PREVENTION OF SILICOSIS AND COMPLIANCE WITH ENVIRONMENTAL REGULATIONS

The International Agency for Research on Cancer has concluded that the scientific literature on crystalline silica is sufficient to conclude that exposures from occupational sources are casually related to an increase in lung cancer. This determination has resulted in reclassifying crystalline silica as carcinogenic to humans. Additionally, the Occupational Safety and Health Administration (OSHA) has implemented a Special Emphasis Program (SEP) to reduce and eliminate the workplace incidence of silicosis from exposure to crystalline silica. This program includes increased enforcement and an outreach educational assistance program.

Potential Impact of SEP

❶ Rulemaking by OSHA will occur for crystalline silica involving a comprehensive standard possibly to include: reduced exposure limits; action levels; dust monitoring; medical surveillance; medical removal and pay protection; methods of compliance; worker training; engineering controls; respirators; and record keeping. Proposed standards are expected to include risk assessment for carcinogenicity, silicosis, and chronic obstructive pulmonary disease (COPD).

❷ Examination by EPA of the cancer risk posed to the general population by silica with possible impact on its regulations for air emissions, operating permits, control devices, and community warnings.

❸ Increased opposition in local land use permitting based on crystalline silica being carcinogenic to humans.

❹ Changes to Material Safety Data Sheets as well as product labeling. (There is a stay on 1926.59/1910.120 (f) (ii) and OSHA cannot enforce the requirement to update labels.)

❺ Increased product substitution for silica and silica-containing products, with potential market loss for some uses.

❻ Increase in worker's compensation and product liability litigation for lung cancer in silica-exposed workers (estimated by Department of Labor at 2 million workers).

In precast concrete operations, activities such as concrete batching and mixing, abrasive blasting, concrete drilling or sawing, dry sweeping or pressurized air blowing of concrete coarse and fine aggregate dust are associated with potential exposure to crystalline silica dust. Precasters should make a commitment to prevent silicosis at their plants. They should recognize when silica dust may be generated and plan ahead to eliminate or control the dust at the source. Awareness and planning are keys to prevention of silicosis.

OSHA compliance officers will be focusing their inspection on sites where silica is not controlled effectively, and will limit their inspections at sites where effective silicosis prevention programs have been implemented.

Table 1 lists OSHA standards that may under appropriate inspection conditions be cited for crystalline silica overexposure. The standards listed in Table 1 are for general industry and construction.

The following is a list of elements, which may be included in an effective program:

- ongoing personal air monitoring program*
- ongoing medical surveillance program
- training and information on crystalline silica provided to workers*
- availability of air and medical surveillance data to workers*
- an effective respiratory protection program*
- hygiene facilitates and clothing change areas are provided
- appropriate recordkeeping*
- personal exposures below the permitted exposure limit

* Note: Required by specific OSHA standards if an overexposure to crystalline silica exists. All of the elements are not necessarily required for a program to be effective.

TABLE 1. Applicable OSHA Standards

OSHA Requirement	Gen. Ind. Std.	Const. Std.
Respiratory protection	1910.134	1926.103 1910.134
Permissible exposure limit and control	1910.1000	1926.55 & .57
Accident prevention & warning signs	1910.145	1926.200
Access to employee exposure and medical records	1910.1020	1926.33
OSHA 200 forms	1904	1904, 1926.22
Abrasive blasting, breathing air, enclosures, controls	1910.94	1926,28, 55, 95, 100, 101, 102, 103, and 300
Hygiene	1910.141	1926.27 and 51
General PPE	1910.132	1926.28, 95, 100-105
Hazard Communication	1910.1200	1926.59
Safety and Health program	—	1926.20
General training	—	1926.21

(PEL) or the facility has an abatement program that also provides for interim worker protection

- housekeeping program is maintained*
- in construction – a safety and health program is in place*
- regulated areas

If concrete units are to be sawn or holes cut on the jobsite, a material safety data sheet (MSDS) should accompany the product and address the physical and health hazards.

What is Silicosis?

Silicosis is a disabling, nonreversible and sometimes-fatal lung disease caused by prolonged overexposure to respirable crystalline silica (particles smaller than 10 microns – about 1/2500th of an inch). This dust can cause scar tissue formations in the lungs, around the trapped silica particles, which reduce the lungs' ability to extract oxygen from the air we breathe. There is no cure for this disease thus; prevention and education are the only answers. Particle size, dust concentration and duration of dust exposure are important factors in determining the attack rate, latency period, incidence, rate of progression and outcome of disease. Typical sand used for fine aggregate does not pose a silicosis threat.

What are the Symptoms of Silicosis?

