinet machines should be equipped with the following **failsafe** control protection:

- A negative-pressure control switch that will prevent operation of the machine unless a negative pressure is evident **within** the cabinet
- An electrical interlock control that will prevent machine operation unless the main access door is in the closed position

(3) All operating **controls** should be of dustproof NEMA Spec. 12 **design**, and the control boxes should be kept closed at all times unless being serviced by a **competent** electrician.

(4) Electrical lighting within cabinet **machines** should be **adequately maintained**, and etched shades or protection glasses that restrict light emission should be promptly replaced.

c. Personal Protective and Life Support Equipment

(1) Each machine operator should be provided with and instructed to wear complete eye protective equipment when operating his machine.

(2) Each machine operator should be provided with and instructed to wear safety boots or toe guards during working hours.

(3) Each machine operator should be provided with and instructed to wear a dust respirator while operating a cabinet machine, an when removing **abrasive** residue and debris from the dust collecting system.

• Automatic Machines

a. Mechanical

(1) The internal surfaces of all automatic machines should be inspected on a regular weekly basis during which the following items should be given special consideration and prompt corrective action:

- Badly abraded recirculating pipes should be replaced.
- Abraded case-hardened wear plates and especially their **retaining** nuts should be promptly replaced.
- Worn, distorted, or otherwise deteriorated floor plates or gratings that can create a trip, slip, or fall hazard should be promptly replaced.
- Abraded and otherwise damaged steel to steel, steel to rubber, or rubber to rubber door seals should be promptly repaired or replaced.
- Abraded frames, casings, or other enclosures that can result in the escape of abrasives or dust should be repaired or replaced.

(2) Dust exhaust fans and shaker-type abrasive waste separation systems were found to be exceptionally noisy, and most systems exceeded the existing 90 dB(A) noise level. All such systems should be re-engineered until the noise levels meet or are below the federally stipulated 90 dB(A).

(3) The discharge of waste materials from magnetic and other type separators should not terminate into open bins or containers. Such bins or containers should be covered to effectively control the emission of dust clouds into open work areas.

(4) All machine drives, coupled or belted, should be mechanically guarded to prevent physical contact. Reference is specifically made to door closing belt drives, exhaust fan belt drives, shaker conveyor and dust collector vibratory drives.

(5) **Removable** floor plates and/or gratings providing access to below grade level shaker-type separators should be kept in position at all times during machine operation. During maintenance work such floor openings should be barricaded to effectively restrict access to the maintenance work area and specifically the unprotected floor openings.

(6) All steel cables used to open and close the doors of automatic machines should be **examined** on a regular quarterly basis. Such cables should be replaced under the following conditions all of which warrant condemnation of a cable:

- Excessive dryness and an exterior brick dust effect that indicates internal corrosion working out to the exterior of the cable.
- Six or more wire breaks within the lay (one complete revolution or wrap) of a single strand of the cable, or indication of flattening or abrasion of one or more strands of the cable.

(7) All dust-collecting systems should be inspected and serviced on a regular weekly basis with prime consideration that:

- All ducts and ventilation screens are clean
- The maximum manufacturer's air flow rates are maintained at all times
- Bags, screens, filters, and other dust collecting devices are in peak working condition
- Dust collection bins and containers are covered to effectively contain the dust discharge

- Discharge bags between the final hopper discharge and the collection bin or container are in good working order
- No blockage exists at any location within the dust collection system and its ultimate discharge

b. Electrical

(1) All doors, main, or manual access, should be equipped with electrical interlocks that will prevent operation of the machine unless all doors are tightly closed. The effect of opening any door should immediately stop machine operation.

(2) All motors used in conjunction with automatic blast cleaning machines should be of totally enclosed dust-proof design.

(3) All electrical controls should be confined in dust-tight enclosures--boxes or cubicles that meet the design criteria of NEMA Spec. 12.

(4) The breaking of a tumble belt or rotating table drive belt should immediately prevent further operation of the machine until the belt is repaired or replaced.

Special Note: In addition to running all parts being cleaned such frequent belt failures cause the operator to remain close to the machine where he can be exposed to dust inhalation.

c. Personal Protective and Life Support Equipment

(1) Each machine operator and/or attendant or assistant should be provided with and instructed to wear complete eye protective equipment.

(2) Each machine operator and/or attendant or assistant should be provided with and instructed to wear safety boots or toe guards.

(3) Each machine operator and/or attendant or assistant should be provided with and instructed to wear coveralls that will restrict the entry of abrasive into clothing breaks from which it can make physical contact with the skin.

(4) During machine operation each machine operator and/or attendant or assistant should be provided with and instructed to wear a dust control breathing respirator. Such a device should also be worn by all workers servicing any phase of the dust collecting system.

II. INTRODUCTION

A. ABRASIVE BLAST CLEANING OPERATIONS

The technique of abrasive blast cleaning involves the utilization of hand-held or automatic equipment which directs a pressurized blast of wet or dry abrasive material against a metal, masonry, or synthetic surface in order to clean the surface, remove burrs, or develop a matte surface finish. The cleaning technique is further used to remove "flashing" (excess material) from molded plastic and rubber. The latter material is cryogenically hardened prior to abrasive cleaning. Among other uses, automatic wet blast machines are used to dress, clean, dry, and pack golf balls. The process is an integral part of many industries. During the various plant surveys conducted as part of this study, pressure blast cleaning operations were viewed at a foundry, a shipyard, a steel fabrication plant, a special purpose job and machine shop, a gas transmission station, a steel mill, and a structural steel supply yard.

The abrasives used for cleaning purposes vary from metal shot and grit, to a large range of nonmetallic abrasives, such as garnet, flint, quartz, and silica sand. Organic substances such as nut shells, cereal husks, and sawdust are used to clean delicate surfaces.

The process is alleged to have originated only as recently as 1904¹ and three principal mediums are now employed in the business:

- Pressure Blast Machines

Dry compressed air is used as a transportation medium to discharge the abrasive through a flexible hose line and nozzle onto the surface being cleaned.

- Centrifugal Blast Wheel Machines

In this method the abrasive force is gained by the use of an impeller wheel. The abrasive is fed into the hub of the wheel and transferred onto its blades. The wheel, rotating at high speed, propels the abrasive with considerable impact velocity onto the work by centrifugal force from the ends of the blades.

- Wet Blasting Machines

In this technique the abrasive is mixed with water, and frequently a rust inhibitor, to form a slurry that is pressurized onto the work surface.

¹ Hunter, David, "The Disease of Occupations." The English Universities Press (1971), p. 992.

B. OPERATIONAL HAZARDS

The use of metal shot and grit and mineral substances, and to a greater degree silica sand, is hazardous to health if the dust created during blasting is inhaled into the workers' respiratory tract. Other conditions that can impair the workers' safety and health include: (1) lengthy exposure to noise levels of over 90 dB(A) from noises that originate within the operators' breathing helmet, at the abrasive discharge nozzle, from the impact of the abrasive on the surface being cleaned, and from noisy dust exhaust systems on cabinet and automatic blast cleaning machines; and (2) the presence of oil mist, smoke, and carbon monoxide contained in contaminated life support air. In addition, there are general safety problems inherent to working in confined spaces or at unusual heights and to doing heavy lifting. Then there is the constant possibility of physical contact with the abrasive discharge.

C. PROTECTIVE REGULATIONS

Under the Williams-Steiger Occupational Safety and Health Act of 1970, the federal government was given the responsibility to establish, as rapidly as possible, safety and health standards to improve industrial working conditions and to provide a maximum of safety and health protection for all industrial occupations. Such rules, regulations, and standards are now contained in the Federal Register, Title 29, Volume 37, Number 105, Part II, dated Saturday, May 29, 1971. It is, however, the responsibility of HEW's National Institute of Occupational Safety and Health (NIOSH) to conduct safety and health research, the findings of which when submitted and accepted by the Occupational Safety and Health Administration, Department of Labor, can be introduced as an extension and improvement to existing safety and health standards. This study was completed in an effort to extend and/or improve the existing rules and regulations as they currently apply to abrasive blast cleaning operations under "Sub-part G, Occupational Health and Environmental Control" Sections 1910.93 through 1910.95 of the previously stated Federal Register.

III. TECHNICAL DISCUSSION

There are basically five types of abrasive blast cleaning systems. The hazards associated with each type were viewed and evaluated during this study.

A. PORTABLE BLAST CLEANING MACHINES (Figures 1 and 2)

The greatest health and accident hazards in abrasive blast cleaning are associated with this type of machine since silica sand is frequently used as the abrasive medium and the resultant dust cannot be effectively controlled. In addition to developing an acute dust situation, the residue abrasive and debris are frequently windblown from the work site and cause residue disposal problems. Frequently, the residue remains on the ground to be leached away as a pollutant into the nearest body of water.

The basics of the machine include a source of compressed air, in the 90 to 100 psi range, capable of producing high volumes of air supply, a container or pressure vessel to contain the abrasive, a metering device to effectively control the air-to-abrasive ratio and flow, a flexible hose to deliver the abrasive, and a hand-held nozzle to aim the abrasive onto the blasting surface. In addition, many portable units have large hopper-fed storage tanks that permit multiple blasting operations from a single supply source.

The units can be operated either manually or automatically. The manual type generally requires a "pot" attendant who manually controls the abrasive flow on the basis of signals received from the nozzle operator. The automatic machines are equipped with controls that start and stop the operation by use of a flow control valve or "deadman" switch on the nozzle. When the operator closes the valve, the machine starts and the air and abrasive mixture is ejected from the nozzle. When the operator releases the flow control valve, the abrasive discharge stops and the machine depressurizes.

Water supply heads are available that can be attached to the nozzle enabling it to jet water into the dry blast discharge saturating the abrasive in suspension, thus converting dry blast into wet blast operation.

B. HAND-OPERATED UNITS WITHIN BLAST CLEANING ROOMS (Figure 3)

Although larger hoppers can be used for the storage of abrasive (since in most cases the abrasive is recycled), the actual operating end of this type of system is similar in all respects to the portable units previously described. The main benefits resulting from the use of blast cleaning rooms are (1) the ability to provide and use a dust control ventilation system, (2) the cost saving from recycling the abrasive, and (3) the fact that the resulting dust and debris does not spread over great areas to expose other workers and machinery to injury and damage.

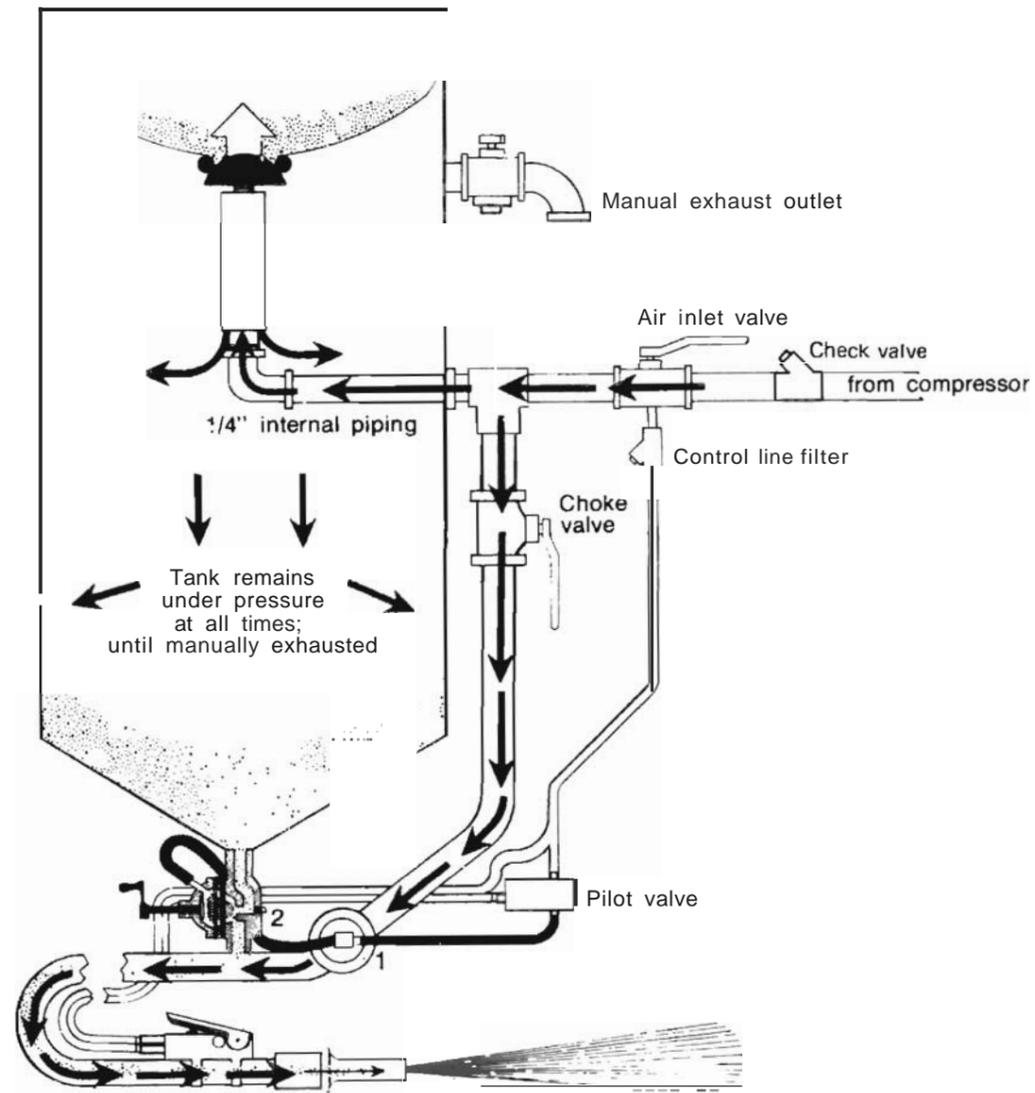


FIGURE 1 PORTABLE BLAST CLEANING UNIT

Courtesy: Pauli & Griffin Co" San Francisco, California.

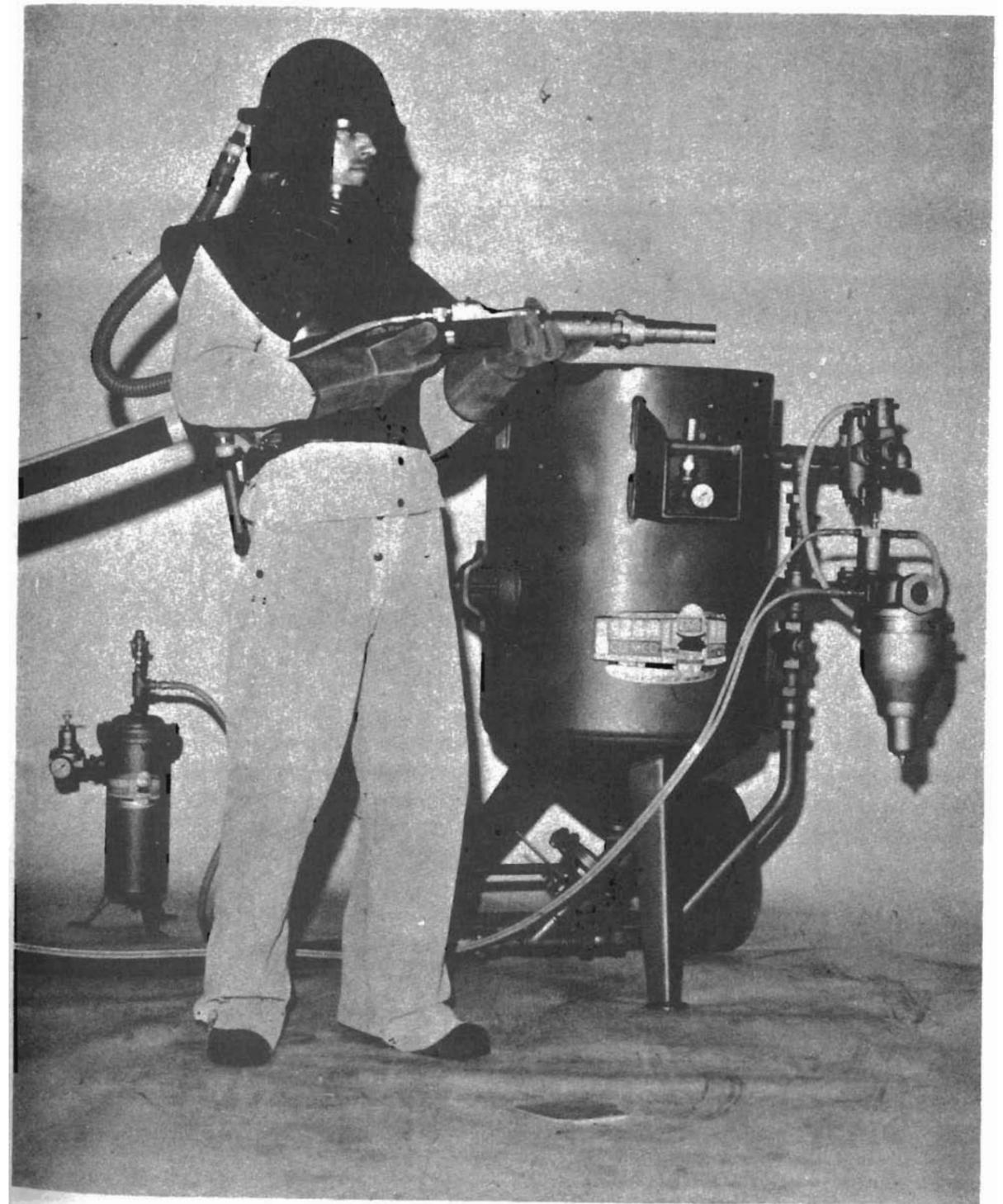


FIGURE 2 PORTABLE BLAST CLEANING UNIT WITH OPERATOR

Courtesy: Clemco-Clementina, Ltd.



FIGURE 3 INTERIOR OF BLAST CLEANING ROOM

Courtesy: Clemco-Clementina, Ltd.

The rooms are generally found at plant locations where there is a continual flow of similar objects for cleaning which in turn permits the continued use of one material-handling system.

Blasting rooms vary in size from single compartments to rooms that permit the use of multiple blast cleaning units within a single enclosure. There are in fact some blast cleaning shops that utilize railroad tracks and flat cars to handle pieces to be cleaned. One such shop within one of the nation's larger shipyards can pressure blast clean large pre-fabricated sections of ships.

The exposure to the blast cleaning operations in this type of unit is very similar to that of portable machines; however, the forced air dust control ventilating system aids visibility, and to some extent reduces the possibility of dust inhalation. The personal protective equipment used by the operator normally duplicates the equipment worn by portable cleaning machine operators.

C. HAND-OPERATED CABINET TYPE BLAST CLEANING MACHINES (Figure 4)

Cabinet type units are generally used for cleaning small parts than can be hand held or positioned on a rotatable mandril. In such units the job and the abrasive is confined within a metal cabinet. The direction of the abrasive discharge is then manually, semi-automatically, or automatically controlled. On the latter, the actual cleaning period is closely timed and can be shut off automatically. The manual machines are equipped with a vision glass and two openings into which the operator inserts his hands and arms into rubber gloves and sleeves which protect him from contact with the abrasive discharge. This type of machine is usually equipped with gasketed doors and is operated with a negative internal pressure to contain the dust within the confines of the machine. Negative pressure sensing switches can be used with this type of unit. They come, however, as optional equipment and do not have a long life expectancy due to the abrasive atmosphere within the cabinet. Likewise, the fingers of the rubber gloves have a short life span.

The machines can be designed for either wet or dry blast cleaning. Glass beads are frequently used as an abrasive medium. An average charge would weigh in the vicinity of 50 lbs. On wet blast machines the abrasive-to-water ratio would be in the vicinity of 25%.

Most units are equipped with dust exhaust systems which are vital to maintain internal visibility although many small benchtop machines lack forced air dust-collecting systems.

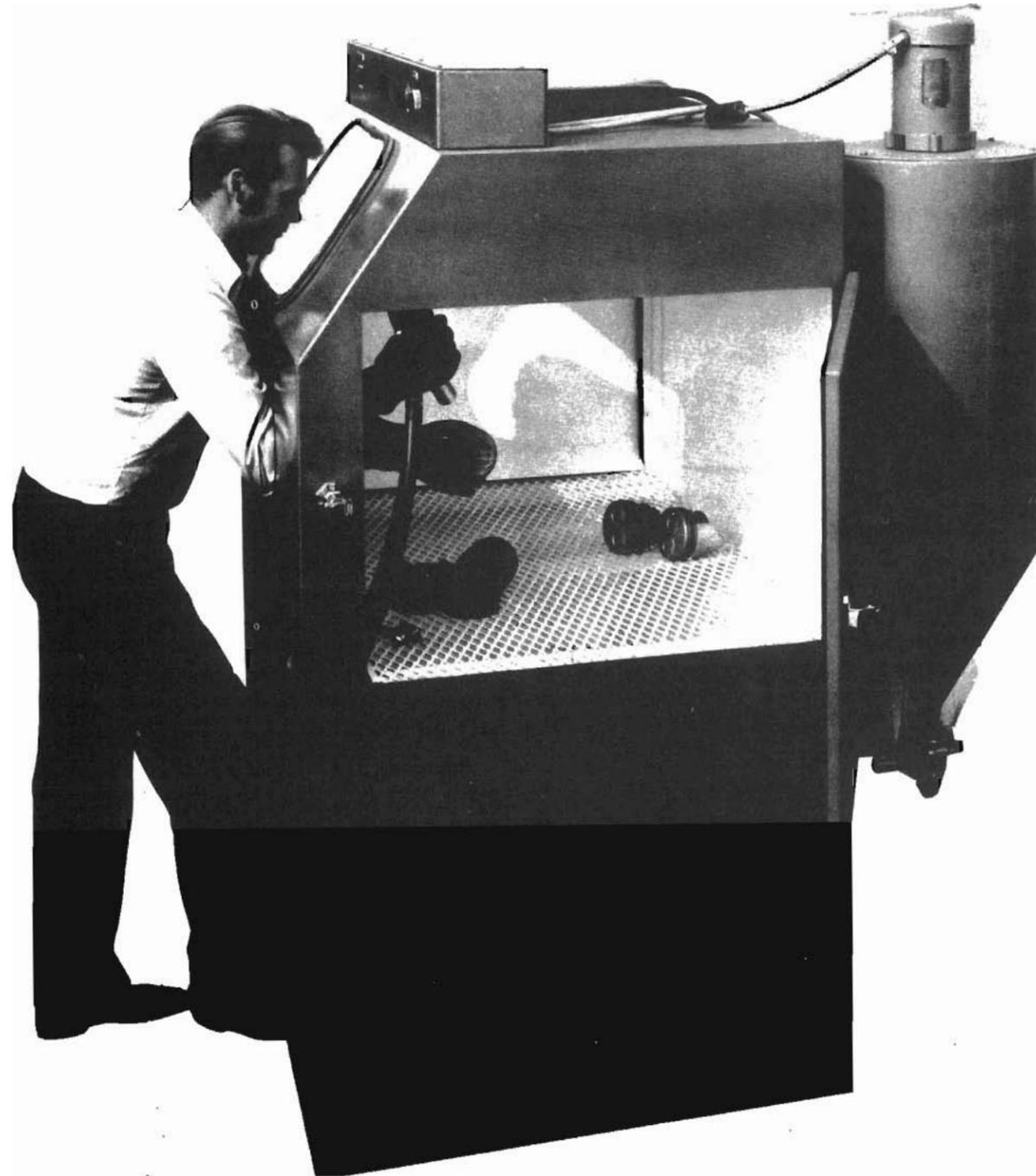


FIGURE 4 HAND-OPERATED CABINET TYPE BLAST CLEANING MACHINE

Courtesy: Empire Abrasive Equipment Corporation.