There are several stages to silicosis. Early stages may go completely unnoticed. Continued exposure may result in the exposed person noticing a shortness of breath upon exercising, possible fever and occasionally bluish skin at the ear lobes or lips. Silicosis makes a person more susceptible to infectious diseases of the lungs like tuberculosis. Progression of the disease leads to fatigue, extreme shortness of breath, loss of appetite, pain in the chest, and respiratory failure, which all may lead eventually to death. Such progression continues even after the exposure to silica ceases. Acute silicosis may develop after short periods of heavy exposure (a few weeks or up to 5 years) in sandblasting. Chronic silicosis usually occurs after 10 or more years of exposure to lower levels of silica. Smoking aggravates the effects of silica exposure; consequently, the elimination of smoking by employees is desirable in any respiratory health effort.

A worker's lungs may react more severely to silica sand that has been freshly fractured or recently broken (sawed, blasted, or treated in a way that produces airborne dust), than silica particles that have aged for sixty days or more. This factor may contribute to the development of acute forms of silicosis.

Air Monitoring

Air monitoring should be performed to measure worker exposure to airborne crystalline silica using approved testing methods conducted by qualified trained personnel. Air monitoring should be performed periodically (preferably quarterly) to measure the exposures for a job (e.g., silica exposure for a sandblaster) to establish exposure levels at a point in time for that job and to determine whether the dust controls that are being used are sufficient and effective. The goal is to prevent exposure and resulting disease not necessarily to meet a legal requirement.

The nature of dust generated in any abrasive blasting process is the combination of the fragmentation of blasting media and the material dislodged from the

* Note: Required by specific OSHA standards if an overexposure to crystalline silica exists. All of the elements are not necessarily required for a program to be effective.

concrete surface. Where fragmentable abrasives such as sand is used, or where a concrete surface is blasted, the airborne dust generated will vary in particle size and chemical composition.

Abrasive blasting creates clouds of tiny, sometimes invisible dust particles that can hang in the air long after blasting has stopped. To cause silicosis, the silica particles must be respirable and able to reach the smallest airways and air sacs in the lungs. This means the particles must be around three to five microns in diameter. When a respirable dust sample is collected, a device (cyclone) is used prior to the collection filter to separate and remove particles that are too large to be taken into the lungs. The cut-off point is 10 microns, or about 1/50th the size of the period at the end of this sentence. These are very small particles – particles the human eye cannot see.

Even though the particles of concern are not visible, it goes without saying that when you see a dust cloud in your operation, there will be particles in that dust cloud that are of respirable size.

The current OSHA Permissible Exposure Limit (PEL) for respirable dust containing crystalline silica (quartz) for general industry is an 8-hour time-weighted average (TWA) [29 CFR 1910.1000] as follows:

$$\text{PEL (mg/m}^3) = \frac{10 \text{ mg SiO}_2/\text{m}^3}{\% \text{ SiO}_2 + 2}$$

where:

$\text{mg SiO}_2/\text{m}^3$ = milligrams of silica per cubic meter of air

$\% \text{ SiO}_2$ = the percentage of silica in the respirable dust

For total silica (quartz) dust the PEL = $\frac{30 \text{ mg/m}^3}{\% \text{ SiO2} + 2}$

Silicosis prevention measures should be based on the National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limit (REL) of 0.05 mg/m^3 respirable crystalline silica as a TWA for up to 10 hrs/day during a 40-hr workweek, since the OSHA PEL is outdated and not protective.

Sampling

Exposure monitoring should cover conditions throughout a full work shift as activities in the work area vary during the shift and change the hazard intensity. Preferably, the air in the work area should be sampled in the workers' breathing zones.

A respirable sample is collected by drawing air at approximately 1.7 liter per minute (± 0.2 liters/min.) through a 10-mm nylon Dorr-Oliver cyclone attached to a 5 micron pore size, 37-mm diameter polyvinyl chloride (PVC) filter cassette. The 5-micron pore size filters reduce problems associated with sample loading and backpressure. This is important to maintaining a constant sampling rate in dusty work environments. Sample air volumes of 408 to 816 liters are recommended.

Care needs to be taken to assure that the cyclones are not inadvertently inverted. Pumps should be checked on at least an hourly basis, if possible, and the flow rates noted, and what the worker was doing at the time of the check documented. If filter overloading is suspected or workers change to another job or procedure, the sampling filter should be replaced with a new filter and the time of changes documented.

Assessments of exposure should be made by a certified industrial hygienist (CIH) or by persons who by virtue of special studies and training have acquired competence in industrial hygiene. The choice of the laboratory to analyze the silica sample is also very important. Only labs certified to do silica analyses by the American Industrial Hygiene Association should be used. (American Industrial Hygiene Association, 2700 Prosperity Avenue, Suite 250, Fairfax, VA 22031, InfoFax: (703) 641-4636, Internet: http://www.aiha.org.

The average cost of a silica sample analysis by X-ray diffraction (XRD) is in the range of $55 to $85. In 1996, the average cost for a CIH was $75 to $125 per hour depending upon the geographical region. The average cost for an industrial hygiene technician was $45 to $75 per hour, again depending upon the geographical region.

How do you go about setting up a sampling program? You can choose to use consultants, your insurance carrier, or do it yourself. The American Industrial Hygiene Association offers a listing of industrial hygiene consultants. Many safety equipment suppliers will know consultants in your area. Employers can contact their local OSHA consultation service for free guidance and assistance. Primarily developed for smaller employers with more hazardous operations, the consultation service is delivered by state government agencies or universities employing professional safety consultants and health consultants. Comprehensive assistance includes an appraisal of all work practices, and environmental hazards of the workplace and all aspects of the employer's present job safety and health program. No penalties are proposed or citations issued for hazards identified by the consultant, but the employer is expected to abate the hazards identified.

Sample calculation for crystalline silica:

A sample from one employee taken for exposure to crystalline silica dusts has the following results:

Sampling Period (Min.)	430
Total Volume (Liters)	405
Respirable weight (mg)	2.633
Respirable concentration (mg/m^3)	6.5
Laboratory results (%)	25.5 quartz ND cristobalite ND tridymite

ND – Non Detected

Calculation of the TWA from the sampling sand analytical data:

Step No. 1: Calculate the PEL for respirable dust containing crystalline silica

$$\text{PEL} = \frac{10\ mg/m^3}{[\%\ \text{quartz} + 2]}$$

$$= \frac{10\ mg/m^3}{[25.5 + 2]}$$

$$= \frac{10}{27.5} = 0.36\ mg/m^3$$

Step No. 2: Calculate the employee's exposure to respirable dust

$$\text{Exposure} = \frac{(\text{sample weight})}{\text{Total volume of air sampled}}$$

$$= \frac{(2.633\ mg)}{405\ \text{liters}\ [1\ m^3/1000\ \text{liters}]}$$

$$= 6.5\ mg/m^3$$

Step No. 3: Adjust (where necessary) for sampling period less than 8-hours. Assume a zero exposure time for the sampling period remaining if there was no exposure during that time.

Adjusted Exposure

$$= \frac{(6.5\ mg/m^3)\ (430\ \text{minutes}) + 0\ (50\ \text{minutes})}{480\ \text{minutes}}$$

$$= \frac{6.5\ mg/m^3\ (430\ \text{minutes})}{480\ \text{minutes}} = 5.82\ mg/m^3$$

Step No. 4: Calculate the Severity of the exposure:

$$\text{Severity} = \frac{\text{Adjusted Exposure}}{\text{PEL}}$$

$$= \frac{(5.82\ mg/m^3)}{(0.36\ mg/m^3)} = 16.17 \qquad \text{Use APF of 25}$$

If the result from Step 4 is greater than 1.0 than an overexposure to crystalline silica exists.

Sample calculation for the NIOSH assigned protection factor (APF) required:

Determine weight of quartz in sample

$$2.633\ mg\ (0.255\%) = 0.671\ mg\ \text{quartz}$$

Determine TWA

$$\frac{0.671\ mg}{405\ \text{liters}\ [1 m^3/1000\ \text{liters}]} = 1.658\ mg/m^3$$

Adjusted Exposure

$$= \frac{(1.658\ mg/m^3)\ (430\ \text{minutes}) + 0\ (50\ \text{minutes})}{480\ \text{minutes}}$$

$$= \frac{(1.658\ mg/m^3)\ (430\ \text{minutes})}{480\ \text{minutes}} = 1.\ 485\ mg/m^3$$

$$\text{APF} = \frac{\text{TWA}}{\text{REL}} = \frac{1.485}{0.05} = 30 \qquad \text{Use APF of 50}$$

Medical Monitoring

Employees should be provided with a description of, and the purposes for a medical surveillance program. The following are the recommended medical procedures for individuals exposed to respirable crystalline silica. These procedures provide a safety net for the individual, but are not a tool of primary prevention.

❶ A baseline examination which includes a medical and occupation history to elicit data on signs and symptoms of respiratory disease prior to exposure to crystalline silica. The medical examination emphasizing the respiratory system, should be repeated every five (5) years if under 20 years of exposure and every two (2) years if over 20 years of exposure. The medical examination should be repeated more frequently if respiratory symptoms develop or upon the recommendation of the examining physician.