D. AUTOMATIC BLAST CLEANING MACHINES (Figure 5)

These units are larger in dimension and are more heavily constructed than cabinet machines. Most of them operate on the centrifugal wheel principle and employ timers and automatic shut-off controls to provide the desired amount of abrasive exposure. The work can be placed on either a rotating table or an endless revolving belt that tumbles the job to expose all surfaces to the abrasive. The machines are loaded either mechanically or manually depending on the weight of the job. On tumble blast machines the belt travel can be reversed to automatically unload the cleaned parts into tubs or skips. Rotating table machines are used to clean very large parts. The table can be swung in and out of the enclosed blasting chamber to facilitate loading and unloading. The cleaning action begins once the doors are closed to confine the dust. Such machines separate the debris from the usable abrasive which is then recycled until it breaks down completely and can no longer be used. There are numerous special purpose machines designed and constructed to perform specific blast cleaning operations. Lengthy sections of structural steel can be passed through a machine for cleaning while heavy hanging rubber skirts contain the dust at the point of exit and entry.

Other machines utilize overhead traveling conveyors and enclosed blasting chambers to permit continuous cleaning of parts while passing through the chamber for a carefully timed cleaning cycle.

E. WET BLASTING CLEANING MACHINES (Figure 6)

This method can be applied to portable machines; however, unless the water saturation in suspension technique is used, heavy duty compressors and hose lines are required to propel the slurry. Normally, special purpose machines use the wet blast method continually recycling the slurry. Since rusting of metal parts becomes a problem, rust inhibitors are frequently added to the slurry.

A typical use for wet blast techniques was viewed in the early part of the survey when a special purpose golf ball cleaning machine was viewed in a manufacturing plant. The machine could clean 300 golf balls every five minutes. The balls were poured into a rotating basket within a cabinet type negative pressure machine. The cleaning slurry was later washed from the balls by a hot and cold water rinse, after which they were air dried and conveyed to the packaging section of the machine.

The wet blast operation greatly aids dust control on portable units but results in muddy, wet, and slippery floors in the immediate blast cleaning area.

Some of the newer water jet blast cleaning machines operate at water pressure of up to 10,000 psi. The equipment consists of a power unit and pump, a water filter, a pressure gauge, and a discharge nozzle. Water flow rates of 4 to 14 gpm are developed. The high water pressures

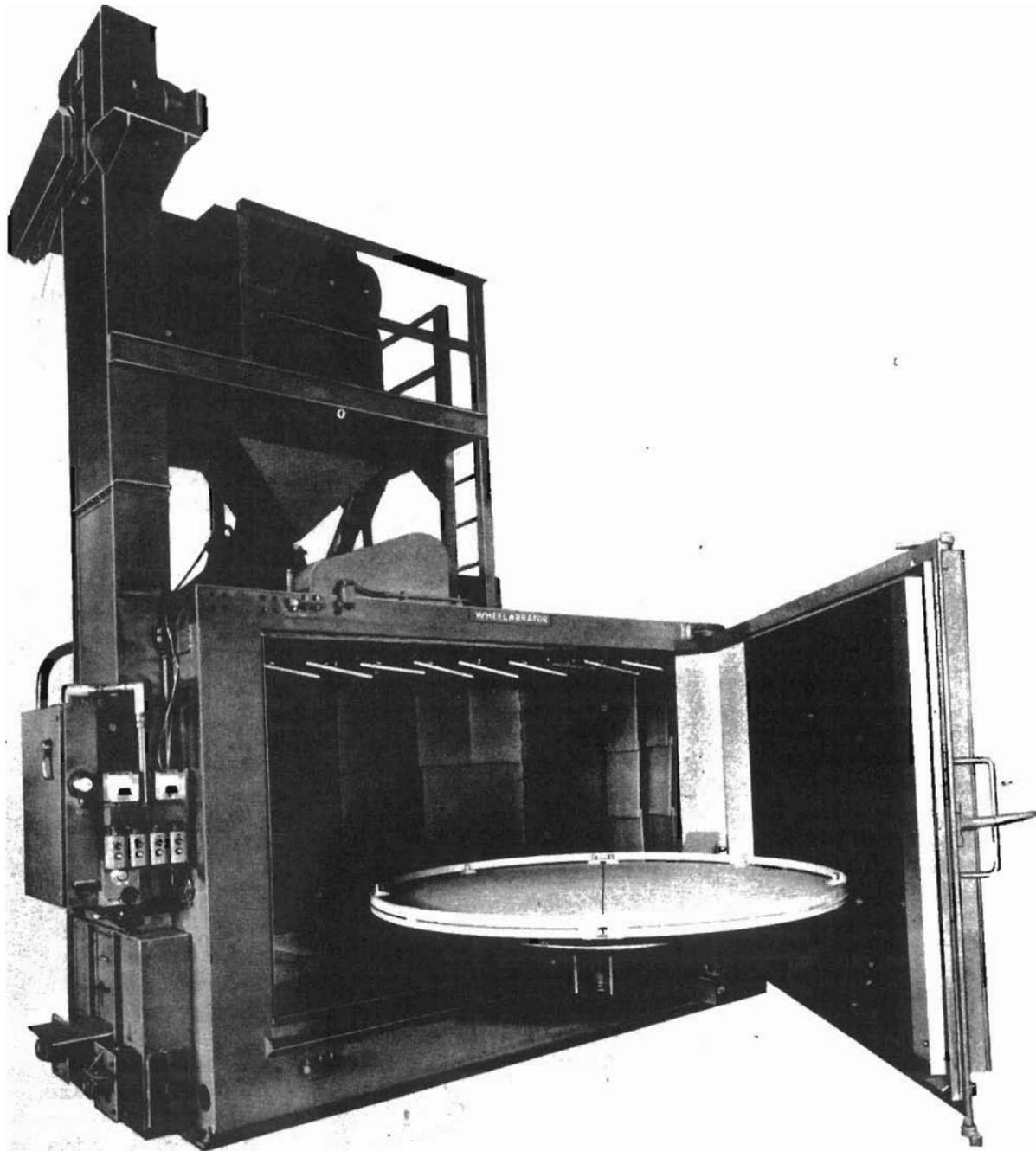


FIGURE 5 AUTOMATIC, SWING TABLE BLAST CLEANING MACHINE

Courtesy: Wheelabrator-Frye, Inc.

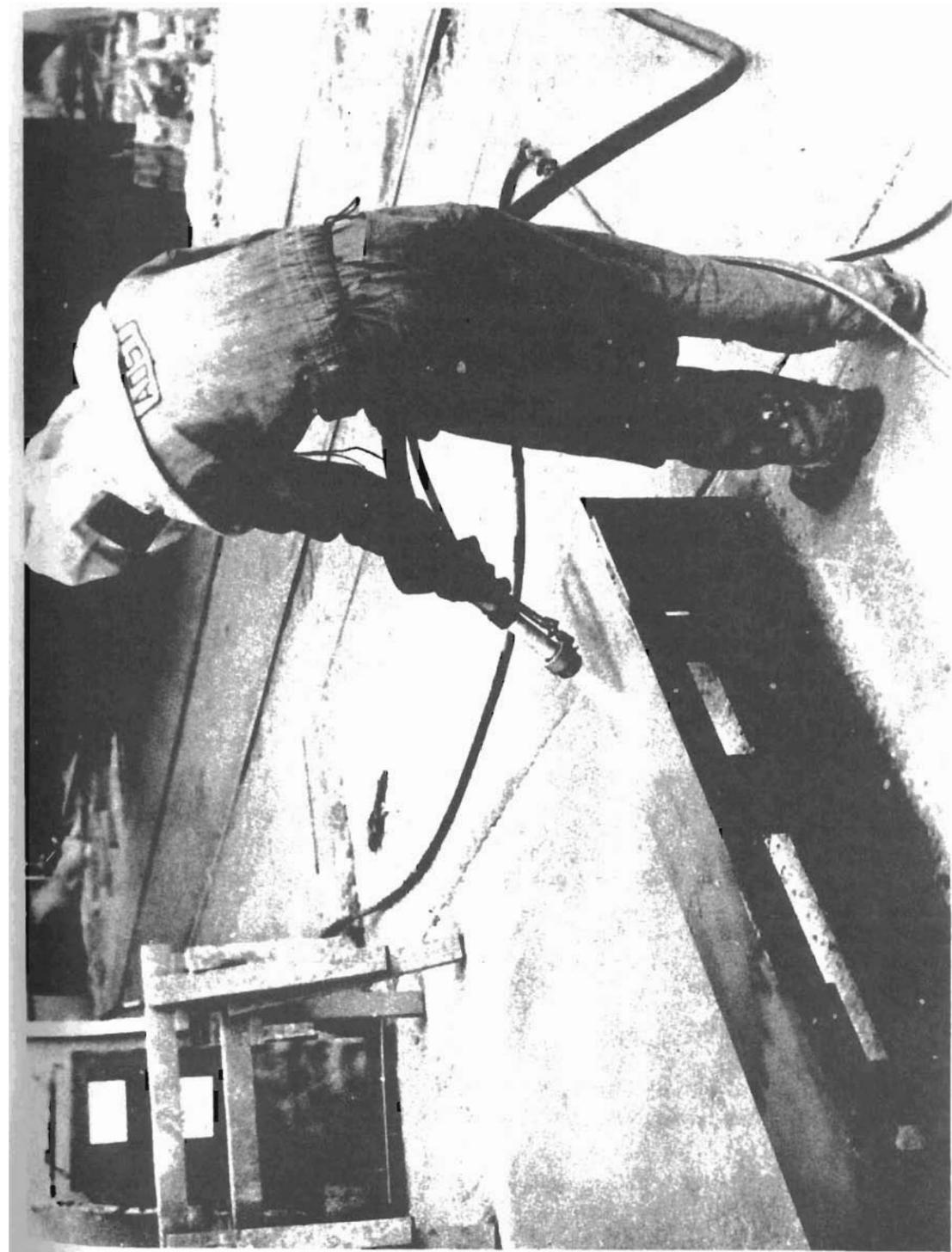


FIGURE 6 PORTABLE WET BLAST CLEANING MACHINE

place considerable strain on the operator¹. Some units utilize a limited supply of abrasive, drawn from an open supply hopper, to aid in the removal of paint from metal and other materials.

IV. PAST HEALTH AND INDUSTRIAL ACCIDENT EXPERIENCE

In an attempt to gain data on past health and accident experience, contact was made with industrial trade unions, members of the medical profession, the industrial accident commissions in all fifty states, and numerous industrial facilities who utilize abrasive blast cleaning procedures. It was quickly learned that there is no central source of accident and health data--the statistics are absorbed into the overall plant accident experience and are not classified as abrasive blast cleaning injuries or health cases. The National Safety Council as a central source of accident data was not in a position to provide definitive accident data directly related to blast cleaning operations.

There is little doubt, however, that sandblasting, and to a lesser degree shotblasting, is a dangerous occupation unless maximum personal protective equipment is provided for the operators and unless the equipment is maintained in peak condition. Our findings indicate that state-of-the-art protective equipment is, by and large, inadequate to provide the degree of protection required for complete security of the worker. In most cases, the protective equipment, as available, is badly maintained and frequently abused by the operator himself.

Some ancient statistics that were accumulated in Great Britain in 1936¹ indicated that sandblasters and shotblasters had an average employment duration of 10.3 years prior to death from silicosis. The employment duration of all other fatal silicosis cases, irrespective of occupational cause, was 40.1 years. The use of sand for blast cleaning operations was prohibited in Britain 24 years ago². However, sand is still used extensively for abrasive blast cleaning in the United States.

Contact with a medical practitioner specializing in pneumoconiosis cases revealed that within recent years he had treated four sandblasters for chest pain, dry cough, weight loss, marked dyspnea. One of the patients died from acute dyspnea after working for eight years as a sandblaster cleaning foundry castings. When blasting, the patient wore a "loose fitting hood with air pumped into the top." The post-mortem showed a diffusely dispersed fine granular infiltration throughout both lungs, more marked in the right lung.

Direct body contact with an abrasive discharge develops horrible injuries that can promptly result in death. When a shipyard worker cleaning metal surfaces between the outer and pressure hulls of a

¹ "Recommended Practice Surface Preparation of Steel and Other Hard Materials by Water Blasting Prior to Coating or Recoating." National Association of Corrosion Engineers Standard RP-01-72 (January 1972).

¹ Merewether, E.R.A. (1936) "Tubercle," 17, p. 385.
² Blasting (Castings and Other Articles) Special Regulations, 1949.

submarine slipped from his angle-iron brace foothold, the abrasive discharge almost severed his left arm. The injury occurred within a period of three seconds, the time period later determined to be the elapsed time for a petcock-type shut-off control to stop the flow of abrasive. The worker fell from his position and bled to death before the accident was detected.

Another serious injury involved a blast cleaning operator who tripped on an uneven floor and dropped the blast cleaning nozzle which was not equipped with a "deadman" shut-off control. A deep hole was abraded a hole in the operator's leg. In this case, the injury resulted in the installation of hold-down type "deadman" switches at all abrasive blast cleaning locations in a large plant facility.

Breathing-air supplies drawn from main air supply compressors has also caused industrial injuries. Cases have been reported where a number of workers using life support air from a central source were overcome by smoke inhalation when the air-supply compressor overheated. Other known cases involve workers who were overcome from carbon monoxide fumes when the breathing-air supply compressor overheated. One fatal accident case is known from carbon monoxide inhalation. It is defined later in this section. Many workers have a double health exposure since they conduct spray painting operations after completing blast cleaning operations.

Various state authorities provided accident data which, although sketchy, substantiates the need for increased safety standards.

Hawaii

Case History

Top head of sandblast tank blew off and sprayed sand in worker's face--blinding him. Worker became mentally unbalanced and died in an institution.

Louisiana

Case History

State experienced 11 deaths during 1968/71 for silica pneumoconiosis. A total of 50 cases treated in past three years.

Michigan

Case History

One worker trapped inside automatic blast cleaning device--injury data not available. One worker injured when duct too heavy with accumulated dust fell on him (inadequate ventilation system).

North Dakota

Case History

A total of 52 no-last-time cases reported during 7/1/66 to 6/30/72.

Pennsylvania

Case History

Sandblast operator died inside tank. Breathing air from main compressor contained carbon monoxide due to compressor's intake being near leaking exhaust pipe. Man had been sandblasting 15 to 20 minutes prior to death (2000 + ppm CO).

Wisconsin

Case History

Condensed accident and health records contain instances of silicosis and other respiratory diseases due to inadequate ventilation and personal protection--no actual case data available.^a



V. EXISTING SAFETY AND HEALTH STANDARDS FOR ABRASIVE BLAST CLEANING

To reduce the accumulated data on existing standards within the United States, Tables I and 2 were developed. Table I presents a synopsis of nationally oriented standards and guidelines. The federally legislated OSHA regulations (CFR, Title 29) are the only nationally enforceable standards at present. The American Conference of Governmental Industrial Hygienists and The American National Standards Institute's material is all of a voluntary nature. Table 2 presents a synopsis of enforceable state regulations in the form in which they were made available.

In reviewing these regulations and guidelines, it is apparent that both duplication and incompleteness exist throughout. For example, voluntary guidelines, OSHA regulations, and state regulations all use a common data base (ACGIH) for dust exposure limitations. However, this exposure problem is frequently not specifically related to the direct hazards encountered by the abrasive blast operator or the nearby worker. Safety regulations are not sufficiently detailed to call attention to and thereby eliminate improper equipment maintenance and degradation. Ventilation requirements are built upon past experience, but often with little emphasis placed on abrasive type or the distinction between air velocity for operator visibility and air change rate for overall dust clearance. Several state regulations are simply paraphrases of federal regulations. Mixed standards as well as incomplete standards clearly illustrate the dire need for federal regulations that would be acceptable to and used by all 50 states.

In developing recommendations for abrasive blasting regulations, reference is made to provisions of existing standards and guidelines where appropriate. No attempt was made to use and upgrade the varying formats of these existing standards; rather criteria were developed independently and structured to extend existing material.

Existing safety and health regulations from Canada and Australia were reviewed. In addition, a synopsis of proposed legislation to ban the use of silica sand for sandblast operations with the Federal Republic of Germany was obtained. Where practical, these foreign regulations have been used to substantiate and support criteria developed from this study.

↑

All foreign data was obtained from Mr. Peter B. Wharton, Hodge Clemeo Ltd., Sheffield, England.

TABLE 2

EXISTING STATE STANDARDS FOR ABRASIVE BLAST CLEANING
 (Summary of Information Received from State Agencies
 During the Period of September 1972 - February 1973)

STATE	STATE STANDARDS, CURRENT & PROPOSED FOR VENTILATION & SAFE PRACTICES OF ABRASIVE BLASTING OPERATIONS (INCL. COMMENTS)
Alabama	<p>Now formulating. Will parallel Williams-Steiger Act of '70 and ammended standards.</p> <p>Program ready Jan. '73. Effective as soon thereafter as legislature passes enabling legislation.</p>
Alaska	<p>Presently revising. Fundamentally mirror standards of Williams-Steiger Act.</p> <p>Program ready after Dec. '72.</p>
Connecticut	<p>Has adapted OH Standards promulgated by U.S. Department of Labor OSH Act of 1970 State Public Health Code Reg. 19-13-E5a.</p> <p>Ventilation regulations for abrasive cleaning are covered under Sec. 1910.94(a) Abrasive Blasting Standard is incomplete: Static Δp in ductwork, Effects of air cleaning device, especially where recirculated,</p> <p>Also: Sec. 1910.94(a) (4) (i) (b) should be more specific regarding checking of existing systems and maximum length of period between Checks.</p>
Georgia	<p>No standards or information. Federal standards will be adopted at such time as legislature passes enabling legislation.</p>
Hawaii	<p>Use "Industrial Ventilation" manual, ACHIH. Worker must wear appropriate helmets and goggles, respirators. Accident Prevention Manual Per Industrial Operations by National Safety Council.</p> <p>Air supplied hoods usually satisfactory because of temperature and usually intermittent operation. Where dust creates a problem, we recommend a wet system.</p>

TABLE 2 (CONTD)

STATE	STATE STANDARDS, CURRENT & PROPOSED FOR VENTILATION & SAFE PRACTICES OF ABRASIVE BLASTING OPERATIONS (INCL. COMMENTS)
Idaho	No published standards specifically regulating abrasive blasting
Kansas	No published data
Louisiana	<p>Importance of this type of occupational exposure and its occurrence in boat building, oil rig platforms, elevated roadways, bridges, etc.</p> <p>Tulane University Medical School's Respiratory Diseases Department has obtained a grant from PHS and those concerned with respiratory diseases to investigate silica dust and its relation to silicosis under various conditions of employment, exposure, smoking habits, etc. (just begun).</p> <p>Recommend: Use a substitute for sand, if possible, such as Stanblast or Black Beauty, or coal combustion glassy residue with very low silica, usually less than 1%. Should be done in enclosures and when wind is favorable with minimum personnel in exposed area, such as Saturdays. Not only blaster should have air-supplied hood, but also men in immediate area should have respirators for pneumoconiosis dust. Blast cleaning of buildings--should use small amount of aspirated water into the sand hose (cannot on metal).</p>
Maine	Has adopted OSHA Standards
Maryland	<p>List of Safety Standards adopted by Maryland, "portions will perhaps apply."</p> <p>Compressed Air Machinery and Equipment Safety Code for B19 (out of print)</p> <p>Eye and Face Protection, Practice for Occupational and Educational 287.1</p> <p>Head, Eyes and Respiratory Organs Safety Code for Prot. of Z2.1 (out of print)</p> <p>Foundries, Safety Code for Protection of Industrial Workers in, B8 (out of print)</p> <p>Regulations which adopts by ref. the TLV of ACGIH OSH Act '70 (Williams-Steiger Act)</p> <p>Refer to ACGIH manual, "Industrial Ventilation"</p> <p>Enclosed Occupational Disease Law (Specifies ACGIH)</p>

TABLE 2 (CONTD)

STATE	STATE STANDARDS, CURRENT & PROPOSED FOR VENTILATION & SAFE PRACTICES OF ABRASIVE BLASTING OPERATIONS (INCL. COMMENTS)
Massachusetts	<p>Recommended Safe Practices (Vent #8) Granite Blasting Rooms exhaust velocity 3500-4500, 150 CFM/ft. opening velocity in plenum chamber 200 LFM.</p> <p>Inside: U.S. Bureau of Mines approved respirator</p> <p>Outside: Not required</p> <p>(#7) Silicon carbide. Allowable <i>care</i> 25×10^6/CF</p> <p>(#6) Granite 7×10^6 particles/CF or inversely proportional to free silica content (35% is normal)</p> <p>Respiratory devices (same as S.C.)</p> <p>(Min. #8) Al. oxide 25×10^6 particles/CF</p> <p>(Vent #7) Blasting rooms. Abrasives other than sand are preferable. Wear approved filtered air supplied blasting helmets. Exhaust air through dust collection before discharge to outdoors. Cyclone not suitable.</p> <p>Exhaust 75 CFM/sq. ft. floor area. Use cloth type net over 10 FPM. Plenum chamber 200 FPM.</p> <p>Air inlet val. equal to that exhausted rate not to exceed 200 FPM. Baffles. 6</p> <p>(Min. #1) silica 2.5×10^6 particles/CF</p> <p>Inversely proportional to free silica but never above 30×10^6 particles/CF 6</p> <p>Amorphous free silica 20×10^6 particles/CF</p>
Michigan	<p>None, strictly abrasive blasting.</p> <p>Use general OH rules and ACGIH manual, "Industrial Ventilation" (Dwg. INS-101) enclosed.</p> <p>Occupational Air Contaminants and Physical Agents (Direct from Federal Register)</p> <p>Our OSHA plan will include ventilation design criteria and standards.</p> <p>Inert or nuisance particles: 50×10^6/CF or 15 mg/M^3, whichever is smaller.</p> <p>Total dust less than 1% SiO_2.</p> <p>Continuous broad band noise R325.2421 Rule 21, 3 pages</p> <p>Impulse Noise 140 dB cathode, ray oscillator Rule 22 or other such.</p> <p>Several rules applying to ventilation, recirculation, use of masks (mentions abrasive blasting respirator, Rule 2442b) etc., 11 pages</p>
Minnesota	<p>"Information we use is readily available from existing guidelines," Minnesota Department of Labor and Industrial Occupational Safety and Health Rules, Document Section, Department of Administration, 140 Centennial BuildJng, St. Paul, Minnesota 55155</p>

TABLE 2 (CONTD)