❷ A baseline chest x-ray should be obtained prior to employment with a follow-up every 5 years if under 20 years of exposure and every 2 years if over 20 years of exposure. A chest x-ray may be required more frequently if determined by the examining physician.

❸ Pulmonary Function Tests (PFT) (spirometry): Should include FEV1 (forced expiratory volume in 1 second), FVC (forced vital capacity) and DLCO (diffusion lung capacity.) PFTs should be obtained for a baseline examination with PFTs repeated every 5 years if under 20 years of exposure and every 2 years if over 20 years of exposure. PFTs may be required more frequently if respirable symptoms develop or if recommended by the examining physician. PFTs are designed to assess the elasticity and proper functioning of the lungs. Many lung diseases affect the PFT results. Typically, smoking causes an obstructive type of abnormality, while pneumoconiosis causes a restrictive abnormality. Combinations of the two abnormalities can also occur.

❹ A chest x-ray should be obtained on employment termination.

The chest x-ray should be chest roentgenogram (posteroanterior 14" x 17" or 14" x 14") classified according to the 1980 ILO International Classification of Radiographs of Pneumoconiosis by a certified class "B reader." A "B-reader" is a radiologist or physician that is trained and certified by NIOSH to read and interpret chest X-rays in a systematic way with special emphasis on detecting lung abnormalities caused by the inhalation of dusts.

The medical follow-up should include the following procedures:

❶ With a positive chest x-ray (1/0 or greater), the employee should be placed in mandatory respiratory protection, or if already wearing a respirator, the program should be reevaluated to assure proper fit and the elements of OSHA's Respiratory Protection Standard, 29 CFR 1910.134 are being met.

❷ The employee should be referred to a physician specialized in lung diseases for a medical evaluation and medical monitoring as warranted by the examining physician. A written opinion from the examining physician as to whether the employee has any detected condition that would place the worker at an increased risk should be provided to the employer and employee, if the chest x-ray is positive (1/0 or greater) while specific medical findings remain confidential. Procedures should be developed for reducing exposures of employees whose X-rays show changes consistent with silicosis.

❸ All medical test results should be discussed with the employee by the physician. If clinically significant non-occupational abnormalities are identified, the employee should be urged to seek treatment.

❹ In accordance with 29 CFR 1910.1020, medical records shall be maintained for at least 30 years following the employee's termination of employment, unless the employee is employed for less than one year and the records are provided to the employee upon termination. This is necessary because of the chronic nature and long latency of silicosis.

Training

Employees should receive training [29 CFR 1926.21] that includes the following:

- Information about the potential adverse health effects of exposure to respirable crystalline silica. Make sure they know what operations and materials present a silica hazard. Advise employees of increased risk of impaired health due to the combination of smoking and silica dust exposure.
- Material safety data sheets for silica, alternative abrasives, or other hazardous materials [29 CFR 1926.59].
- Instruction about the purpose and set-up of regulated areas marking the boundaries of work areas containing crystalline silica.
- Information about safe handling, labeling, and storage of toxic materials [30 CFR 56.20012, 56.16004, 57.20012, 77.208].
- Discussion about the importance of engineering controls, personal hygiene, and work practices in reducing crystalline silica exposure.
- Instruction about the purpose, proper use and care of appropriate protective equipment (including protective clothing and respiratory protection).
- Monitoring, monitoring results and medical surveillance.

Engineering Controls

A plant should evaluate the circumstances leading to exposure to crystalline silica, and the use of effective controls. Proven methods of control include engineering controls such as dust suppression, process isolation, and ventilation; administrative controls include substitution of alternative abrasives in blasting; employee training; exposure monitoring; and as the last resort, the use of personal respiratory protection.

Air emissions data have shown that grinding and dry cutting of concrete frequently creates gross exposures to respirable silica. Hand grinders should use water or be equipped with vacuum hoods on the grinding guard. The dust, which is sucked into the receiving line, should be carefully collected in a filter bag away from the worker and discarded in a dumpster to prevent it from joining the yard dust. Most concrete saws use a wet cut method, which is designed primarily to cool and preserve the blade. Care should be taken to assure that a strong spray and fine mist also prevails over the rear cutting trough area where the dust cuttings will be expelled. This otherwise inert alkaline slurry should similarly be collected and disposed in an area where foot and mobile traffic will not pulverize the material once it is dry.

The most effective control of airborne concentrations of silica dust is at the source of contamination by physical enclosure of the abrasive blasting operation and/or use of local exhaust ventilation to prevent dust from being released into the air.