STATE	STATE STANDARDS, CURRENT & PROPOSED FOR VENTILATION & SAFE PRACTICES OF ABRASIVE BLASTING OPERATIONS (INCL. COMMENTS)																		
Minnesota (continued)	<p>Also use: ACGIH manual, "Industrial Ventilation"</p> <p>We suggest the following areas for further study or definition:</p> <ol style="list-style-type: none"> 1. Should be a clear definition of sand blasting. 2. There is a problem of recirculating air from sand blasters. 3. Need information on types of sand blasting materials used. 4. Need guidelines on hydro-blasting. 5. Need information on ventilation control and respiratory protection. 6. Need standards for related types of sand blasting such as "stone blasting" to engrave markers in the tombstone industry. <p>We are interested in this type of study and would like information on results.</p>																		
Mississippi	<p>Have not completed State Plan. Expect "established Federal Standards" OSHA '70 shall be the Occupational Safety and Health Standards for Mississippi until state standards are developed and promulgated. Expect for most part federal regulations will be adopted.</p>																		
Montana	<p>No state requirements or standards</p>																		
Nebraska	<p>No specific data</p> <p>Following the concept set forth in 29CFR 1910-94 Pg. 10506, Col. 1, 2 and 3 feel that with proper enforcement this is most adequate.</p>																		
Nevada	<p>-(No letter) Copy of Basic Safety Orders 7/1/64, Department of Industrial Safety, Nevada Industrial Comm., Carson City, Nevada.</p> <p>From table in Basic Safety Orders p. 92</p> <table border="1"> <thead> <tr> <th>Mineral Dust Substance</th> <th>Million Part./CF</th> </tr> </thead> <tbody> <tr> <td>Asbestos</td> <td>5</td> </tr> <tr> <td>Dust</td> <td>50</td> </tr> <tr> <td>Mica</td> <td>15</td> </tr> <tr> <td>Silica, free & uncombined:</td> <td></td> </tr> <tr> <td> High (over 50% free silica)</td> <td>5</td> </tr> <tr> <td> Medium (5-50% free silica)</td> <td>20</td> </tr> <tr> <td> Low (below 50% free silica)</td> <td>50</td> </tr> <tr> <td>Talc</td> <td>15</td> </tr> </tbody> </table>	Mineral Dust Substance	Million Part./CF	Asbestos	5	Dust	50	Mica	15	Silica, free & uncombined:		High (over 50% free silica)	5	Medium (5-50% free silica)	20	Low (below 50% free silica)	50	Talc	15
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STATE	STATE STANDARDS, CURRENT & PROPOSED FOR VENTILATION & SAFE PRACTICES OF ABRASIVE BLASTING OPERATIONS (INCL. COMMENTS)												
Nevada (continued)	<p>Foundry parting compounds shall not contain more than 1% free or uncombined silica by weight. Manufacturer's tolerance of 0.1 of 1% permitted.</p> <p>Ventilation Personal Protective Equipment } General statements only</p>												
New Hampshire	<p>No information or data</p>												
New Jersey	<p>No regulations relating solely to abrasive blast cleaning. Have related safety requirements in several regulations.</p> <p>Have a proposed Chapter 122, Local Exhaust Systems of Title 12, NJAC that includes ventilation regulations for blast cleaning. Dated 9/9/71. Based on ANSI documentation NFPA Standards and ACGIH manual, "Industrial Ventilation." Now revising to make it at least as effective as covered in 29 CFR Part 1910.</p> <p>Enclosed copy of 9/9/71 draft Chapter 122 Local Exhaust Systems, when reproduced, will send copy.</p> <p>Abrasive Blasting Section } Taken mostly from ANSI (earlier text) from Webster.</p> <p>Ventilation Section - Control velocity at point of origin for abrasive blasting 500-2000 FPM. Transport velocities large particles 5000 FPM.</p>												
New Mexico	<p>No information, studies, or criteria on ventilation requirements.</p>												
New York	<p>Copy of Industrial Code Rule #12 "Control of Air Contaminants" Industrial Code Rule #18 "Exhaust Systems" Section 12-2.6 in Industrial Code give General provisions* Section 12-3.1 gives TLV's**</p> <p>Section 18.16 in Code Rule 18 detailed specs for exhaust systems for various abrasive blasting operations. Intended to safeguard worker and others in vicinity.</p> <p>*Shall be enclosed as completely as practicable and have local exhaust system.</p> <table border="1"> <thead> <tr> <th></th> <th>MP/CF</th> </tr> </thead> <tbody> <tr> <td>**Asbestos</td> <td>5 MP/CF</td> </tr> <tr> <td>Dust (nuisance, no free silica)</td> <td>50 MP/CF</td> </tr> <tr> <td>Graphite (natural)</td> <td>15 MP/CF</td> </tr> <tr> <td>Mica (below 1% free silica)</td> <td>20 MP/CF</td> </tr> <tr> <td>Portland cement</td> <td>50 MP/CF</td> </tr> </tbody> </table>		MP/CF	**Asbestos	5 MP/CF	Dust (nuisance, no free silica)	50 MP/CF	Graphite (natural)	15 MP/CF	Mica (below 1% free silica)	20 MP/CF	Portland cement	50 MP/CF
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TABLE 2 (CONT'D)

STATE	STATE STANDARDS, CURRENT & PROPOSED FOR VENTILATION & SAFE PRACTICES OF ABRASIVE BLASTING OPERATIONS (INCL. COMMENTS)
New York (conUnued)	<p>Silica Class I 50 MP/CF Class I Rock up to and including 5% free SiO₂ by weight Class II 20 MP/CF Class II 5 to 10% Class III 10 MP/CF Class III more than 10% Class IV 5 MP/CF Class IV more than 40% Total dust (below 1% free silica) 50 • using light field USPH Report 47 No. 12 3/12/32 From Industrial Code Rule #18 Section 18 15 Exhaust systems for abrasive blasting operations Class I Natural sand used: Length to width ratio 2:1 or less. Downdraft not less than 80 FPM over entire projected area. Exhaust openings on 2 long sides, lowest point not more than 10" above floor. If over 2:1, then lateral ventilation not less than 100 fpm. Class II Other than natural sand: 40 FPM and 50 FPM, respectively. At least 30 fpm through all openings into enclosure Inlets suitably baffled. Rotary Abrasive Tables: 500 FPM through all openings Barrels 500 FPM Hand Cabinets 500 FPM</p>
North Carolina	<p>Bulletins only: Safety and Health Standards Article 3 Ventilation Control of Dust, Gases, Fumes, Vapors: only specified No. Carolina TLV Mimeo bulletin expanding on above: Ventilation Federal 1910.94 Personal Protective Equipment (Article 22) 2 pages Mentions respiratory protection 1910.94 Abrasive blasting 1910.94 (a)(5)(ii) Eye protection 1910.94 (a)(5)(v)(b) Particle filter 1910.94 (a)(5)(iii) Heavy canvas gloves 1910.94 (a)(5)(v) Occupational head protection 1910.135 Supplementary Bulletin 113-good general information on ventilation control. Nothing on abraslve blast cleaning.</p>

TABLE 2 (CONT'D)

STATE	STATE STANDARDS, CURRENT & PROPOSED FOR VENTILATION & SAFE PRACTICES OF ABRASIVE BLASTING OPERATIONS (INCL. COMMENTS)
North Dakota	<p>Industrial Safety Code General Section on Ventilation Personal Protective Safety Equipment Tools Power Machinery and Equipment Also use ANSI 29.4"1968 Ventilation and Safety Practices of Abrasive Blast Cleaning Operations</p>
Ohio	<p>Referred to Division of Industrial Safety Will reply after holiday season</p>
Oklahoma	<p>No information or data In process of finalizing plan for occupational health and safety. No published documents as yet. Voted to adopt Federal Standards of occupational safety and health.</p>
Oregon	<p>Occupational Health Regulation, Oregon State Board of Health Rule 22-020 Abrasive blasting (2 short pps.) (General) Shall wear helmets or hoods, etc. Employees working adjacent shall wear eye and respiratory protection (ammended 4/16/71)</p>
Pennsylvania	<p>Regulations of the Department of Labor and Industry 1968 Regulations for Construction and Repair including amendments (no mention of abrasive blast cleaning) Department of Environmental Resources, Division of Occupational Health regulates toxic materials and dust Only requires respirators be U.S. Bureau of Mines approved and operator receive periodic X-Ray if using silica Special regulations if involves entry into confined spaces Copy of Pennsylvania bulletin Vol. 2, No. 13, 3/25/72 marked 201.14 physical exam. 201.31 assistance precautions (entering confined space) 201.72 TLV's nuisance particulates 10 mg/M³ or 30 mppf whichever is smaller of total dust 1% S0₂ Quartz TLV in mppf $\frac{\%}{100} \frac{300}{\% \text{ Quartz}} +10$</p>

TABLE 2 (CONTD)

STATE	STATE STANDARDS, CURRENT & PROPOSED FOR VENTILATION & SAFE PRACTICES OF ABRASIVE BLASTING OPERATIONS (INCL. COMMENTS)
Pennsylvania (continued)	<p>TLV for respirable dust in mg/M^3 $\frac{10 \text{ mg/M}^3}{\% \text{ Resp. Quartz } +2}$</p> <p>TLV for total dust, respirable, non-respirable $\frac{30 \text{ mg/M}^3}{\% \text{ Quartz } +3}$</p> <p>Silica: Use quartz formula Tridymite: 1/2 value from found in quartz Sent regulations for compressed air apparatus</p>
Puerto Rico	<p>General Code of Safety and Industrial Hygiene Mineral dusts p 65. Silica, crystalline Amorphous including natural diatomaceous earth 20 mppcf Silicates (less than 1% crystalline silica) Asbestos 20 Perlite 30 Portland cement 50 Scapstone 20 Talc (non-asbestiform) 20 Talc (fibrous) use asbestos limit Tremolite (see talc, fibrous) Graphite (natural) 15 Inert or nuisance particles 30 (or 10 mg/M^3, whichever is smaller of total dust $\leq 17.50_2$.</p> <p>Conversion factors mppcf x 35.3 = million particles per cu. meter = particles per cc.</p> <p>Notice of intended changes: 1971 Mineral dusts: Asbestos all types 5 fibers/ml > 5 w length Coal dust (bituminous) 2 mg/M^3 Cristobalite Use 1.2 val. from count or mass for quartz Inert or nuisance particles 10 mg/M^3 or 30 mppcf whichever is smaller of total dust < 1% SiO_2</p> <p>TLV in mppcf: $\frac{300}{\% \text{ quartz } +10}$</p> <p>TLV for respirable dust in mg/M^3: $\frac{10 \text{ mg/M}^3}{\% \text{ resp. quartz } +2}$</p>

TABLE 2 (CONTD)

STATE	STATE STANDARDS, CURRENT & PROPOSED FOR VENTILATION & SAFE PRACTICES OF ABRASIVE BLASTING OPERATIONS (INCL. COMMENTS)
Puerto Rico (continued)	<p>TLV for total dust resp. and non- resp. $\frac{30 \text{ mg/M}^3}{\% \text{ quartz } +3}$</p> <p>Silica (fused): Use quartz formula Tridymite: Use 1.2 value calc. from formulae for quartz Noise: No noise whose intensity affects auditive power.</p>
Tennessee	<p>All Standards presently being reviewed in light of Federal OSH Standards. Will send copy when finalized and make comment. Federal Standards will be our guideline.</p>
Virginia	<p>Experience primarily with foundry operations employing 5 to 50 employees.</p> <p>Make measurements of dust concentrations, silica content, and ventilation air flows. Then make recommendation for deficiencies based on TLV's for current year and on the manual, "Industrial Ventilation" (both by ACGIH).</p>
Washington	<p>Use ACGIH manual, "Industrial Ventilation" Sent copy of p 5-4 (all there is)</p> <p>Also send WAC-296-24-675 Safe Practices of Abrasive Blast Operations Code for Wash. Recently revised draft which will go to public hearing 8/24/72 for adoption.</p> <p>Taken essentially from Federal Register. Appendix: Ventilation Air Velocity Blast Cleaning Cabinet Inward at hand openings min 500 FPM Rotary Blast Tables min 200 to 250 FPM Blast Cleaning Rooms Well Baffled 300 FPM Abrasive Separators 200 to 250 FPM</p>
Wisconsin	<p>Ventilation Regulations 2</p> <p>1. Not less than 80 CFM/FT floor area for downdraft ventilation. 2</p> <p>2. Not less than 80 CFM/FT cross section area for cross draft ventilation.</p>

TABLE 2 (CONT'D)

STATE	STATE STANDARDS, CURRENT & PROPOSED FOR VENTILATION & SAFE PRACTICES OF ABRASIVE BLASTING OPERATIONS (INCL. COMMENTS)																						
Wisconsin (continue)	3. Minimum duct velocity 4500 FPM 4. All inlets designed and baffled to provide not less than 500 FPM The above is scheduled for amendment as follows: <table border="1"> <thead> <tr> <th>Operation of Equipment</th> <th>Min. Air Flow</th> <th>Min. Duct Velocity</th> <th>Suggested Vent. Cont. Design</th> </tr> </thead> <tbody> <tr> <td>(a) Abrasive Blasting (Dry)</td> <td></td> <td></td> <td></td> </tr> <tr> <td>1. Cabinets</td> <td>20 FPM</td> <td>3500</td> <td>VS-IOI</td> </tr> <tr> <td>2. Rooms exhaust vent. provided over entire projected area</td> <td>80 FPM downdraft</td> <td>3500</td> <td>VS-IOI</td> </tr> <tr> <td>3. Rotary tables</td> <td>200 CFM/ sq.ft. of total openings (without curtains)</td> <td>3500</td> <td>VS-IOI</td> </tr> </tbody> </table> Proposed amendments have been reviewed by NIOSL and found consistent with their standards.			Operation of Equipment	Min. Air Flow	Min. Duct Velocity	Suggested Vent. Cont. Design	(a) Abrasive Blasting (Dry)				1. Cabinets	20 FPM	3500	VS-IOI	2. Rooms exhaust vent. provided over entire projected area	80 FPM downdraft	3500	VS-IOI	3. Rotary tables	200 CFM/ sq.ft. of total openings (without curtains)	3500	VS-IOI
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Wyoming	Adhering at present to U.S. Department of Labor, Occupational S&H Administration Part. 1910.																						
<u>STATES THAT DID NOT RESPOND TO ENQUIRY</u>																							
Arizona	Illinois	South Carolina																					
Arkansas	Indiana	South Dakota																					
California	Iowa	Texas																					
Colorado	Kentucky	Utah																					
Delaware	Missouri	Vermont																					
Florida	Rhode Island	West Virginia																					

VI. DUST EXPOSURE

A. PROBLEM OVERVIEW

Abrasive blast cleaning inherently develops dense clouds of dust that are detrimental to health and cause an unsafe working environment. Broken down abrasives, pulverized surface coatings and encrusted substances, and abraded material from the blasted object all contribute to the development of the airborne dust during blasting. Also, re-entrainment of material having settled and collected in the working area results from direct nozzle blasts. Airborne particles penetrate the upper respiratory tract when inhaled, collect in the nose and throat, and form deposits in the ears and eyes. This discomfort causes distraction from work at hand. Inhaled particles less than 10 µm in diameter are capable of penetrating to the smallest and most remote passages of the human lung. Materials of such a respirable size are often toxic and capable of causing permanent and lethal lung damage. Silica sand (quartz), in the past a primary abrasive, is one cause of silicosis, a slowly developing disease that often results in death years after exposure has ceased. Lead, a component of paint removed by abrasive blasting, is another toxic material commonly associated with such airborne dust. Dust exposure has been very common throughout the abrasive blasting industry. It is evident that greater action must be taken to insure protection of the worker from such a hazardous environment.

B. DUST AS A HEALTH HAZARD

The American Conference of Governmental Industrial Hygienists (ACGIH) has tabulated data for many substances describing airborne concentrations above which inhalation may be hazardous. This concentration is expressed in terms of a Threshold Limit Value (TLV), and represents the concentration of a substance to which nearly all workers may be repeatedly exposed without adverse effect. Exposures are considered to occur during an eight-hour workday over five days in each workweek. TLV's are defined as the time-weighted concentrations for an eight-hour day; excursions to higher concentrations are allowable for limited time periods (typically 10-15 minutes) provided that they are balanced by periods of lower concentrations to give a weighted average equal to the TLV. Continued exposures determined to be above the TLV are considered potentially detrimental to health.

ACGIH has published this information with the intention of its being used as a guideline, not as a set of hard and fast rules defining absolute boundaries between safe and unsafe conditions. TLV's are based upon the best available information from industrial experience, experimental animal studies, and human experience where possible. Instrumentation available for measuring dust levels varies in ability to accurately detect true concentrations. Therefore, TLV data must be tempered with good judgment in its application.

TABLE 3

THRESHOLD LIMIT VALUES FOR MATERIALS COMMONLY ASSOCIATED WITH ABRASIVE BLASTING

MATERIAL	ACGIH, 1970 (1) (Adopted by OSHA)		ACGIH, 1972 (2)	
	mppcf	mg/M ³	mppcf	mg/M ³
Silica				
	Crystalline Quartz (respirable)	250/(%SiO ₂ +5)	10/(%SiO ₂ +2)	10/(%SiO ₂ +2)
	(Total)	30/(%SiO ₂ +2)	300 (%SiO ₂ +10)	30/(%SiO ₂ +3)
Cristobalite		Use 1/2 value from quartz formula		Use 1/2 value from quartz formula.
Tridymite		Use 1/2 value from quartz formula.		Use 1/2 value from quartz formula
Amorphous		80/(%SiO ₂)	20	
Nuisance (or biologically inert) materials such as iron oxide, slag, steel with less than 1% quartz by wt.				
(respirable)	15			
(Total)	50		30	10
Lead (as used in paint)		0.20		0

"Threshold Limit Values for Substances in Workroom Air Adopted by ACGIH for 1970," American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio, 1970.

"Threshold Limit Values for Substances in Workroom Air Adopted by ACGIH for 1972 " American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio, 1972.

Table 3 lists TLV's for substances commonly found in the abrasive blasting environment. Two generations of ACGIH values are listed as the earlier version (1970) has been adopted for application and enforcement by federal authorities (OSHA). These exposure values are considered to be the best available at present.

Reference is made throughout this report to the respirable component of dust. By definition, this refers to that component of the airborne dust capable of passing into the smallest passageways and alveolar sacs of the human lung. Table 4 outlines the currently accepted percentages of airborne material passing through the upper, mucous-coated passages and reaching the respiratory region.

TABLE 4
RESPIRATORY FRACTION OF AIRBORNE DUST

(As Determined by the U.S. AEC and (1, 2, 3)
Recommended by the U.S. Bureau of Mines)

Aerodynamic Diameter (μm) (Unit Density Sphere)	% Passing to Small Passageways of Human Lung
2	100
2.5	75
3.5	50
5.0	25
10.0	0

- "Sampling and Evaluating Respirable Coal Mine Dust: A Training Manual," Bureau of Mines Information Circular, February 1971.
 - "Calibration of a Two Stage Air Sampler," Ettinger, H.J., and Royer, G.W., Los Alamos Scientific Laboratory of the University of California, Los Alamos, New Mexico, November 1969.
 - "Size Selective Samplers for Estimating Respirable Dust Concentrations," Lippmann, M., and Harris, W.B., Health Phys. 8,155 (1962).
- C. SCOPE OF DUST EXPOSURE STUDY

It was the primary intent of this portion of the study to collect dust concentration data at abrasive blasting installations and thereby determine the need for dust controls and for worker protection measures. The degree of compliance with federally established exposure limits provided a working index in formulating opinions.

Effective dust control systems and worker protection can adequately reduce dust exposure to nonhazardous levels. Confining, collecting, and otherwise controlling dust through ventilation systems prior to its spread to adjacent areas serves to protect workers near an abrasive blast facility. Respiratory protection devices are necessary only when controlling techniques are insufficient to prevent dust spread in hazardous quantities. Protection of the blast operator in situations where he is directly exposed to the dust cloud by use of a hand-held nozzle proves to be more critical. A well-maintained, respirated helmet is usually sufficient. However, control of air flow around the blast operator proves to be helpful in reducing very high dust concentrations.

Airborne dust concentrations for twenty-two industrial abrasive blasting installations were determined. The main concerns were (1) with dust levels surrounding the blast operator (especially where silica sand was being discharged from hand-held nozzles), (2) with dust concentration in areas adjacent to the abrasive blast facility where other workers might be exposed, and (3) with associated situations such as dust collectors and bins where airborne dust would form. All situations that offered potential for airborne dust were investigated.

D. SURVEY OF INDUSTRIAL ABRASIVE BLASTING INSTALLATIONS

1. Data Acquisition Procedure

Breathing zone, respirable, and total dust concentrations were measured at each installation surveyed during blasting. These data were summarized and tabulated for comparison with currently allowed exposures.

Dust concentration at blasting cessation in enclosures was measured for adequacy of air clearance. Ventilation and dust removal is discussed separately in Chapter VII of this report.

All dust concentrations were directly determined by use of GCA Corporation's Respirable Dust Monitor RDM-101-1. This device provides an automatic digital readout of concentration in mg/M³ of sampled air. A detailed description of this device is presented in Appendix B. Both the respirable component of airborne dust and the total amount of breathable airborne dust were determined. Limitations on sampling duration and number of readings taken were due principally to the erratic nature (on/off) of the blasting process.

2. Data Tabulation

Recorded dust concentration data were summarized and transcribed onto a format which allows direct interpretation in view of current, applicable standards and guidelines. Collected data are grouped according to blasting equipment type: portable blasting units, blast cleaning rooms, hand-operated cabinet machines, and automatic machines. This technique presents a review of each category for trends in dust formation as well as a review of each installation individually.

Figure 7 is a sample of a completed dust evaluation form. Completed forms for all installations surveyed are included in Appendix A. [A-1 - A-4 (automatic machines); P-1 - P-10 (portable machines); C-1 (cabinet machine); R-1 - R-7 (room-type machines).] Features of the form are as follows:

a. Location and Applicable Standards

Each installation is identified only by the state in which it is functioning (no situations were encountered in which counties or regions had enforceable guidelines). On this basis, only state and federal standards were applicable and enforceable. ACGIH and ANSI Z9.4 standards are included for comparison purposes.

b. Abrasive Used and Surface Coatings of Blasted Object

Dust generated by the blasting process is primarily composed of breakdown products of abrasive materials, surface coatings, and encrusted substances. Provision was made for noting these materials. When sand was used, a sample was collected and subsequently evaluated for silica (SiO₂) content. Data are tabulated, along with estimated duration of abrasive blasting in an eight-hour day, to allow specific comparison with TLV's as stated in applicable guidelines.

c. Acceptable Dust Concentrations and Exposure Durations

Federal regulations (OSHA), state regulations (if any), ACGIH and ANSI Z9.4 guidelines are directly quoted. Both TLV data and permissible short term (10-15 minute) excursions were included for respirable and total dust.

Special note must be made of TLV information as presented for silica. The formula given for determining silica TLV numbers requires use of a value for % (by wt.) silica in the airborne dust. The actual measurement of this value was considered unnecessary since, when a silica sand abrasive is used, a substantial proportion of generated dust is silica. Estimates of silica composition in airborne dust were therefore considered to be from 50 to 100%. TLV levels were accordingly calculated to be 0.1 - 0.2 mg/M³ for the respirable dust component and 0.3 - 0.6 mg/M³ for the total dust measurement. With consideration given to the variability characteristics of abrasive blasting, as well as to the "guidelines" nature of the TLV's, this concentration range appeared sufficient to determine compliance or noncompliance with regulations.

d. On-Site Data

Collected data are reported according to respirable and total dust concentration. Ambient (before blasting) data are shown to allow determination of the increase in dust due to the blasting process. In addition to measurements taken during blasting, dust clearance information at blasting cessation is noted where appropriate for enclosures. The locations of data acquisition are shown by verbal description and a rough

DUST DATA

FACILITY PORTABLE BLASTING MACHINE, INSTALLATION P-6 LOCATION STATE TEXAS
 APPLICABLE STANDARDS OR GUIDELINES OSHA (CFR, TITLE 29), ACGIH (VOLUNTARY), ANSI Z9.4 (VOLUNTARY)

ABRASIVE SAND	ACCEPTABLE DUST CONCENTRATIONS AND EXPOSURE DURATIONS			PERMISSIBLE EXCURSION
	STANDARD	MATERIAL	8-HR TLV	
IF SILICA SAND	CRYSTALLINE QUARTZ 100 WT. %	RES. SiO ₂	0.1-0.2 MG/M ³	OSHA (NONE), ACGIH (3x)
	TRIDYMIT	TOTAL SiO ₂	0.3-0.6	OSHA (NONE), ACGIH (3x)
	CRISTOBALITE	RES. INERT	5	OSHA (NONE),
SURFACE (COATING) OF BLASTED OBJECT	IRON OXIDE,	TOTAL INERT	15	OSHA (NONE),
	PAIN	TOTAL INERT	10	ACGIH (1.5x)

ESTIMATED DURATION OF BLASTING 12 HRS/DAY FACILITY SCHEMATIC (TOP VIEW)

ON-SITE DUST CONCENTRATION MEASUREMENTS	LOCATION OF MEASUREMENT	FACILITY SCHEMATIC (TOP VIEW)	
		D1	D2
• EXTERIOR AMBIENT AIR DUST LEVELS			
RESPIRABLE	D1 UPWIND PRIOR TO BLAST		
TOTAL			
• BLASTING DUST LEVELS			
RESPIRABLE	D2 10' UPWIND FROM BLASTER		
TOTAL	D3 5' UPWIND FROM BLASTER		
	D4 10' DOWNWIND FROM BLASTER		
	D5 30' DOWNWIND FROM BLASTER		

• DUST LEVEL AT BLASTING SHUTDOWN TIME AFTER SHUTDOWN

RESPIRABLE	TOTAL
<1.0 MG/M ³	4.5 MG/M ³
7.9	18.1
13.0	5.8
5.0	

WIND 500 - 800 LFM

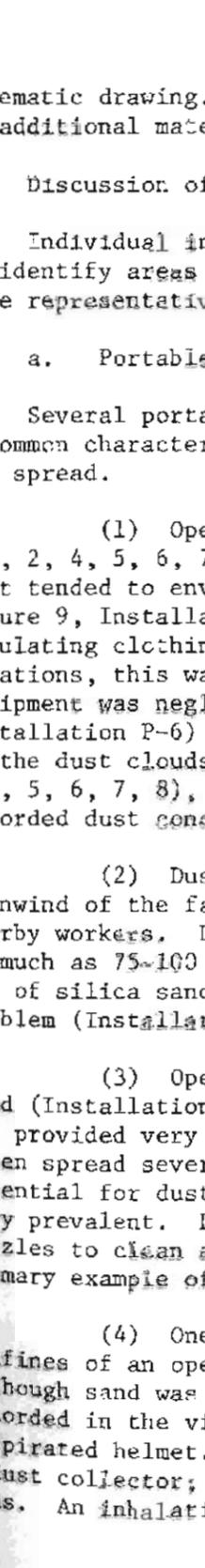


FIGURE 7 DUST EVALUATION FORM (SAMPLE)

schematic drawing. For more detailed locations, reference should be made to additional material shown for each installation in Appendix A.

3. Discussion of Data

Individual installations were reviewed and attempts have been made to identify areas of excess dust exposure. All dust concentrations recorded were representative of steady-state conditions during blasting.

a. Portable Abrasive Blasting Units

Several portable units were evaluated in varying work environments. A common characteristic of these devices was unrestricted dust generation and spread.

(1) Open air, unrestricted abrasive blasting (Installations P-1, 2, 4, 5, 6, 7, 8) created a very dense cloud of airborne material that tended to envelop the blaster (Figure 8, Installation P-6 and Figure 9, Installation P-7). A well-maintained respirated helmet and insulating clothing offered sufficient protection when used. In two locations, this was either not done (Figure 9, Installation P-7) or equipment was neglected to the point of ineffectiveness, (Figure 10, Installation P-6) so that the blast operators were directly exposed to the dust clouds. When silica sand was used as the abrasive (Installations P-1, 5, 6, 7, 8), there existed a very severe exposure hazard since recorded dust concentrations were far in excess of established TLV's.

(2) Dust generated in open-air blasting was carried to areas downwind of the facility and therefore had the potential for affecting nearby workers. Dust concentrations in excess of TLV's were recorded as much as 75-100 feet downwind of a blasting operation. Again, the use of silica sand as an abrasive constituted the most severe health problem (Installations P-5, 6, 7).

(3) Open-air installations using an abrasive other than silica sand (Installations P-2, 4) did not develop a respirable dust exposure but provided very unclean working conditions for nearby workers. Dust often spread several hundred feet from the blasting operation. The potential for dust accumulation in eyes, ears, nose, and throat was very prevalent. Downwind deposition of slag abrasive during use of three nozzles to clean a ship in drydock (Installation P-4) was found to be a primary example of this situation.

(4) One portable abrasive blasting rig was viewed within the confines of an open-ended, exhaust-ventilated shed (Installation P-9). Although sand was being used as the abrasive, no health hazard was recorded in the vicinity of the operator, who was protected with a respirated helmet. However, exhausted materials were not passed through a dust collector; sand was simply blown over a wide area by the exhaust fans. An inhalation exposure hazard existed in the area behind the shed.

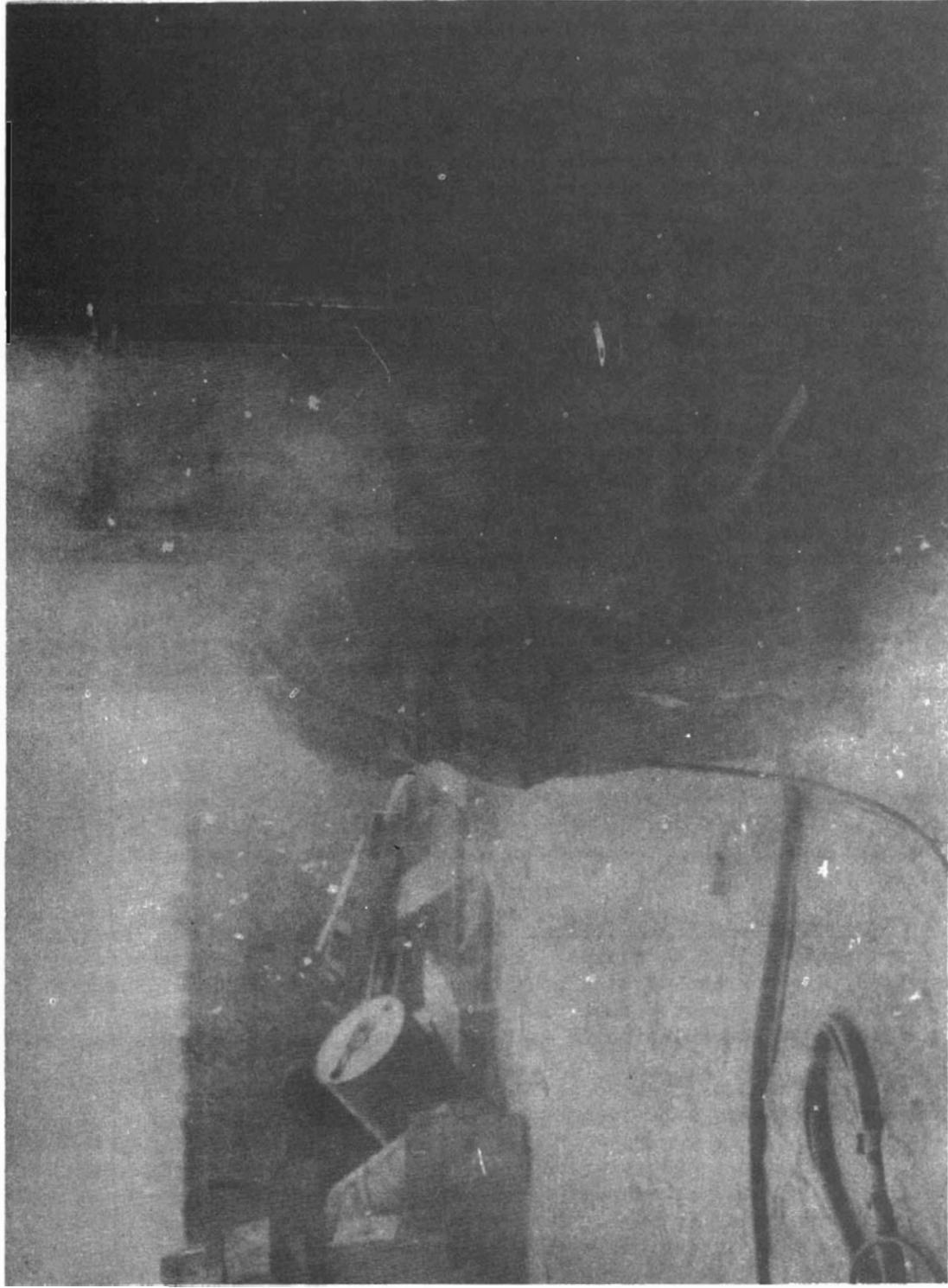
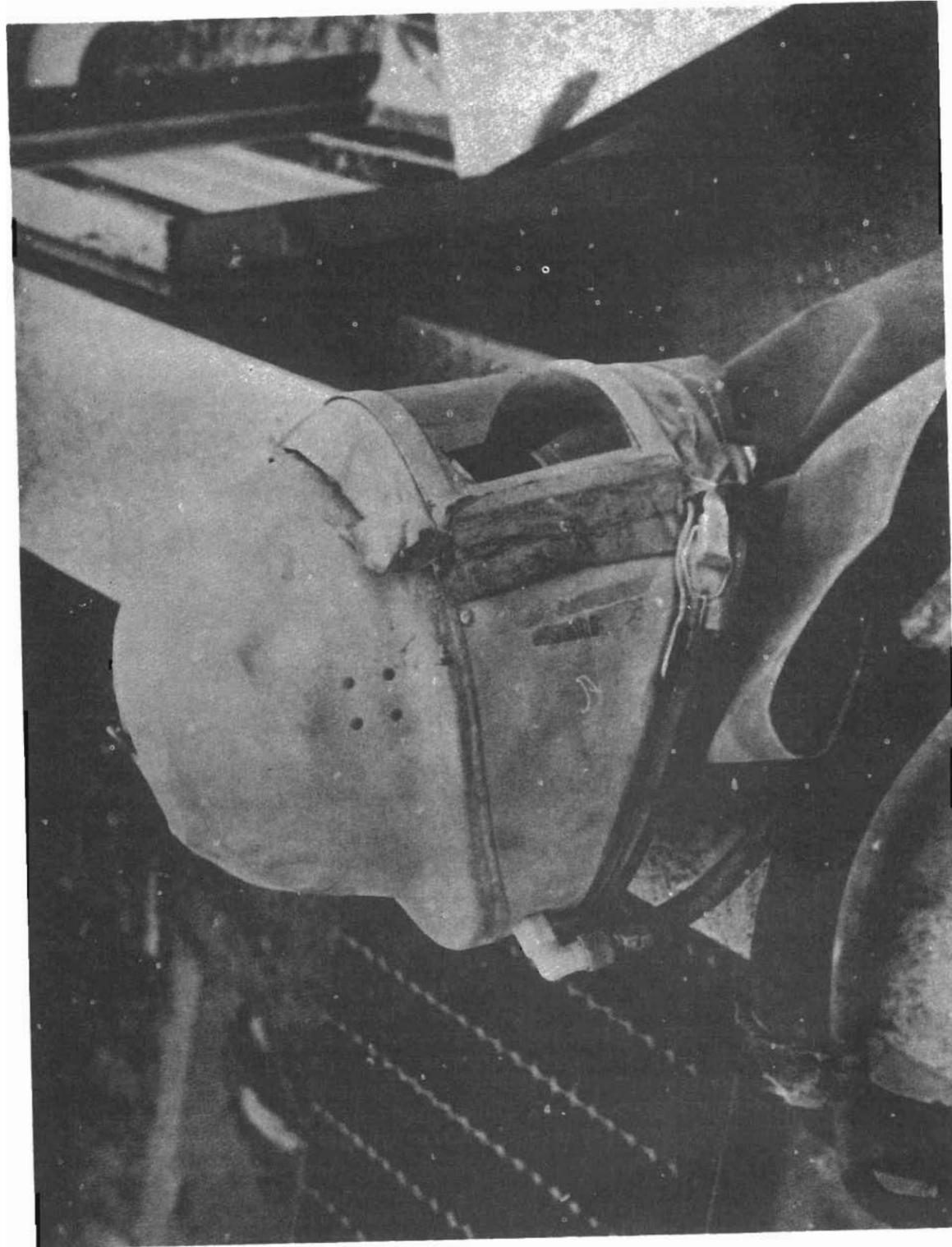


FIGURE 8 BLAST OPERATOR ENVELOPED BY DUST CLOUD



FIGURE 9 BLAST OPERATOR ENVELOPED BY DUST CLOUD



NEGLECTED RESPIRATED HELMET

(5) A portable device used to clean the internal surfaces of a water tank was surveyed (Installation P-IO). A cross flow, exhaust ventilation system was introduced to clear dust as it formed. Material was passed directly to a dust collector where exhaust air was discharged to the atmosphere. No hazard to nearby workers existed from the exhausted air. The blast operator was adequately protected by a respirated helmet and protective clothing.

(6) A portable device, using sand as an abrasive, was tested within the confines of a top-exhausted hood (Installation P-3). Inadequate air flow and dead regions caused accumulation and spread of heavy concentrations of dust. Both the blaster and nearby workers were affected by dust concentrations well in excess of established TLV's.

b. Abrasive Blast Cleaning Rooms

Only slag and steel shot were used as abrasives during visits to blast cleaning rooms (Installations R-1, 2, 3, 4, 5, 6, 7). Little or no dust exposure hazard existed at any site (with the exception of Installation R-1) where the room door was left open to accommodate large pieces for blast cleaning.

(1) Several units displayed excessive wear. Holes were abraded in side walls and other openings such as bolt holes were evident (Installations R-3, 4, 6). The escaping dust and abrasive was a nuisance factor and developed an eye injury exposure from expelled shot.

(2) Cleaning rooms equipped with abrasive recycle equipment and dust collection/separation facilities develop little dust leakage (Installations R-2, 3, 5, 6, 7).

(3) All rooms exhibited a dust cloud around the blast operator during hand-hand nozzle blasting. Dust measurements showed rapid clearance upon cessation of blasting. Initial high concentrations lowered quickly and, when considered in view of a time-weighted TLV, provided no hazard (Installations R-2, 3, 4, 5, 6, 7). (Chapter VII of this report examines this aspect of dust hazards in more detail.)

c. Cabinet Abrasive Blast Cleaning Machines

Only one cabinet machine (Installation C-I) was viewed that used silica sand as an abrasive.

(1) No dust hazard existed even with the operator's face only inches from the device. This was, however, a well-maintained machine. Any leakage from a poorly maintained machine could cause dust exposure.

d. Automatic Abrasive Blast Cleaning Machines

Several automatic units were evaluated. All used steel shot as an abrasive and isolated the operator from the actual blasting operation.

(1) Well-maintained equipment was observed that provided no dust hazard to the operator or nearby workers (Installations A-I, 2, 3, 4).

(2) When door seals were worn or damaged, escaping dust and abrasive became a nuisance that again developed potential eye injury hazards from flying shot (Installation A-4).

(3) One automatic unit discharged cleaned steel girders that were covered with accumulated, residual steel shot. This was blown off with a hand-operated air gun (Installation A-I) used by an unprotected worker. Abrasives other than steel shot are potentially hazardous under continuous working conditions.

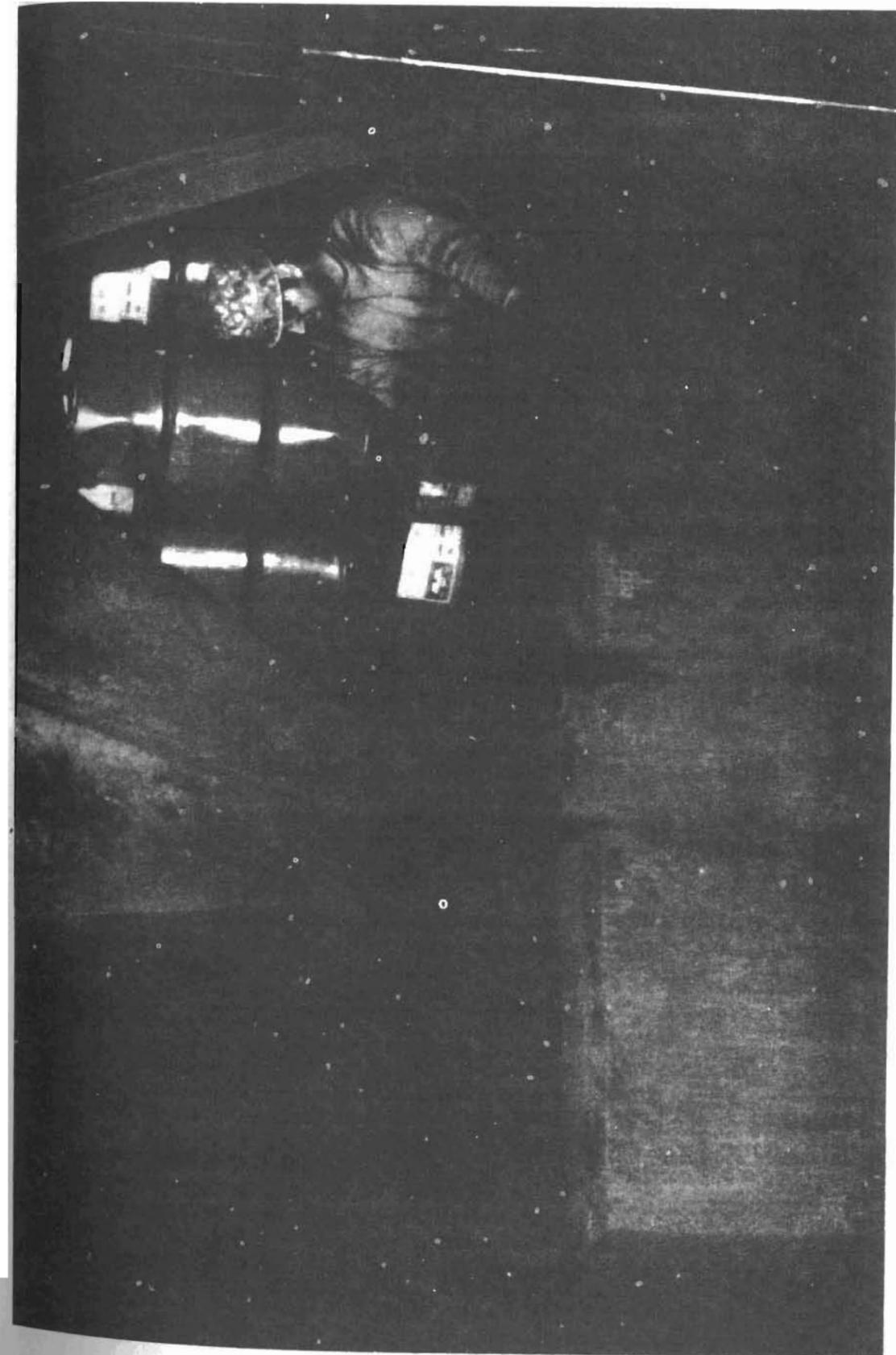
(4) Workers beating the bags of a dust separator/collector (Figure 11) were exposed to temporary, but very heavy dust clouds (Installation A-4). This resulted in a temporary, discomforting exposure at best as the material is of a very fine particle size and caused choking and gagging.

(5) One facility (Installation A-4) in a foundry used an automatic machine to clean castings. Silica sand, used in the casting process, still coated the objects and comprised 31% by weight of the settlings after a blasting cycle. Dust of this nature escaping through door seals could develop a very serious situation.

E. SUMMARY OF DUST EXPOSURE HAZARDS

Table 5 presents a summary of our findings in evaluating airborne dust at and around the various abrasive blasting installations. Several trends are evident when this data is reviewed by equipment type:

- Enclosed, ventilated facilities such as blasting rooms, in good repair, demonstrated little dust leakage and therefore no hazard from dust exposure to either a protected blast operator or nearby unprotected workers.
- Enclosed facilities such as blasting rooms, in moderate disrepair with leakage through door seals, and through holes worn in walls, had only local elevated dust concentrations that created a nuisance rather than a serious hazard.
- Enclosed, ventilated facilities such as automatic and cabinet blasting machines, in good repair, demonstrated little dust leakage and therefore no hazard from dust exposure to either an operator or nearby workers.



F. GUR... UNPROTECTED WORKER CLEARING DUST COLLECTION HOPPER

TABLE 5
SUMMARY OF DUST EXPOSURES

ABRASIVE BLASTING INSTALLATION	FEDERAL EXPOSURE LIMITATIONS FOR DUST (OSHA, CFR TITLE 29)	TLV, mg/M ³	RECORDED DUST CONCENTRATIONS														
			AT BLAST OPERATOR				NEARBY AREAS				ABOVE TLV						
			BELOW TLV	MODERATE (<2 x TLV)	EXCESSIVE (>2 x TLV)	TOTAL	BELOW TLV	MODERATE (<2 x TLV)	EXCESSIVE (>2 x TLV)	TOTAL	BELOW TLV	MODERATE (<2 x TLV)	EXCESSIVE (>2 x TLV)	TOTAL			
PORTABLE UNITS	ABRASIVE	RESP.	TOTAL	RESP.	TOTAL	RESP.	TOTAL	RESP.	TOTAL	RESP.	TOTAL	RESP.	TOTAL	RESP.	TOTAL	RESP.	TOTAL
P-1	Sand	0.1-2	0.3-0.6	•													
P-2	Black Beauty	5	15	•													
P-3	Sand	0.1-0.2	0.3-0.6														
P-4	Black Beauty	5	15														
P-5	Sand	0.1-0.2	0.3-0.6	•													
P-6	Sand	0.1-0.2	0.3-0.6														
P-7	Sand	0.1-0.2	0.3-0.6														
P-8	Sand/Water	0.1-0.2	0.3-0.6														
P-9	Sand	0.1-0.2	0.3-0.6														
P-10	Black Beauty	5	15														
2	BLAST CLEANING ROOMS																
R-1	Black Beauty	5	15														
R-2	Steel Shot	5	15														
R-3	Steel Shot	5	15														
R-4	Steel Shot	5	15														
R-5	Steel Shot	5	15														
R-6	Steel Shot	5	15														
R-7	Steel Shot	5	15														
	CABINET MACHIN																
C-1	Sand	0.1-2	0.3-0.6														
	AUTOMATIC MACHINES																
A-1	Steel Shot	5	15														
A-2	Steel Shot	5	15														
A-3	Steel Shot	5	15														
A-4	Steel Shot	5	15														

- Non-enclosed, portable, hand-operated blasting machines generated extensive dust clouds. Typically, no control was exercised to prevent unrestricted dust spread. Several installations demonstrated hazardous dust exposures to unprotected blast operators and to nearby workers.
- Where metallic shot or slag was used as an abrasive, dust concentrations around protected blast operators and nearby workers consistently fell within the present OSHA limitations and ACGIH guidelines.
- Where silica sand was used as an abrasive, dust concentrations around protected and unprotected blast operators and nearby workers were consistently much in excess of the present OSHA limitations and ACGIH guidelines.

The duration of abrasive blasting typically ranged from four to eight hours in each working shift. Variability in blasting times, and therefore exposures to whatever dust concentrations were developed, depended on the time required to load and unload objects being cleaned, on the time required to put on protective gear, and on the amount of work available for blasting during a shift. Evaluation of dust exposure hazards were reviewed in terms of a four to six hour blasting period out of an eight hour workday. This, in effect, allowed twice the quoted TLV (in terms of a time weighted average) to be considered an acceptable concentration. However, it must be realized that many installations not requiring frequent "down" periods will approach eight hours (or perhaps more) per day of actual blasting. Therefore this summary should be considered a "best" case evaluation. At two installations, the same blast operator worked for twelve hours each day, seven days each week. When blasting is extended beyond four to six hours, much closer adherence to the TLV concentration level is required.

It is interesting to note that where excessive dust concentrations were recorded in Table 4, levels were usually much in excess of 2x the TLV concentration.

F. RECOMMENDED CRITERIA

The most demanding aspect of controlling dust exposures is to eliminate any situation where dust concentrations are harmful to human health. Irritant and nuisance dust levels are important, but secondary. Reliance should be made on best available data in determining concentrations and exposures harmful to health. In this regard, the American Conference of Governmental Industrial Hygienists' (ACGIH) continuously updated TLV information on industrial materials is appropriate. Federal regulations should continue to use this data, but should be geared to the incorporation of updated numbers as they become available.

Silica sand stands apart from all other abrasive materials encountered. It is a highly toxic material--even in low airborne concentrations. The most obvious recommendation is to ban silica sand from use in the abrasive blasting industry. Except in very unusual circumstances where economics are prohibitive or the cutting properties of sand cannot be matched, the use of silica sand should be prohibited.

Recommendations for the protection from dust exposure of workers associated with abrasive blasting are listed in reference to the blast operator, associated or nearby workers, and equipment maintenance:

1. Abrasive Blast Operator

(a) All abrasive blasting operators using hand-held blast nozzles in open-air portable or fixed facilities, in blast cleaning rooms or booths, or in any other enclosures should be protected by air-respirated, nonleaking helmets, regardless of abrasive material used.

(b) All abrasive blasting equipment operators using automatic or hand-operated cabinet machines should be **protected** from nuisance-type dust leakage by suitable respirator masks and safety glasses.

(c) Maximum respiratory protection should be mandatory when silica sand is used as an abrasive, regardless of blasting equipment type.

(d) Respiratory protection equipment should be inspected daily and replaced or repaired when any leakage is detected.

2. Nearby Workers

(a) When open-air **abrasive** blasting or any other abrasive blasting operation is performed so as to allow generated dust to spread to nearby workers, suitable measures should be taken to protect those workers:

(1) Respirator masks and **safety** glasses should be used to protect against nuisance-type dusts.

(2) When dust levels are sufficiently heavy to cause marked discomfort, distraction from work, or a health hazard (according to the best available guide such as ACGIH TLV's), workers should be required to use respirated hoods or change working location until blasting has ceased.

(b) Workers associated with automatic and other blasting machines requiring performance of an operation such as airblowing excess abrasive or dust from the cleaned object, should be protected from nuisance-type dust by suitable respirator masks and safety glasses.

(c) Maximum respiratory protection should be mandatory when silica sand is used as an abrasive regardless of blasting equipment type.

(d) Respiratory protection equipment should be inspected daily and replaced or repaired when any leakage is detected.

3. Equipment Maintenance

(a) All blast cleaning equipment, especially blasting rooms, booths, cabinet type and automatic machines should be well maintained to prevent development of dust leaks. This applies to any dust escape, whether simply nuisance or in sufficient quantity or size to cause a health hazard by impact or inhalation.



VII. VENTILATION AND DUST REMOVAL

A. PROBLEM OVERVIEW

Dust, as generated by abrasive breakdown and pulverized surface materials, develops a serious safety problem. Dense dust clouds formed in the immediate vicinity of hand-held abrasive blast nozzles reduce visibility and often obscure the working area. Production time is lost whenever blast operators hesitate or shut down to allow dust clearance. If enclosures are not cleared of airborne dust at cessation of blasting, the blast operators may be exposed to harmful concentrations of dust when they remove respirated helmets. Dust accumulations also create slippery floor conditions. It is therefore necessary, both for worker safety and efficient job performance, to confine, collect, or otherwise control the generated dust. Well-designed and maintained ventilation systems for enclosed blasting operations within rooms and booths provide for both adequate dust control and dust removal.

1. Technical Background

An abrasive blasting nozzle typically ejects 250-2500 pounds per hour of abrasive material¹. Nozzle throat velocities can range up to 4000 feet per second and thus impart considerable momentum to airborne materials. Large amounts of dust formed by broken-down, ricocheting abrasive and pulverized surface coatings can be spread in many directions.

Without an overriding air flow, dust remains in the vicinity of its generation due to rather large air resistance to its motion. This is especially true of the smallest and most hazardous respirable particle sizes. Table 6 presents data on the stopping distances of various particle sizes and densities in still air with an initial high velocity. Without ventilation there is little tendency for dust to disperse. In addition, the smaller the particle size, the more time it will take to settle by gravity, and therefore, the longer it will remain airborne. In fact, particulates of respirable size can remain in air suspension for hours. Table 7 presents settling times for materials of various sizes and densities. Figure 12 graphically illustrates settling times as a function of particle size for two abrasive materials, silica and steel. As shown, respirable silica particles (less than 10 μm) are capable of remaining airborne up to eight hours in still air.

2. Vision Impairment

Reduced visibility occurs when air flow around the blast operator and the associated work area is not sufficient to sweep away the developed dust

¹ -----

"The A.B.C.'s of Surface Preparation," Clemco-Clementina, Ltd., San Francisco, California, 1966.

TABLE 6

STOPPING DISTANCE OF PARTICULATES IN STILL AIR

PARTICLE SIZE (μm)	PARTICLE DENSITY (lb/ft^3)	HORIZONTAL STOPPING DISTANCE (INCHES)(1,2,3)	TYPICAL ABRASIVE DENSITIES	
			MATERIAL	DENSITY (lb/ft^3)
10	10	2.53		
	100	25.3		
	150	38.3		
	200	50.9		
	500	127.6		
5	10	0.63	Sawdust	12
	100	6.31	Pumice	40
	150	9.53	Walnut Shells	50
	200	12.7	Slag	49-117
	500	31.8	Sand (SiO_2)	95
3	10	0.23	Glass Beads	139
	100	2.28	Mild Steel	489
	150	3.42		
	200	4.53		
	500	11.4		
2	10	0.10		
	100	1.02		
	150	1.51		
	200	2.16		
	500	5.03		
1	10	0.03		
	100	0.29		
	150	0.44		
	200	0.58		
	500	1.47		

(1) Calculated in accordance with methods outlined in: "The Movement of Aerosol Particles," Light, W., Journal of the Society of Cosmetic Chemists, 23, 657-678, September 14, 1972.

(2) Assume still air with no transient or ventilation currents.

(3) A high nozzle throat velocity of 4300 ft/sec was used as a worst case for calculations.

TABLE 7

5-FOOT SETTLING TIMES FOR PARTICULATES IN STILL AIR

PARTICLE DIAMETER (μm)	PARTICLE DENSITY (lb/ft^3)	SETTLING TIME (minutes) (1,2)	TYPICAL ABRASIVE DENSITIES	
			MATERIAL	DENSITY (lb/ft^3)
10	10	52.4		
	100	5.2		
	150	3.5		
	200	2.6		
	SOD	1.0		
5	10	210.0	Sawdust	12
	100	21.0	Pumice	40
	150	14.0	Walnut Shells	50
	200	10.5	Slag	49-117
	500	4.2	Sand (SiO_2)	95
3	10	588.0	Glass Beads	139
	100	58.8	Mild Steel	489
	150	39.0		
	200	29.4		
	500	11.7		
2	10	1300.0		
	100	130.0		
	150	88.0		
	200	65.8		
	SOD	26.3		
1	10	4520.0		
	100	452.0		
	150	302.0		
	200	226.0		
	500	90.7		

(1) Assume still air with no transient or ventilation currents.

(2) Calculated in accordance with methods outlined in: "The Movement of Aerosol Particles," Light, W., Journal of the Society of Cosmetic Chemists, 23, 657-678, September 14, 1972.

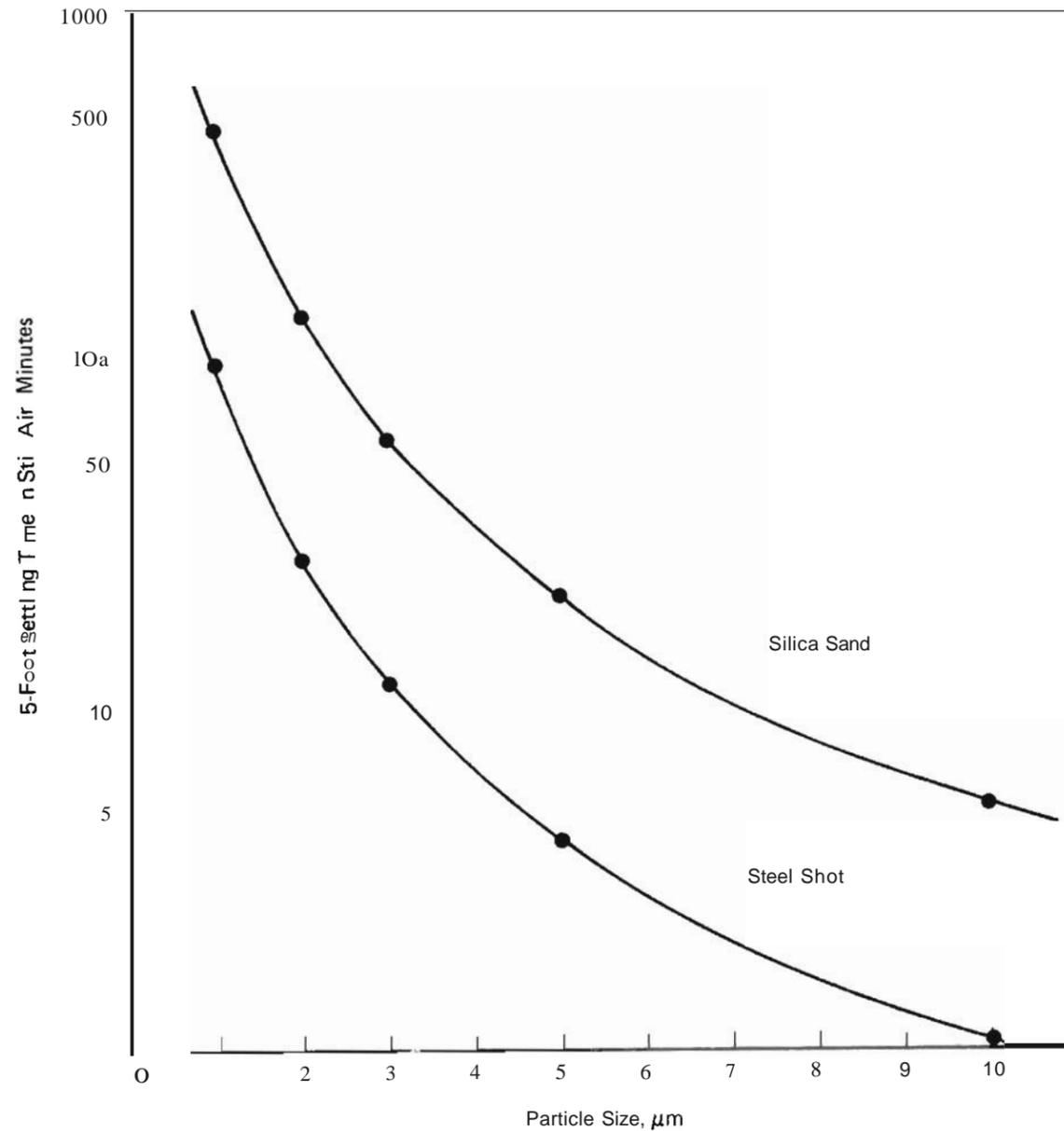


FIGURE 12 PARTICLE SETTLING TIME (Abrasive Size Versus Time for 5-Feet)

cloud. The blast operator's inability to clearly see his work will often require frequent process shutdown to allow dust to settle. Undue time is lost, thus rendering the blast cleaning operation inefficient and costly. Also, the blast operator's inability to clearly see his footing--which could be slippery due to collected dust--provides an additional accident exposure.

3. Dust Exposure

Exposure of personnel to dust in the abrasive blasting environment is such an important industrial hygiene problem that it has been considered in detail in Chapter VI of this report. In this chapter, however, the primary area of concern is adequate dust clearance after cessation of blasting. Clearance rates in enclosures should be sufficient to preclude exposures inconsistent with existing health standards when the blaster removes his protective head gear.

B. EXISTING VENTILATION STANDARDS AND SYSTEM DESIGN GUIDELINES

Past experience in ventilation of abrasive blasting enclosures has provided the basis for existing system design and operation guidelines. No detailed engineering criteria are available. Recommended air flow rates are based upon those which have typically been successful in clearing dust and maintaining visibility such that (1) the blaster need not slow the work process or shut down to allow dust to settle, and (2) the blaster is in complete control of his equipment and himself. The variability of abrasive blasting enclosure configurations, abrasives, and blast-cleaned objects has precluded development of an all-inclusive design format.

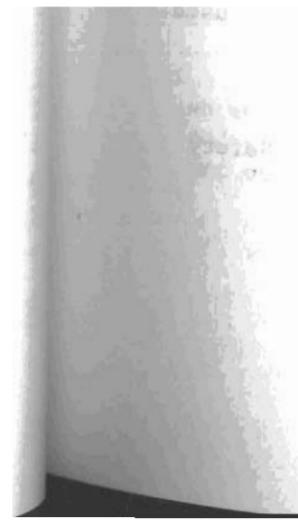
Several standards for proper ventilation design are available; they all appear to be interrelated and based on a common (and conservative) past experience. A brief description of each follows:

- Code of the Federal Regulations, Title 29, Chapter XVII, Part 1910, 18 October 1972

Blast cleaning enclosures are to be exhaust ventilated... to provide prompt clearance of dust laden air within the enclosure at cessation of blasting.

Air inlets and access openings baffled to prevent dust spread.

Specific reference is made to ventilation standards Z9.2 and Z33.1 of the American National Standards Institute.



- American National Standards Institute (ANSI) Z9.2 - 1971, Local Exhaust Systems

Required air velocity is based on practical experience. The minimum dust control velocities for abrasive blasting rooms is given as 60-100 LFM in a downdraft air flow configuration. Inlet air velocity through openings in cabinet machines should be a minimum of 500 LFM.

The statement is made that air flow velocities or volumes may be determined by imitating existing situations where control has been attained.

- American National Standards Institute (ANSI) Z9.4 - 1968, Ventilation and Safe Practices of Abrasive Blasting Operations

Blast cleaning enclosures are to be exhaust ventilated so an inward air flow is maintained. The exhaust rate should be sufficient to provide prompt clearance at cessation of blasting.

Air inlets and access openings baffled to prevent dust spread.

Performance of equipment will be the final criterion...keep **escape** of dust to a minimum, maintain a reasonable visibility, and provide for a rapid clearance.

Recommended inward dust control air velocities are specified as 500 LFM for a cabinet machine, 200-250 LFM for a rotary table, and 300 LFM for a room.

References are made to Ventilation Standards ANSI Z9.2 and Z33.1.

Note: By a personal communication from the ANSI Z9.4 committee², Arthur D. Little, Inc., was made aware of a proposed, more detailed theoretical approach to specifying enclosure ventilation air rates.

Even though past experience with abrasive blasting rooms again serves as a basis for these proposed rates, an attempt is being made through calculations to allow both for very large enclosures and for the type of abrasive material used.

² Letter from American National Standards Institute, Committee on Safety Code for Exhaust Systems, September 26, 1972.

An air flow rate of 80 CFM/FT² (square foot of flow area) in a downdraft system with a silica sand abrasive was deemed appropriate as a starting point. This in fact corresponds to the recommended 80-LFM velocity put forth by the ACGIH Ventilation Guide. Dilution effects for rooms with large floor areas per operator and abrasives of nonsilica substances were incorporated into air flow calculations. Although the validity of several assumptions and mathematical techniques used is questionable, the approach provides an attempt at a concise presentation of design ventilation criteria.

- American Conference of Governmental Industrial Hygienists, Industrial Ventilation, 11th Edition

Recommends air flow rates for adequate ventilation of abrasive blast rooms. The range is given as 60-100 LFM (no mention of abrasive) with typical values given as 80 LFM for downdraft and 100 LFM for crossdraft.

Cabinet machines are specified to have a **minimum** inward dust control velocity of 500 LFM at all openings. Rotary tables are specified to have an air flow of 200 CFM/FT² at openings.

C. SCOPE OF VENTILATION AND DUST REMOVAL STUDY

Air flow rates were determined along with overall working conditions within enclosed and semi-enclosed abrasive blasting installations. Collected data was compiled in a form consistent with existing ventilation guidelines for comparison purposes.

Airborne dust concentrations in abrasive blasting enclosures at blasting cessation were also monitored. Dust levels were reviewed with reference to acceptable exposure limitations as defined in Chapter VI.

Also, adequacy of air inlet baffling and inlet air velocity was reviewed for each enclosure.

D. SURVEY OF INDUSTRIAL ABRASIVE BLASTING INSTALLATIONS

1. Data Acquisition Procedure

Of 22 industrial abrasive blasting installations visited, 10 were of an **enclosed** or semi-enclosed configuration. We determined air flow rates and general working conditions as described both by the blast operators and our own observations.



a. Ventilation Rates

Air intake ports, exhaust ducting, and room cross-sectional areas were used as locations for air velocity measurements. Several enclosure designs prohibited all of these locations from being sampled; however, where possible, air velocity readings were recorded from at least two locations. Velocity measurements were taken by use of a Datametrics Series 800-VTP Airflow Multimeter (hot wire anemometer). A description of this device is presented in Appendix B. The probe was inserted directly into the air flow stream, and in most cases, several velocity readings were taken to profile the duct or room cross-section. Air volume flow rates were calculated from averaged velocity figures and then used to determine the rate of air change.

b. Dust Clearance

Dust concentration data was determined at blasting cessation by following the same procedure outlined for overall dust exposure in Chapter VI.

2. Data Tabulation

a. Ventilation - Visibility

Table 8 presents a detailed summary of characteristic dimensional data and operating air flow rates for each abrasive blasting enclosure. Air velocities and calculated air flow rates are presented in Appendix A for each enclosed installation. Equipment was grouped according to air flow pattern, i.e., either downflow or crossflow. Calculated parameters were prepared in a format to allow direct comparison with existing ventilation guidelines.

b. Ventilation - Dust Clearance

As described in Chapter VI, dust clearance information was included with the overall dust concentrations data acquisition effort. Table 9 summarizes concentrations at specified times after cessation of blasting. This information may be directly compared with exposure TLV concentrations and permissible concentration excursions.

3. Discussion of Data

Information gathered from each of the ten abrasive blasting enclosures has been reviewed. Air change rates (number/minute) and air volume flow rates (cu ft/sq ft of flow area) were determined in both downdraft and crossdraft configurations and compared to existing guidelines.

Only three enclosures demonstrated sluggish dust removal from the blast operator's working area so that visibility was impaired.

TABLE 8
BLASTING ENCLOSURE VENTILATION DATA

INSTALLATION	ENCLOSURE TYPE	ENCLOSURE DIMENSIONS				FLOOR AREA (sq ft)	FLOOR AREA (sq ft)	VOL. @ 5 CPM	CHANGES	AIR FLOW		MEASURED VEL. @ BLAST	REMARKS
		L (ft)	W (ft)	H (ft)	D (ft)					AVERAGE VOLUME	CALC. VEL.		
R-4	Crossdraft	10	15	15	2250	150	2700	2	11 CFM/ft ²	18	18 LPM	Dust clearance seemed adequate at shutdown, blast operator visibility during blasting needed improvement.	
R-2	Downdraft	10	12	10	1200	120	1800	2	15	15	15	Dust clearance seemed adequate at shutdown, blast operator visibility variable, spots of dust.	
R-3	Downdraft (Side Plenums)	12	12	52	52	144	10,100	8.8	70	70	70	Dust cleared at shutdown, blast operator had good visibility during blasting.	
R-6	Crossdraft	45	12	15	8100	540	12,600	23	23	23	23	Dust clearance good at shutdown, blast operator had good visibility during blasting.	
R-7	Crossdraft	25	1400	75	1400	56	3120	2.2	56	56	56	No dust problem, rapid clearance at shutdown, blast operator says visibility ok during blasting.	
R-	Crossdraft	10	70	90	72	3460	4.8	48	48	48	48	Dust clearance good at shutdown, blast operator says visibility ok during blasting.	
P-9	Crossdraft	20	10	12	2400	200	16,900	0	140	140	140	Rapid dust clearance at shutdown, dusty but swept away during blasting.	
P-3	Upright Hood	10	560	56	3980	80	3980	49	49	49	49	Poor ventilation pattern, cleared at shutdown, visibility poor during blasting.	
P-10	Crossdraft	2	5	13	89	63	5970	5.5	57	57	57	Very good dust clearance at shutdown, visibility ok during blasting.	

TABLE 9

RECORDED DUST CLEARANCE CONDITIONS

INSTALLATION	ABRASIVE BLASTING ENCLOSURE		AIRBORNE DUST CLEARANCE RATE (1)		
	FLOW PATTERN	NO. OF AIR CHANGES PER MIN	ABRASIVE	TIME AFTER BLASTING SHUTDOWN (seconds)	DUST CONCENTRATION, RESPIRABLE TOTAL (mg/M ³)
R-2	Downdraft	1.2	Steel Shot	15 90	4.2 <1.0
R-4	Downdraft	1.3	Steel Grit	60 180	6.8 1.7
R-3	Downdraft Side Plenum	1.5	Steel Shot	120	1.1
R-6	Downdraft Side Plenum	1.5	Steel Shot	15 120	<1.0 <1.0
R-5	Crossdraft	4.8	Steel Shot	15 120	1.2 1.0
R-7	Crossdraft	2.2	Steel Shot	30 120	2.2 1.5
P-3	Updraft	7.1	Sand	120	<1.0
P-9	Crossdraft	7.0	Sand	15	<1.0

(1) The GCA RDM-101 Dust Monitor was used in gathering this data. 60-second samples were taken beginning at the above noted times after blasting shutdown.

None of these facilities were such that dust clearance at blasting cessation created any major problem.

None of these facilities demonstrated inadequate air inlet baffling or inlet air velocity so as to allow dust escape.

a. Ventilation - Visibility

Currently accepted ventilation design guidelines suggest air velocities (historically with silica sand abrasives) at 60-100 LFM as being adequate for ventilation of downdraft and crossdraft rooms. This corresponds to an average volume per flow area of 80 CFM/FT². In addition, only indirect reference is made to the adequacy of somewhat lower flow rates for nonsilica abrasives. However, the results of our survey showed that with nonsilica abrasives, air velocities lower than those typically recommended are satisfactory for worker visibility.

(1) Blasting rooms utilizing downdraft ventilation (Installations R-1, R-2, R-3, R-4, R-6) with nonsilica abrasives demonstrated flow rates of from 11 to 70 CFM/FT². All used only one operator with a hand-held nozzle. The two installations with impaired visibility (Installations R-3 and R-4) were characterized by the lowest air flow: 15 and 11 CFM/FT², with 1.5 and 1.3 changes per minute, respectively.

(2) Both blasting rooms with crossdraft ventilation (Installations R-5, R-7) and nonsilica abrasives demonstrated good visibility with 48 and 56 CFM/FT². Air changes were determined to be 4.8 and 2.2, respectively.

(3) Silica sand was used as the abrasive in an open-ended, crossdraft shed (Installation P-9) operating at 140 CFM/FT² of flow area and 7.0 air changes per minute. Clearance was exceptionally good.

(4) In one operation using a portable device with silica sand abrasive in an upflow hood (Installation P-3), the air flow was determined to be 49 CFM/FT² with 7.1 air changes per minute. However, this air flow pattern counteracted the natural tendency of dust to settle and markedly stirred the dust. Visibility was very poor.

(5) Blast cleaning the inside surface of a steel tank (Installation P-IO) with a slag abrasive was reviewed. The blast operator reported adequate visibility except in tank corners where the crossdraft air pattern was not effective. Air flow of 57 CFM/FT² and 5.5 air changes per minute were recorded.

b. Ventilation - Dust Clearance

Table 9 is a summary of dust concentrations taken within the abrasive blasting enclosures at cessation of blasting. Each sample collection was 60 seconds in duration and was initiated at the time noted in the table.

These concentrations represent the average dust values for the 60 seconds following the start of sample collection. Although respirable dust levels appeared relatively high immediately at blasting cessation, air flows provided rapid dust removal so that no exceptionally hazardous conditions were found.

(1) The highest initial dust concentrations were found in enclosures with the lowest number of air changes. Initial concentrations for nonsilica abrasives (Installations R-1, R-2, R-3, R-4, R-5, R-6, R-7, and P-IO) were above the respirable TLV of 5 mg/M³. However, with the blast operator delaying at least 15 seconds before removing his helmet, any possibility of exposure to these high dust concentrations will have passed. Even with the lowest values of 1.2 - 1.3 air changes per minute, dust concentrations were quickly brought to concentrations well below TLV's. When viewing these brief exposures in terms of the time-weighted TLV, no health exposure hazard existed.

(2) Silica sand presents a problem requiring more detailed consideration; however, in the two sites reviewed (Installations P-3 and P-9), clearance was both rapid and adequate.

c. Ventilation - Dust Leakage

All enclosures were provided with baffled air inlet ports and demonstrated no abrasive leakage when baffles were in good repair. Corresponding inlet air velocities were variable but ranged from 250-600 LFM and were sufficient to prevent backflow of dusty air through inlet ports.

E. SUMMARY OF VENTILATION AND DUST REMOVAL CONDITIONS

The following points appear evident from the review of data taken at individual installations:

- Downdraft and crossdraft blasting rooms using steel shot and slag abrasives provided good working visibility in all cases where the air flow rate was at or above 18 CFM/FT².
- Two blasting rooms using steel abrasive had sluggish dust clearance with impaired visibility at air flow rates of 11 and 15 CFM/FT².
- A large hood, with ceiling exhausted air flow, provided poor dust removal and developed poor vision conditions. Silica sand was used as the abrasive and the air flow reading was 49 CFM/FT².
- Two additional facilities had satisfactory dust removal during blasting: (1) An open-faced, crossdraft-ventilated shed adequately removed silica sand at 140 CFM/FT². (2) A shipboard



tank was ventilated at 57 CFM/FT². This adequately cleared a slag abrasive during internal surface cleaning.

- All facilities developed rapid dust removal at blasting cessation and did not create a dust exposure health hazard for the blast operator after helmet removal. Air rates as low as 1.2 - 1.3 changes per minute were satisfactory.
- All facilities had adequate air inlet baffling and inlet air velocity so as to prevent unrestricted dust escape. Inlet air velocities were found to be as low as 250 LFM.

F. RECOMMENDED CRITERIA

The primary objective of proper ventilation in abrasive blasting enclosures is to insure good visibility by the removal of generated airborne dust from the vicinity of the blast operator. In addition, control of dust is necessary to prevent spread to adjacent work areas when blasting takes place in semi-enclosed facilities, and to prevent unrestricted dispersal and backwash on the blast operator when blasting takes place in either semi-enclosed or totally enclosed facilities:

1. Ventilation - Dust Control

a. A downdraft or crossdraft exhaust-type ventilation system should be designed into abrasive blasting enclosures to provide effective dust removal. The enclosures should be designed and well maintained to prevent air leakage through seals, holes, or other openings which would interfere with a uniform downdraft or crossdraft flow pattern.

b. Downdraft ventilation should be preferentially used in totally enclosed abrasive blasting facilities. Dust removal by air flow is thereby augmented by the natural tendency of dust to settle by gravity.

c. For adequate dust clearance, a minimum air flow rate of approximately 20 CFM/FT² should be used with nonsilica abrasives. Higher minimum rates should be used with low density or toxic abrasives that exhibit a tendency to fracture extensively. For example, past experience has shown 80 CFM/FT² to be effective for the control of silica sand dust.

d. Crossdraft ventilation is also effective both in totally enclosed abrasive blasting facilities and in semi-enclosed abrasive blasting facilities. Air flow rates should be in the same range (preferably higher) but not lower than those for downdraft systems designed for identical operating conditions.

e. Updraft ventilation should not be used in abrasive blasting enclosures.

f. All required openings on abrasive blasting enclosures should be designed with baffling to prevent unrestricted dust leakage. Also minimum inlet air velocities of 250-300 LFM through such baffled openings should be developed to prevent dust leakage.

2. Ventilation - Dust Exposure

Blast operators should not be exposed to harmful concentrations of dust at removal of protective, respirated helmets. Therefore, overall air change rates should be sufficient to rapidly clear dust from abrasive blasting enclosures upon blasting cessation.

a. Abrasive blasting enclosures should be designed with uniform downdraft and crossdraft air flow patterns to insure the most prompt clearance. Turbulence by leakage or poor flow distribution slows dust clearance rates and should be eliminated.

b. Uniform air rates greater than 1.2 changes per minute, combined with velocities sufficient to provide good visibility during blasting, should be provided to quickly reduce dust concentrations and alleviate any potentially dangerous dust exposures.



VIII. SOUND LEVEL EXPOSURE

A. PROBLEM OVERVIEW

Because abrasive blasting is an inherently noisy operation, an investigation of the safety and health of associated workers must include an assessment of possible hearing damage. The purpose of making sound measurements, then, is to document the sound levels to which the workers are exposed and compare these levels with hearing damage criteria. Further, it was not the purpose to relate sound levels to specific pieces of equipment, nozzles in particular, or their operating parameters such as capacity, flow rate, pressure, workpiece, angle of blasting, etc. Such concerns are properly the subject of a separate noise reduction study.

B. MEASURED INDUSTRIAL CONDITIONS

1. Hand-Operated Nozzles (Portable Units and Blasting Rooms)

One common feature for both portable units and blasting rooms is the hand-held and manipulated nozzle. In either case, the noise source is equally close to the operator's ear, and being in the near field the noise level should be substantially independent of field effects. The data bears out this effect. The sound data for both types of facilities have been grouped together. Sound data forms are presented in Appendix A.

a. Blast Operators

The single number measurements with A-weighting and Flat (20 kc) are presented in Table 10. Column 1 is the installation identification; column 2 is the sound level at the blast operator's ear, under the helmet, with breathing air the only noise source; column 3 gives the total range of levels observed during active blast cleaning; column 4 is either the best long-time average as determined by the investigator reading the instrument (in the slow response mode) or the arithmetical average of the column 3 range; and column 5 notes the allowable operating time in hours per day if the OSHA provisions were in effect¹

b. Nearby Workers

Since some abrasive blast cleaning operations require supporting Workers who are situated near the operation, the noise level was also measured at some distance to the actual blasting. These measurements are listed in Table 11. The column headings are the same as for Table 10 except for column 2 which indicates the measurement distance from the source. The distance has meaning in that it presents the position of other nonrelated workers or possible passers-by.

¹Federal Register, 16 December 1972, Vol. 37, No. 343, Part I.

TABLE 10
SOUND LEVELS AT EAR OF BLAST OPERATOR (UNDER HELMET)
FOR HAND-OPERATED NOZZLES

Installation	With Helmet with Breathing Air Only		Blasting Range		Blasting dB(A)	Avg. (20)	OSHA Allowable Hours/Day
	dB(A)	(20)	dB(A)	(20)			
R-4(1)	82		98/108		102		1-1/2
R-4(2)	77	96	98/102	94/104	100	102	2
P-7	70		98/108	96/100	100	99	2
P-5(1)	72	84	78/88	81/88	82	85	8+ (unusually low)
P-6(1)	100	100	98/102	94/102	99	101	2+
P-6(2)	100	100	104/108	100/112	106	106	1/2+
P-9(1)	87	92	95/102	96/107	98	101	2+
R-3	87.5	95	112/124	114/122	120		none
R-2			103/116	104/116	107	110	1/2+
P-10	66	77	113/126	113/122	118	118	none
R-1(1)	73	94		99/104	95	101	4
R-1(2)	73	94	95/105	101/106	100	102	2
P-2(1)	81	93	98/104	98/102	98	99	2+
P-3				98/108	100	102	2
R-6	89	100	90/98	96/104	97	99	3
R-5(1)	88	92	106/113	108/116	111	III	1/4+
R-7	94	96	98/106	98/108	102	103	1-1/2

TABLE 11
SOUND LEVELS NEAR HAND-OPERATED NOZZLES

Installation	Measurement Distance-From	Blasting Range		Blasting Avg.		OSHA Allowable Hours/Day
		dB (A)	(20)	dB (A)	(20)	
R-4(3)	3'-- Outside Blasting Room Walls	96/110	98/112	102	101	1-1/2
P-5(2)	6'-- Blaster Nozzle			94	96	4+
P-9(2)	35'-- Blaster Nozzle	92	91/96	92	93	6
P-4(1)	70'-- Blaster Nozzle	87	87/89	87	88	8+
P-4(2)	70'-- Blaster Nozzle	92/96	92	94	92	4+
P-4(3)	35'-- Blaster Nozzle	99	100/102	99	101	2+
P-4(4)	40'-- Blaster Nozzle	90/91	88/90	90	89	8
R-5(2)	3'-- Outside Blasting Room Walls	90/104		97		3
P-2(?)	8'-- Blaster Nozzle	102/105	102/105	103	104	1+
P-2(3)	46'-- Blaster Nozzle	94/98	94/98	96	96	3+

2. Remotely Operated Units (Automatic Rooms and Cabinets)

From an acoustic viewpoint, remotely operated units and cabinets are different from all other types of blasting operations because the operator (or other worker) is shielded from the noise source by the enclosure walls. Also, there is no meaningful distinction among these types with regard to hearing conservation. The data for these units is shown in Table 12. It is known, however, that fans associated with dust collecting systems develop high noise levels.

C. DISCUSSION

Although the use of a single number sound level like 90 dB(A) is the general trend for noise criteria as the noises are generally broadband in character, there are instances where stated levels of discrete tones or octave bands also are part of the criteria or regulation. Consequently, the spectra of abrasive blasting noise should be known in order to determine the appropriateness of a single number criteria.

For six abrasive blasting facilities in Massachusetts, octave band measurements were made in addition to the single number measurements. These octave band data are shown in Figure 13.

A detailed description of the sound measuring and the techniques used for taking the measurements is presented in Appendix B.

The sound levels obtained for abrasive blasting facilities are dependent upon many environmental and physical parameters. Among these would be nozzle size, and air flow, workpiece geometry, breathing air flow, and room geometry. The levels, as reported, represent averages over a period of time--30 seconds to 5 minutes--and were quite variable. Despite the variability encountered both during blasting and in the facility parameters (with the exception of Installation P-5[1]), the sound levels are remarkably similar. In outdoor abrasive blasting, the worker is in the near field (that is, very near to the noise source) close to the reflecting surfaces of the workpiece. While working in enclosed blast rooms, the worker is in a small hard-wall reverberant chamber where near-field and far-field conditions are not distinguishable, but the noise at the worker's ear appears to be dominated by the near field of the source. In the one instance of Installation P-5[1], the worker was in a relatively open field, the workpiece was a small 4" pipe saddle, and the work table was a 2" x 8" length of lumber on saw horses. The reflecting surfaces were small and/or quite distant. The surroundings approach those of a free field, thus accounting for the unusually low sound level.

As the small difference between the A-weighting and flat (20 kc) data indicates, the overall sound level is dominated by the mid- to high-frequency bands. Consequently, the A-weighting level is not significantly lower than the 20-kc level, as might be expected, due to the characteristics of the A-weighting scale. The octave band data also verify that this is possible.

TABLE 12
CABINETS OR AUTOMATIC ROOMS
SOUND AT OPERATORS STATION AND/OR NEAREST OTHER WORKER

Install- ation	Worker or Operator Distance	Blasting Range		Blasting Avg.		OSHA Allowable Hours/Day
		dB (A)	(20)	dB (A)	(20)	
A-3	10'	82/85		83		8+
A-4(1)	25'	85/87	94/95	86	94	8+
A-4(2)	1'	90	95/97	90	96	8
A-2(1)	3'	96/99	98/101	97	99	3
A-2(2)	15'	94/95	97/98	94	97	4+
A-I(1)	2'	108/113		110		1/2
A-1(2)	12'	94/100	95	97	95	3
C-1	1/2'	87/90	87/90	88	88	8+

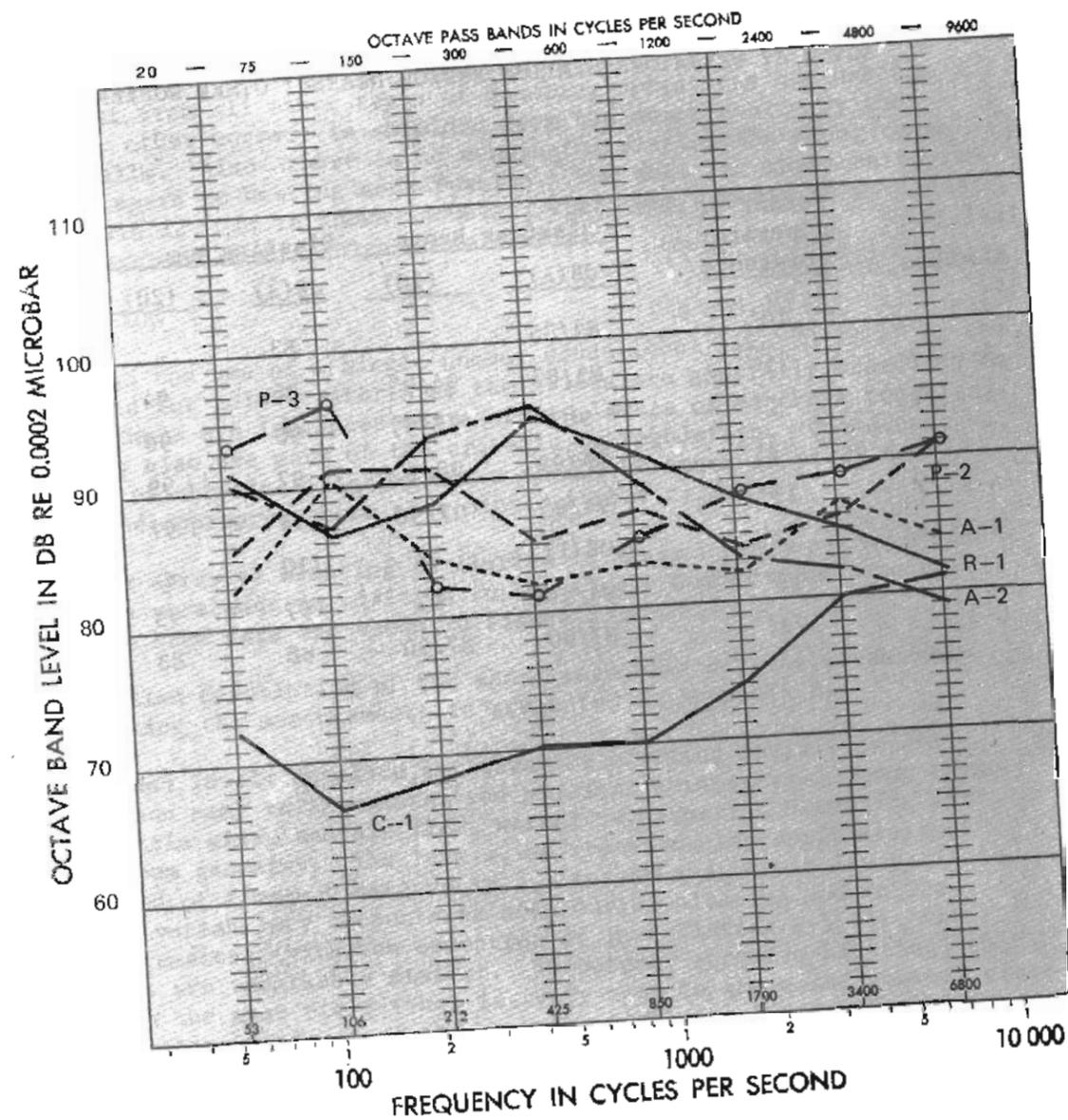


FIGURE 13 OCTAVE BAND MEASUREMENTS AT SELECTED FACILITIES.
20 kc FLAT RESPONSE

The octave band levels of Figure 13 indicate the essential characteristic of high air flow rates through nozzles--that is, a wide band noise nearly constant with frequency, caused by jet turbulence.

The trend, however, is clear; the levels are very high and when compared to the OSHA regulations, the allowable operating time or allowable worker exposure is very short and often was less than his stated working time per day. In conversation with some blast operators, it was concluded subjectively that hearing loss had occurred. Considering the short number of allowable hours per day appearing in the last column of Table 10, the same conclusion could be made objectively. Of considerable interest, however, was the disturbing fact that the breathing-air noise itself created high noise levels within the helmet.

Table 11 shows that some measure of "protection" is offered by the increased distance from the nozzle of other workers. Pure distance alone (spherical spreading with 6 dB reduction per doubling of distance) cannot always assure lower noise levels since the geometry of the installations could nullify the effect due to reflections or focusing. Installation P-4 demonstrates this effect in the drydock area for the two locations at 70 feet.

In the case of blasting cabinets or automatic rooms, it would be expected that the enclosure would offer considerably more protection to the operator due to the barrier effect of the enclosure walls. In general, this would be true, but the protection from the blasting nozzle can be nullified by the addition of other air sources. In Installation A-2 of Table 12, the noise at 15 feet was due entirely to the exit air cleaning nozzles which blew residual shot off the workpiece. In Installation A-1, these air-cleaning nozzles were hand operated thus creating, in effect, another blast operator's position.

Without qualification abrasive blasting with hand-held nozzles presents a serious problem in terms of worker hearing loss. With cabinet or room type blasting, the problem is, or can be made to be, of minimum concern. In the case of large blasting facilities and/or unique surface geometries, transient workers or unrelated activities can be seriously affected.

D. NOISE REDUCTION

There are three major methods that can be used for noise control: (1) reduce the noise at the source by making the noise conversion process less efficient; (2) eliminate or modify the noise transmission path, or (3) shield the worker. These methods are common to all noise problems. The very nature of the abrasive blasting process requires high flow rates; the sound power output is a high power function of the velocity, and an effort to reduce flow velocities will be resisted since presumably it will result in lower material removal rates. Attachments to the nozzle to reduce the turbulence and, hopefully the noise, will add either bulk or

mass to the nozzle that the worker must hold and manipulate. The transmission path air cannot be modified for the hand-held nozzle blasting operation so it appears that shielding the worker's ears has the most hope for success.

There is an indication that the helmet could be improved as a shield against nozzle noise. At Installation P-7, the measurements in Table 10 show that inside the helmet, the sound level was 98 dB(A) and outside 104 dB(A) at 2" from the helmet surface. Because two microphones with simultaneous measurements with a significant number of subjects would have been required to definitely establish this trend, the potential value of helmets to hearing protection can only be speculated.

Of equal importance in helmet modifications would be the reduction of breathing-air noise by reducing air flow velocity or suitable muffling the existing nozzle noise. It had been observed in one instance that high breathing air flow velocities were used to provide a cooling effect for the operator. Although additional operating and maintenance expense would be incurred, supplying cooled air at lower flow rates would be desirable for hearing conservation. The direction of these improvements, however, would tend to increase the weight of the helmet, and sufficient shielding might result in a completely unacceptable helmet for blasting.

Ear plugs and ear muffs also provide protection for the ear. The muffs should be an integral part of the helmet to prohibit helmet use independent of muff use. The use of ear plugs is the responsibility of the worker, but plugs may be required in addition to the muffs if helmet modifications alone become impractical. The insertion of ear plugs by workers having dirty and gritty fingers also creates an industrial hygiene problem.

E. RECOMMENDED CRITERIA

The most up-to-date criterion which has received the most thoughtful consideration is the OSHA Regulation Section 1926.52 reproduced here (Figure 14) from the Federal Register of December 16, 1972. Further reductions of the levels by 5 dB are presently being discussed. It is not likely that state or local municipalities would have criteria better established or justified than the above.

The evaluation of damage risk from exposure to noise is an exceedingly complex process. The statement that the exposure is a risk is made because there is no single number with which to rate a noise level below which no risk is incurred unless that number is unrealistically low².

² Kryter, K. D., "The Effects of Noise on Man," Academic Press, 1970, New York, Chapter 5.

§ 1926.52 Occupational noise exposure.

(a) Protection against the effects of noise exposure shall be provided when the sound levels exceed those shown in Table D-2 of this section when measured on the A-scale of a standard sound level meter at slow response.

(b) When employees are subjected to sound levels exceeding those listed in Table D-2 of this section, feasible administrative or engineering controls shall be utilized. If such controls fail to reduce sound levels within the levels of the table, personal protective equipment as required in Subpart E, shall be provided and used to reduce sound levels within the levels of the table.

(c) If the variations in noise level involve maxima at intervals of 1 second or less, it is to be considered continuous.

(d) (1) In all cases where the sound levels exceed the values shown herein, a continuing, effective hearing conservation program shall be administered.

TABLE D-2—PERMISSIBLE NOISE EXPOSURES

Duration per day, hours:	Sound level dBA slow response
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
½	110
¼ or less	115

(2) (i) When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their

combined effect should be considered, rather than the individual effect of each. Exposure to different levels for various periods of time shall be computed according to the formula set forth in subdivision (ii) of this subparagraph.

(ii)

$$F_e = \frac{T_1}{L_1} + \frac{T_2}{L_2} + \dots + \frac{T_n}{L_n}$$

where:

F_e = The equivalent noise exposure factor.
 T = The period of noise exposure at any essentially constant level.

L = The duration of the permissible noise exposure at the constant level (from Table D-2).

If the value of F_e exceeds unity (1) the exposure exceeds permissible levels.

(iii) A sample computation showing an application of the formula in subdivision (ii) of this paragraph is as follows. An employee is exposed at these levels for these periods:

- 110 dbA ¼ hour.
- 100 dbA ½ hour.
- 90 dbA 1½ hours.

$$F_e = \frac{1/4}{1/2} + \frac{1/2}{2} + \frac{1 1/2}{8}$$

$$F_e = 0.500 + 0.25 + 0.188$$

$$F_e = 0.938$$

Since the value of F_e does not exceed unity, the exposure is within permissible limits.

(e) Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

FIGURE 14 OSHA REGULATION SECTION 1926.52

But as Kryter points out, the dB(A) weighting scale has been shown to be adequate for many industrial noises because the spectrum shape of the noises tends to be higher in the low frequencies. If the noise has a greater energy content in the high frequencies, say 2000 Hz and above, which is more indicative of the noise measured for abrasive blasting, then the use of the A-scale may be suspected as not providing a proper measure of the risk. Kryter, in fact, recommends the use of what he calls the D₂ scale. This scale is similar to the A-scale but emphasizes the range of frequencies from about 2000 to 6000 Hz. These scales are shown in Figure 15.

We cannot recommend unequivocally the use of the D₂ scale in preference to the A-scale at this time even though the D₂ scale appears to have merit. The preponderance of the statistical A-scale data, and the common use and availability of the A scale argue in its favor and continued use. It must be noted, however, that the spectrum characteristics of abrasive blasting are not the same as the general class of industrial noises.

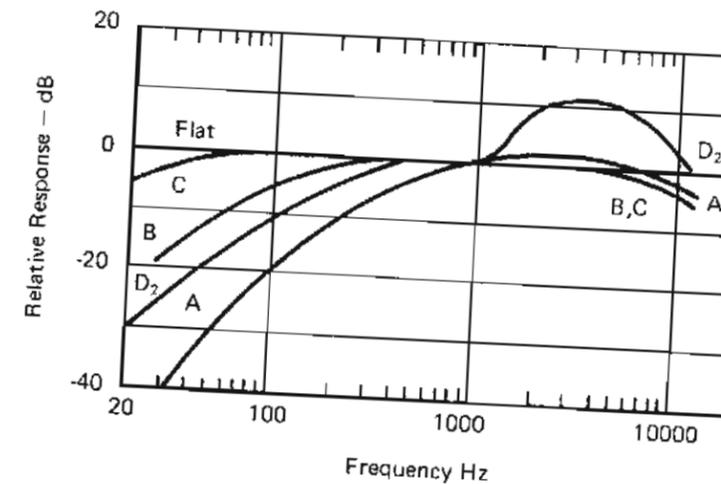


FIGURE 15 FLAT, C, AND A-WEIGHTING SCALES ARE COMMONLY IN USE; D₂ IS RECOMMENDED.

Reproduced by permission of the author and the publisher from Figure 8, page 14 of *The Effects of Noise on Man* by Karl D. Kryter, Academic Press, New York, 1970.

IX. VISION IMPAIRMENT

A. PROBLEM OVERVIEW

It was anticipated that pressure blast cleaning operators would be exposed to vision impairment during the course of work operations. On this basis operator vision tests were conducted utilizing a standard Snellen Eye Chart before and after completion of blasting operations. It was also possible, in most cases, for the survey observers to roughly determine the degree of vision impairment by viewing the cleaning operation through the observation ports provided in the doors of most blast cleaning rooms. In certain cases a member of the survey team conducted actual blast cleaning procedures to personally test the reduction in visibility from dust development and other vision restricting sources.

B. OBSERVATIONS

Ocular tests indicated that vision impairment is not a major occupational problem. Restrictive viewing develops from repeated abrasive impact on the vision glass of helmets. More frequent replacement of the glass promptly corrects the situation. A fast, less expensive solution to the problem is developed by the use of adhesive, transparent mylar films that cover the glass to prevent abrasive etching. The protective film can be readily applied to and stripped from the vision glass.

Frequently, to prevent abrasive etching, copper screens are inserted over the vision glass in breathing hoods. Such screens do reduce Visibility, but the reduction is negligible and cannot be considered a major impairment to the operator's vision.

Within pressure blast cleaning rooms the overhead lights are frequently damaged. It is quite rare to find all available lights operative. In most cases the protective glass shades are badly etched by abrasive contact and light emission is reduced in proportion to the extent of etching.

On only one occasion was the worker's vision impaired to the extent that the worker was actually working blind. This case involved an operator who was using a portable blasting unit to clean offshore drill rig deck housings (Figure 8 on Page 56). Vision was impaired by a dense abrasive dust cloud and an etched vision glass (Figure 10, on Page 58).

Vision impairment occurs only when the air flow around the blast operator and the work area is not sufficient to clear away the developed dust cloud. Three such cases were seen within blast cleaning rooms during the various plant surveys. This topic is discussed in detail in Chapter VII under dust removal by ventilation, and criteria for eliminating causes of visual impairment are included in the criteria for general safety in Chapter X.

X. GENERAL SAFETY

A. PROBLEM OVERVIEW

In addition to having dust and noise problems, pressure blast operators are exposed to other potential injury and health exposures from the use of various machines and from hazardous work locations. For instance, they frequently work in confined spaces and at varying heights and elevations and perform spray paint operations when they have completed blast cleaning work.

B. BLAST CLEANING MACHINES

The job hazards vary with the type of machine used. In this chapter the assessment of accident and health exposures is related to specific abrasive blast cleaning machines as follows.

1. Hand-Operated Portable and Room-Type Blast Cleaning Machines

The operator of hand-held equipment works in the open when cleaning surfaces of high buildings, swimming pools, the hulls, decks, and superstructures of ships, high steel structures, and aids to navigation at which time he utilizes a flexible hose and abrasive discharge nozzle system (Figure 16). Similar equipment is also used within the confines of an enclosed blast cleaning room which are usually complete with a dust control and collection system.

The unsafe factors, exclusive of dust and noise problems, that were seen repeatedly at various locations fall into special hazard categories:

- a. mechanical,
- b. electrical, and
- c. personal protective and life support equipment

Our observations in each area form the basis for the following recommendations;

a. Mechanical Conditions and Recommendations

(1) All units should be equipped with a positive fast-acting abrasive shut-off control that must be depressed by the operator to commence blasting operations. The design should be such that the machine cannot be operated by the weight of the hose and nozzle if the nozzle is dropped, or by other means of "on ground" depression, cutting, or pinching by pedestrian, vehicular, or other traffic.

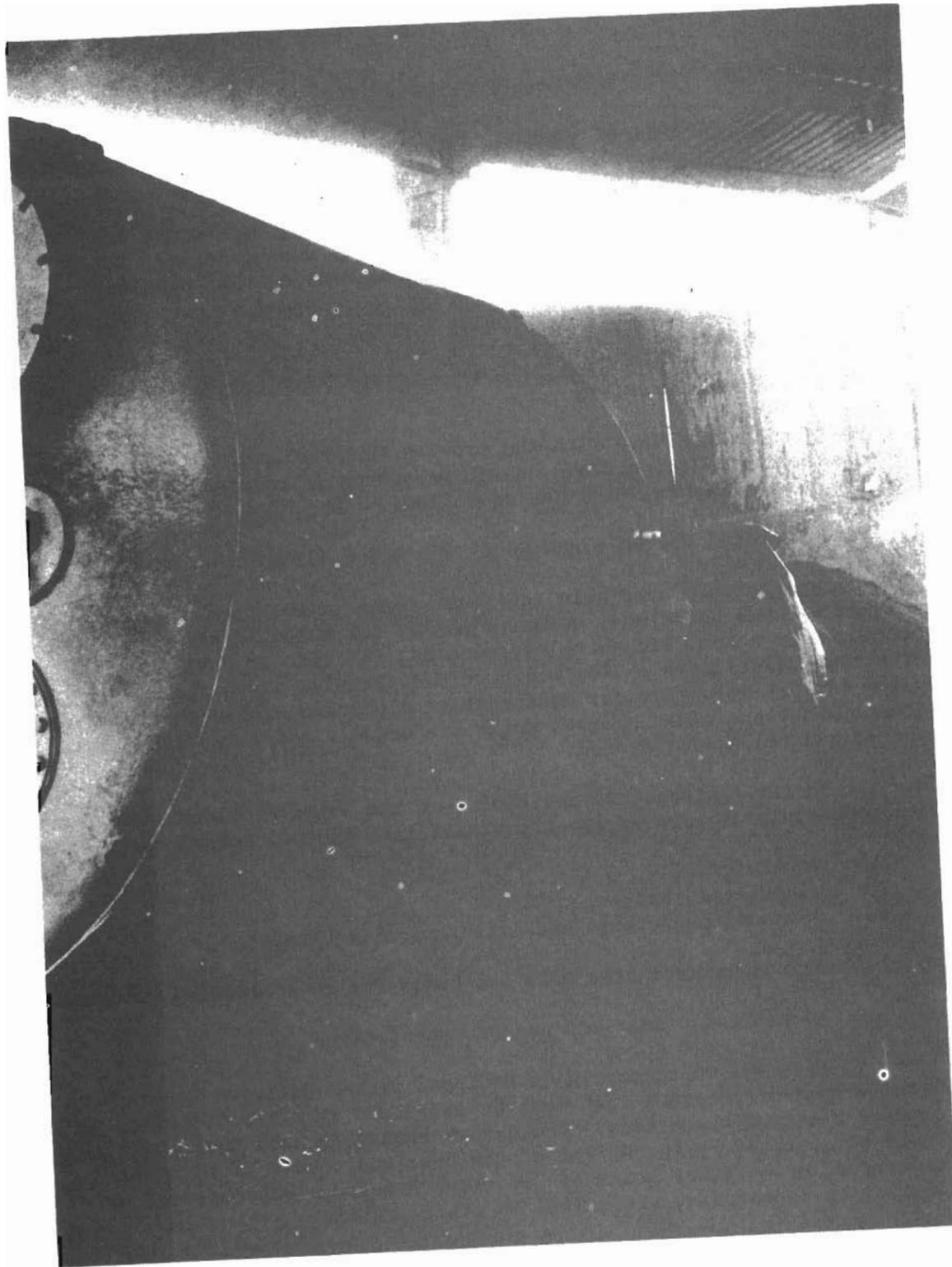


FIGURE 16 HAND-OPERATED PORTABLE BLAST CLEANING MACHINE

(2) Hose lines which are exposed to internal deterioration from abrasive action should be subjected to regular nondestructive integrity testing on an elapsed time basis. The initial test after use can be of a greater time span than the subsequent tests which should be conducted more frequently depending on age. The elapsed time between testing should be determined by the hose manufacturers based on the types of hose construction and on the type of abrasives for which the hose has been designed or will be used. The user should maintain test records and make them available to the OSHA Compliance Officers or any other designated safety inspectors.

(3) On a time-use basis, all metal pipe lines, joints, bends, valves, connectors, and nozzles should be subjected to regular internal inspection to detect deterioration from internal abrasion. Defective parts should be replaced promptly to avoid sudden and accidental failure. The time test period should be established by the user on the basis of previous failure and/or past replacement time procedures. The user should maintain and make them available for examination by OSHA Compliance Officers and other designated safety inspectors.

(4) Pressure "pots" or vessels used in conjunction with abrasive blast cleaning operations should be examined for internal deterioration on a regular two-year frequency. Following each five years of operation, the "pot" or pressure vessel should be subjected to a hydrostatic test at a pressure of 1-1/2 X designated maximum working pressure. Such inspections and testing should be conducted and/or witnessed by an individual who has attained proven competency in this work such as an ASME/National Board Commissioned Inspector, or a state or deputized insurance company inspector. The use of pressure "pots" or vessels which lack a removable hand-hole plate that permits internal examination should be prohibited. All "pots" or vessels should be constructed in accordance with ASME pressure vessel code requirements.

(5) Pop-up valves used to pressurize the "pot" or pressure vessels should not be fabricated of all rubber construction. Rubber seals may be used as long as the valves have an internal metal core of greater diameter than the opening in the tank top. Rubber-covered valves and tank top seals should be checked frequently for deterioration, and defective parts should be promptly replaced.

(6) Pressure "pots" or vessels should be designed in a manner that will permit free and easy entry of the abrasive, reduce spilling, and generally aid in the prevention of strains and sprains when the "pot" is being filled manually. In this respect it is preferable that the upper fill head be of concave design.

(7) The interior floors, ledges, and shelf surfaces (whenever practical the latter two items should be avoided) of blast cleaning rooms should be cleaned of waste abrasive and debris on a regular daily basis whenever the facility is used. The person or persons conducting such cleaning operations should be supplied with and instructed to wear suitable respiratory protection during such cleaning operations. In addition, all floor surfaces within the room or chamber should be continually examined for abrasive deterioration and distortion and prompt repairs should be made to provide an even floor surface that will not contribute to slipping and falling accidents.

(8) Blast cleaning rooms should be inspected on a regular weekly basis to detect holes, abraded metal enclosure surfaces, and defective door seals that can permit the escape of abrasive material. Such defective sections should be subjected to welding repair or replacement as the extent of deterioration warrants. Whenever practical, the interior of blast cleaning rooms should be rubber lined to reduce operating noise and to protect the metal sidewalls from abrasive deterioration.

(9) In a similar manner to Item 8, split or divided blast cleaning rooms that permit the entry of work on an overhead traveling crane should have the division seals examined, at least weekly, and defective seals should be replaced promptly.

(10) Whenever the blast cleaning process entails the cleaning of heavy or bulky objects, an adequate means of handling such items prior to, during, and after blast cleaning should be provided.

(11) All doors of a blasting enclosure should be kept closed at all times when blasting is being done and should be kept closed for a reasonable time after the blasting has ceased.

(12) All moving mechanical devices, conveyor belts, and other mechanical drives should be mechanically guarded to prevent physical contact with moving machinery. Protection by remoteness (Figure 17) is not considered adequate since maintenance personnel can still be injured in the machinery.

(13) Each blast cleaning room should have at least two inspection ports located in such a position that the operators can be clearly viewed from an external source at all times. The internal protective guard or cover for such inspection ports should be maintained to open and close freely and thereby protect the vision glass from abrasive etching.

(14) Doors providing entrance and exit for blast cleaning rooms should operate freely and should not be obstructed or otherwise restrict fast exit. The doors should not be lockable on the inside or in any way prevent the entry of emergency assistance into the blasting enclosure.

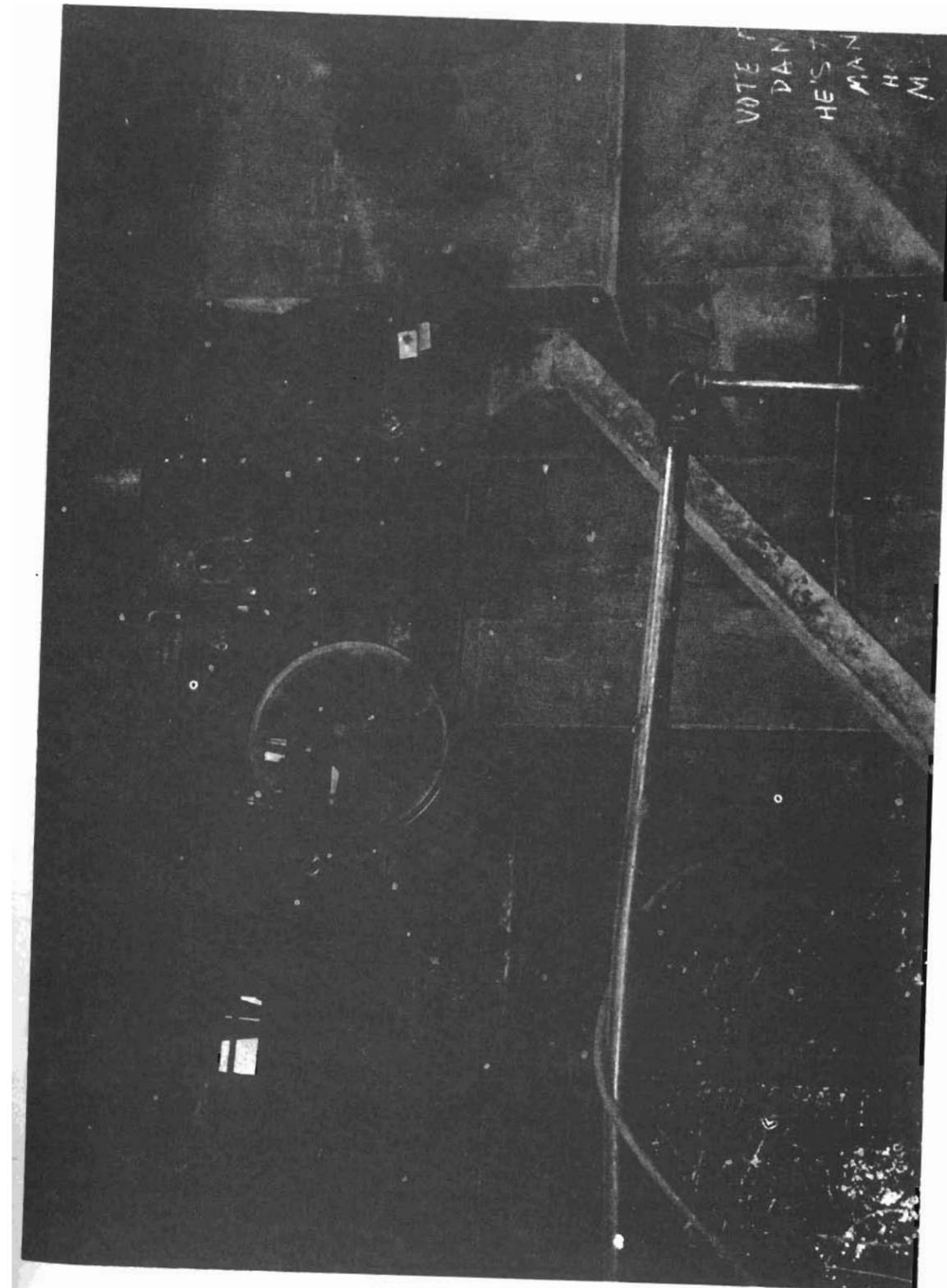


FIGURE 17 UNGUARDED BELT DRIVE FOR EXHAUST FAN

(15) Waste abrasive should be cleared from work areas on a regular daily basis and should not be permitted to accumulate or stockpile. (Figure 18.) The method of disposal should not cause environmental problems.

b. Electrical Conditions and Recommendations

An overview of machine safety as related to electricals should include considerations in the following areas:

- Equipment adequacy
- Circuit design
- Placement and positioning of devices
- Identification (color coding or tagging)
- Environmental
- Testing and checking
- Guarding
- Instructional materials
- Standards and specifications
- Machine and equipment grounding

Under these broad area headings it is possible to categorize the many specific points which should become electrical safety considerations. The specifics should include the following:

(1) All motors used in conjunction with abrasive blast cleaning equipment should be of totally enclosed dust-proof design.

(2) All electrical controls should be confined in dust-tight enclosures meeting the design criteria of The National Electrical Manufacturers Association (NEMA) Spec. 12.

(3) The main abrasive supply hose line should be provided with an efficient means for the discharge of static charges from the blasting nozzle. It is preferable that the grounding system be built into the hose line rather than utilizing a separate grounding cable attached to the outside of the hose since exterior grounding systems are easily damaged and rendered worthless. The grounding system should be subjected to a ground continuity test on a regular weekly basis prior to the commencement of work operations at the beginning of each work week. Test records should be maintained and be made available for review when requested by federal, state, municipal, or other safety inspectors.

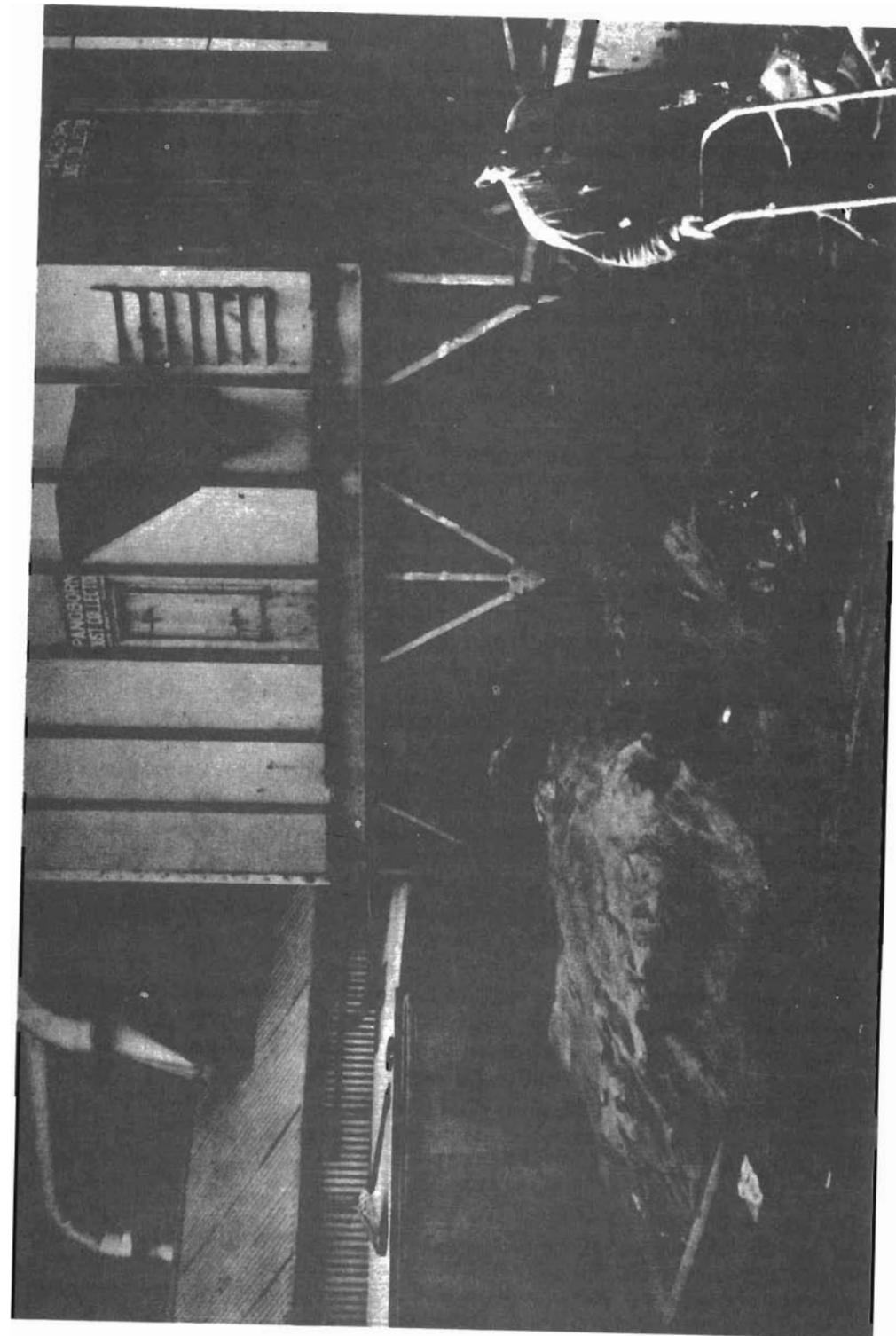


FIGURE 18 MOUNDS OF ABRASIVE WASTE MATERIAL

(4) All electrical lighting within the confines of blast cleaning rooms should be 100 percent operative at all times, and the protective glass shades or plates should be promptly changed when the glass becomes etched and restricts light emission. The illumination within every blasting chamber should not at any time be less than twenty foot-candles over all parts of the chamber measured in a horizontal plane at three feet above the floors.

c. Personal Protective and Life Support Equipment

Each operator should be provided with and instructed to wear the following personal protective equipment:

(1) An air-supplied breathing helmet, which bears a distinguishing mark indicating that it has been allotted to an individual operator. Such helmets should not have been previously worn by any other person or should be subjected to a thorough cleansing and disinfecting since last being used by another person.

(2) The use of helmets and/or masks lacking a self-contained source of breathing air should be prohibited since they lack an air seal to prevent dust entry into the helmet or mask and are frequently used for periods of time in excess of the designed temporary or short-term use.

(3) The air supplied into self-contained breathing helmets should not be drawn from the main air supply compressor. A separate oil-free compressor should be used to supply breathing air. In addition, the breathing air should be air conditioned and cooled to a temperature in the range of 65°F. It should also be passed through an air purifier before entering the operator's helmet. Each breathing-air supply system should be equipped with an audible alarm that will warn the blast cleaning operator, his helper, or other workers in the vicinity that the breathing supply is contaminated with smoke or carbon monoxide.

(4) Self-contained breathing helmets should be designed to accommodate and permit the use of sound reducing ear muffs either as built-in protection or to fit over conventional ear muffs. Until sound reduction techniques within self-contained breathing helmets has been applied, the use of ear muffs and/or ear plugs should be mandatory to insure that the 90 dB(A) level is not exceeded. This also applies to other workers within the high noise level area.

(5) Vision glasses in self-contained breathing helmets should be replaced promptly when the glass becomes etched from abrasive impact. The condition of such glasses should be checked on a weekly basis by the blast cleaning operator's direct work supervisor. The use of protective mylar films over vision glasses is highly recommended.

(6) Abrasive blast cleaning workers should be provided with and instructed to wear safety boots or toe guards.

(7) Each operator should be provided with and instructed to wear suitable gauntlet gloves and coveralls that will prevent abrasive materials from contacting the skin from entry through breaks in clothing. This requirement is additional to the protection afforded from leather or rubberized capes associated with self-contained breathing helmets and protective leg chaps. The lower leg of such coveralls should be belted and buckled or taped closed around the workers safety boot to prevent the entry of abrasive.

(8) In addition to the stipulated personal protective equipment, a suitable, clean locker or container should be provided for each operator to store equipment in a clean condition. Such storage accommodation should be in a dust-free area outside of the blasting area but as close as practical to the area of operations.

(9) Silica sand as an abrasive cleaning agent should be prohibited from use with all hand-held abrasive blast cleaning machines.

(10) No worker that has been involved in extensive (over 4 hours) blast cleaning operations should be assigned to spray paint operations within the same work day.

2. Hand-Operated Cabinet Machines

In this type of machine the operator inserts his hand and arms into rubber gloves and sleeves and blast cleans parts which are installed on a jig or are held in one hand while the abrasive discharge nozzle is controlled in the other hand (Figure 4 on Page 26.)

a. Mechanical Conditions and Recommendations

(1) The exhaust fans of cabinet machines should be acoustically engineered to the extent that the resulting noise level does not exceed the federally stipulated 90 dB(A).

(2) All cabinet machines, including small bench-top type units, should be equipped with a forced-air type dust collecting system. Gravity-settling dust-collecting systems should be prohibited since they restrict vision and can become overpressured causing leakage of abrasive.

(3) The use of open-front cabinet machines as used in the suede preparation and cleaning industry should be prohibited

(4) The observation port on all hand-operated cabinet machines should utilize only safety glass. Each vision glass should be designed to visually indicate that safety glass observation ports have been provided.

(5) Door seals on cabinet units should be inspected weekly, and defective seals should be promptly replaced.

(6) All metal surfaces within cabinet machines should be designed to eliminate flat dust collecting surfaces. Angled surfaces should be provided that will aid in directing the abrasive and debris into the dust collecting system,

(7) Dust collecting systems on cabinet machines should be cleared of blockage on at least an hourly operational basis. Dust collection bags should be inspected on a regular weekly basis and defective bags should be promptly replaced.

(8) Foot-type controls used to activate cabinet machines should be equipped with a stirrup-type guard that will prevent accidental operation of the machine.

(9) The internal surfaces of all cabinet machines should be inspected on a regular weekly basis to determine any thinning of the metal casing from abrasive action. Deteriorated sections discovered during inspection should be promptly repaired or replaced.

b. Electrical Conditions and Recommendations

(1) All machines should be provided with an efficient means for the discharge of static electricity from the blasting nozzle. In addition, the cabinet machine operator should be provided with an easily attachable grounding strap that will protect him from static electrical shock.

(2) All cabinet machines should be equipped with the following failsafe control protection:

- A negative-pressure control switch that will prevent operation of the machine unless a negative pressure is evident within the cabinet.
- An electrical interlock control that will prevent machine operation unless the main access door is in the closed position.

(3) All operating controls should be of dustproof NEMA Spec. 12 design, and the control boxes should be kept closed at all times unless being serviced by a competent electrician. Figure 19 illustrates this problem

(4) Electrical lighting within cabinet machines should be adequately maintained, and etched shades or protection glasses that restrict light emission should be promptly replaced.

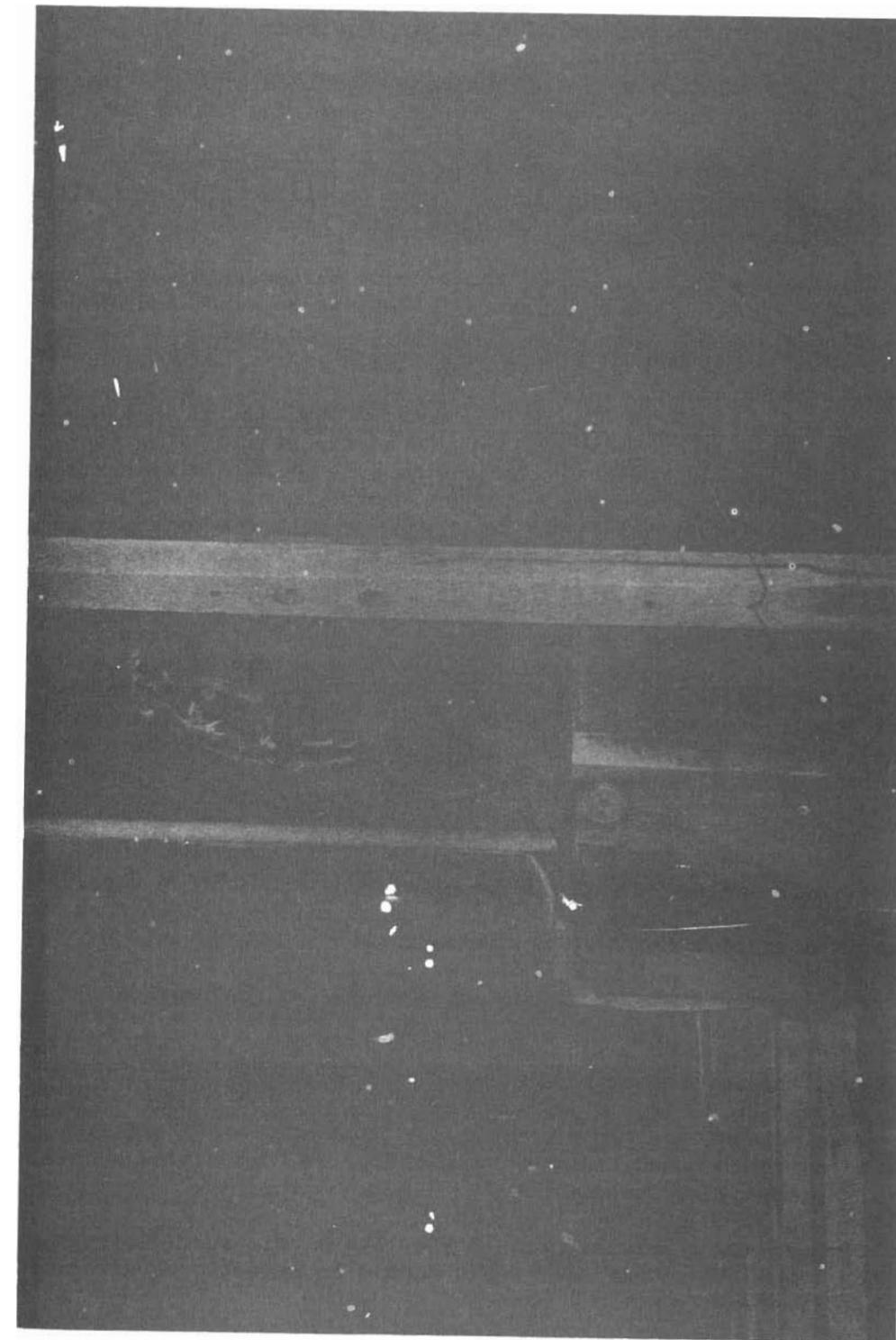


FIGURE 19 OPEN ELECTRICAL CONNECTION BOX AND ACCUMULATED WASTE

c. Personal Protective and Life Support Equipment

(1) Each machine operator should be provided with and instructed to wear complete eye protective equipment when operating his or her machine.

(2) Each machine operator should be provided with and instructed to wear safety boots or toe guards during working hours.

(3) Each machine operator should be provided with and instructed to wear a dust respirator while operating a cabinet machine, and when removing abrasive residue and debris from the dust-collecting system.

3. Automatic Machines

With this class of machine, the work to be cleaned is either mechanically or manually inserted into the machine or onto a mechanical conveying system. The part is then tumbled, rotated, or directly passed through the path of an abrasive discharge which cleans the part during a timed cleaning period (Figure 20). The cleaned parts are then manually or mechanically removed in preparation for the next timed cleaning cycle.

Many machines in this category are custom designed to suit a specific cleaning need. The commodities cleaned can vary through a range of synthetic and plastic materials to very large castings and structural steel beams of considerable length. A quite recent trend is to provide a machine capable of cleaning a ship's entire hull in a one-sweep-per-side drydock procedure.

a. Mechanical Conditions and Recommendations

(1) The internal surfaces of all automatic machines should be inspected on a regular weekly basis during which the following items should be given special consideration and prompt corrective action:

- Badly abraded recirculating pipes should be replaced.
- Abraded case-hardened wear plates and especially their retaining mats should be promptly replaced.
- Worn, distorted, or otherwise deteriorated floor plates or gratings that can create a trip, slip, or fall hazard should be promptly replaced.
- Abraded and otherwise damaged steel to steel, steel to rubber, or rubber to rubber door seals should be promptly repaired or replaced.
- Abraded frames, casings, or other enclosures that can result in the escape of abrasives or dust should be repaired or replaced.

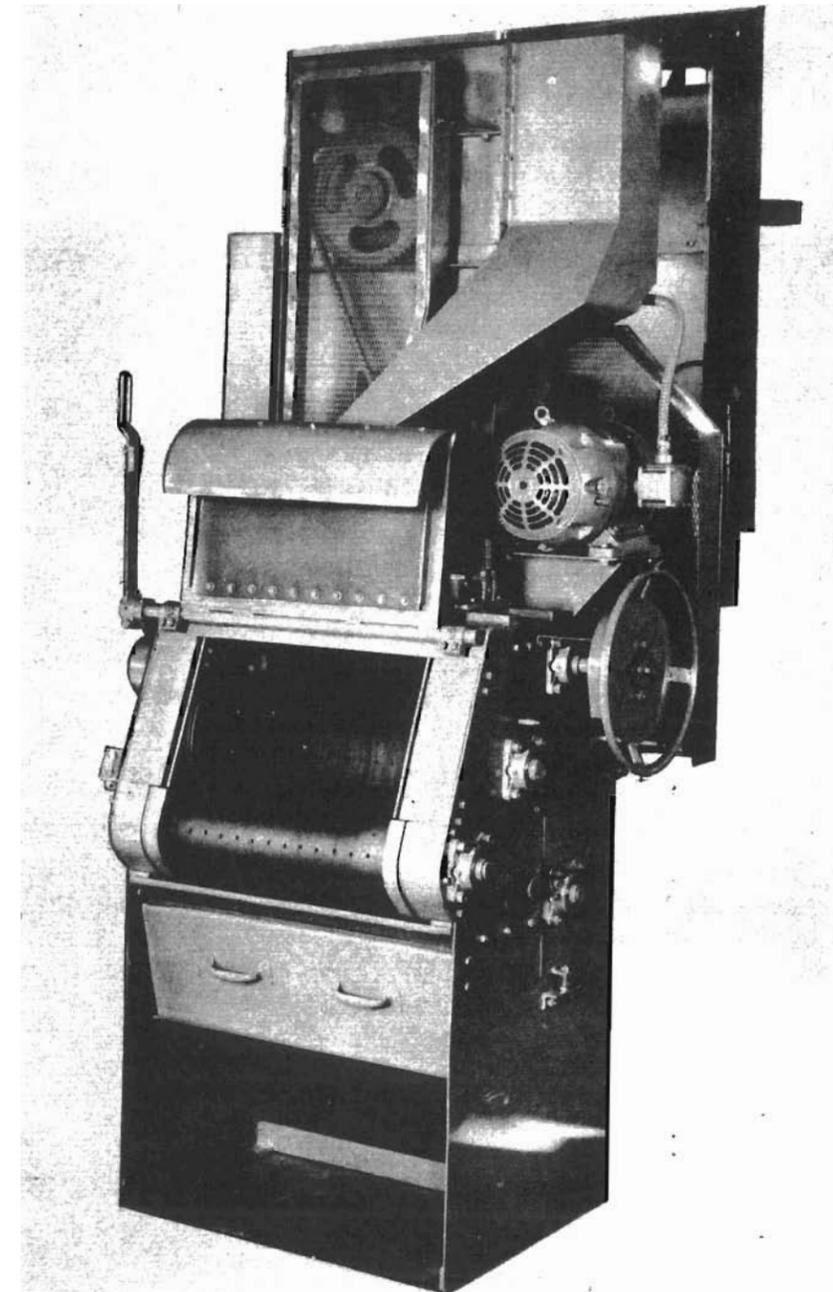


FIGURE 20 TUMBLE BLAST CLEANING MACHINE

Courtesy: Wheelabrator-Frye, Inc.

(2) Dust exhaust fans and shaker-type abrasive waste separation systems were found to be exceptionally noisy, and most systems exceeded the existing 90 dB(A) noise level. All such systems should be re-engineered until the noise levels meet or are below the federally stipulated 90 dB(A).

(3) The discharge of waste materials from magnetic and other type separators should not terminate into open bins or containers. Such bins or containers should be covered to effectively control the emission of dust clouds into open work areas (Figure 21).

(4) All machine drives, coupled or belted, should be mechanically guarded to prevent physical contact. Reference is specifically made to door-closing belt drives, exhaust fan belt drives, shaker conveyor and dust collector vibratory drives.

(5) Removable floor plates and/or gratings providing access to below grade level shaker-type separators should be kept in position at all times during machine operation. During maintenance work such floor openings should be barricaded to effectively restrict access to the maintenance work area and specifically the unprotected floor openings.

(6) All steel cables used to open and close the doors of automatic machines should be examined on a regular quarterly basis. Such cables should be replaced under the following conditions all of which warrant condemnation of a cable:

- Excessive dryness and an exterior brick dust effect that indicates internal corrosion working out to the exterior of the cable¹.
- Six or more wire breaks within the lay (one complete revolution or wrap) of a single strand of the cable, or indication of flattening or abrasion of one or more strands of the cable.

(7) All dust-collecting systems should be inspected and serviced on a regular weekly basis with prime consideration that:

- All ducts and ventilation screens are clean
- The maximum manufacturers air flow rates are maintained at all times
- Bags, screens, filters, and other dust collecting devices are in peak working condition
- Dust collection bins and containers are covered to effectively contain the dust discharge

¹ The brush application of boiled linseed oil insures automatic lubrication from the center hemp core throughout the cable when running or in tension.

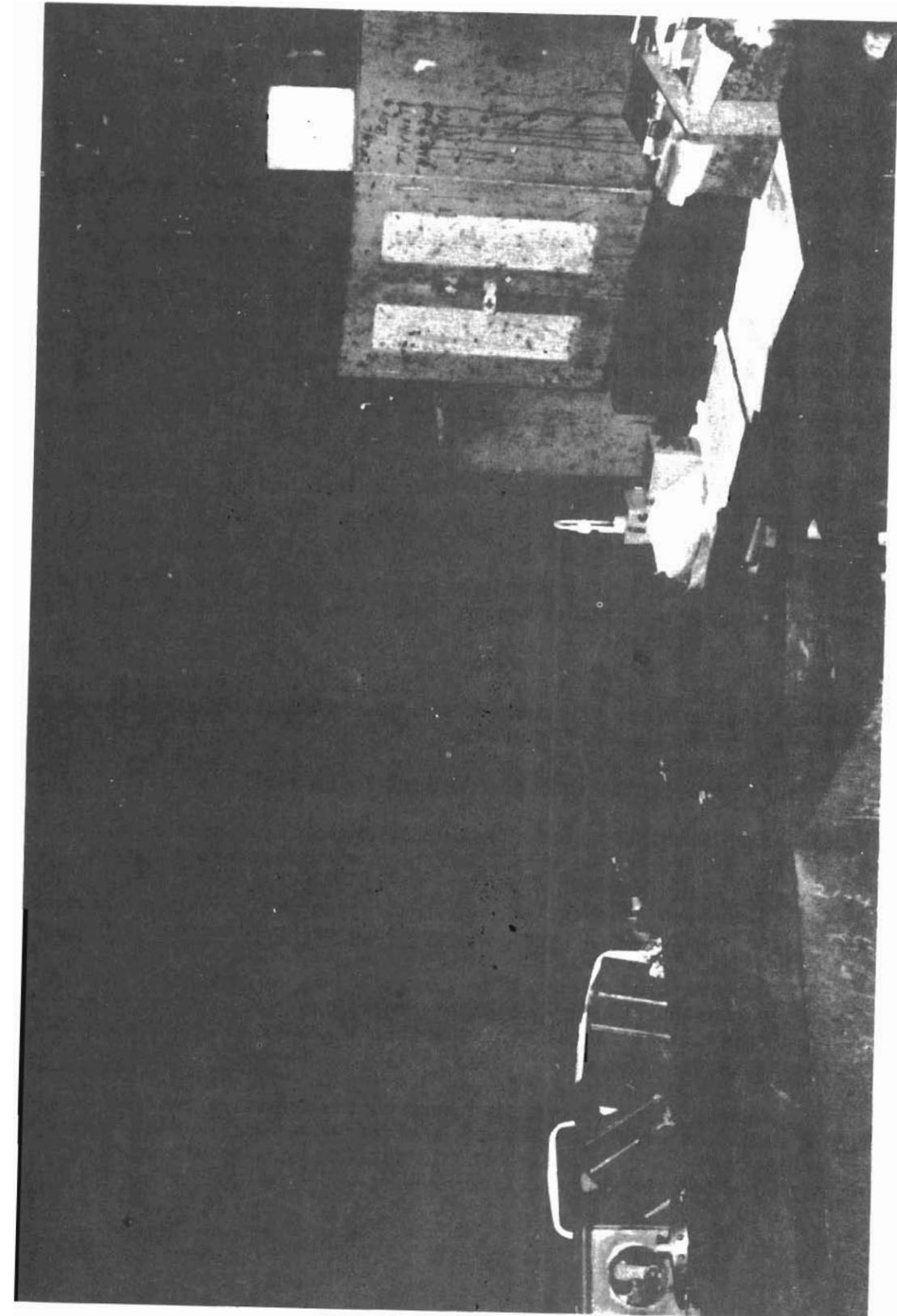


FIGURE 21 OPEN WASTE CONTAINER AND DISCHARGE NEAR WORK STATION

- Discharge bags between the final hopper discharge and the collection bin or container are in good working order
- No blockage exists at any location within the dust collection system and its ultimate discharge

b. Electrical Conditions and Recommendations

(1) All doors, main, or manual access, should be equipped with electrical interlocks that will prevent operation of the machine unless all doors are tightly closed. The effect of opening any door should immediately stop machine operation.

(2) All motors used in conjunction with automatic blast cleaning machines should be of totally enclosed dust-proof design.

(3) All electrical controls should be confined in dust-tight enclosures--boxes or cubicles that meet the design criteria of NEMA Spec. 12.

(4) The breaking of a tumble belt or rotating table drive belt should immediately prevent further operation of the machine until the belt is repaired or replaced.

Special Note: In addition to ruining all parts being cleaned, such frequent belt failures cause the operator to remain close to the machine where he can be exposed to dust inhalation.

C. Personal Protective and Life Support Equipment

(1) Each machine operator and/or attendant or assistant should be provided with and instructed to wear complete eye protective equipment.

(2) Each machine operator and/or attendant or assistant should be provided with and instructed to wear safety boots or toe guards.

(3) Each machine operator and/or attendant or assistant should be provided with and instructed to wear clear coveralls that will restrict the entry of abrasive into clothing breaks from which it can make physical contact with the skin.

(4) During machine operation each machine operator and/or attendant or assistant should be provided with and instructed to wear a dust control breathing respirator. Such a device should also be worn by all workers servicing any phase of the dust-collecting system.

APPENDIX A

Installations Surveyed