Abrasive blasting rooms contain the hazard and protect adjacent workers from exposure. However, such rooms may increase the risk for blasters, since they must work inside the enclosure in high concentrations of hazardous blasting material. Blasting rooms must be ventilated to reduce these concentrations and to increase visibility. A supplied-air respirator is required for any blaster working inside a blasting room.

When enclosing an operation, a slight vacuum should be used to create negative pressure so that leakage will result in the continuous flow of external air into the enclosure and minimize contamination of the workplace. This can be accomplished with a well-designed local exhaust ventilation system that physically encloses the process as much as possible, with sufficient capture velocity in accordance with 29 CFR 1910.94. The room should have exhaust capacity of at least one (preferably three) air change per minute. The room should not be entered before at least six air changes have occurred, as respirable-size dust particles stay airborne for a considerable length of time. Exhaust air should be discharged to the outside through an appropriate dust collector. The dust collector should be set up so that accumulated dust can be removed without contaminating work areas.

Ventilation equipment should be checked daily to ensure adequate performance – ensure good draw, no leaks, and pressure differential gauge is not different from previous inspection. Measures should be taken to ensure that any discharge will not produce health hazards to the outside environment. System effectiveness should be checked soon after any change in production, process, or control which might result in significant increase in airborne exposure to silica. The dust control system should always be used and kept well maintained.

In the room, a cleanup method other than broom sweeping or compressed air blowing should be used to collect the abrasive agent after blasting (e.g., vacuum cleaning with a high efficiency filter). If the blasting agent and concrete dust is removed manually, respiratory protection should be used.

Respiratory Protection

Respirators should be used only as the last resort to prevent or minimize exposures to airborne contaminants. Source controls such as substitution, automation, enclosed systems, local exhaust ventilation, wet methods, and good work practices should be used first. Such measures should be the primary means of protecting workers. However, when dust source controls cannot keep exposures below the OSHA PEL or NIOSH REL, controls should be supplemented with the use of respiratory protection during abrasive blasting. The use of respirators requires that silica levels in the air have been measured to establish what type of respirator is needed to provide effective protection.

When a respirator is used, neither the time factor nor the concentration factors are reduced, and total reliance on the respirator is the exposure control. Proper respirator selection, fitting, and training are needed prior to reliance on this exposure control.

Respiratory Protection Program

When respirators are used, the employer must establish a comprehensive written respiratory protection program, as required in the OSHA respiratory protection standard [29 CFR 1910.134, 1910.1000, and 1926.103]. Important elements of this standard are:

- Periodic environmental monitoring. Environmental monitoring by trained personnel should be conducted in all abrasive-blasting applications, including blast area clean-up and bag house maintenance. This is necessary to select the proper respirator assigned protection factor (APF) and ensure that workers are not overexposed (i.e., measured silica dust concentration is less than the exposure limit multiplied by the respirator APF).

- Regular training of personnel in proper use of respirator, and its limitations.
- Selection of proper NIOSH-approved respirators. If silica sand is used as an abrasive, despite its much greater hazard relative to other abrasive agents, only the highest level protection respirators (i.e., respirators certified by NIOSH for blasting: Type CE pressure-demand or positive pressure and with NIOSH recommended APFs of 1000 or 2000) should be used. Anytime environmental conditions, airborne contaminants, or their concentrations are highly variable or poorly defined, high level respiratory protection should be used, even if silica is not the abrasive agent.
- A medical evaluation of the worker's ability to perform the work while wearing a respirator. No one should be assigned a task requiring use of respirators unless found physically able by a physician or other licensed healthcare professional to do the work while wearing the respirator.
- Respirator fit testing. Determination of face piece fit should involve both qualitative (QLFT) and quantitative (QNFT) tests. A qualitative test relies on the wearer's subjective response to the introduction of an aerosol challenge agent, such as irritant fume, denatonium benzoate, or saccharin, into the area around the face of the respirator wearer. A quantitative test uses some actual measurement of a challenge agent (e.g., corn oil) in a test chamber divided by the concentration of the agent in the respirator.
- Maintenance, inspection, cleaning, repair, and storage of respiratory protection equipment. Respirators will only provide a satisfactory level of protection when they are selected, fitted, used, and maintained according to the manufacturer's written instructions, NIOSH approval limitations and guidelines, and OSHA regulatory requirements.

  Respirators should be assigned to individual workers for their exclusive use. Respirators should be cleaned and disinfected after each day's use. Respirators must be inspected during cleaning. Worn or deteriorated parts must be replaced. Damaged or altered respirators must not be used. All respirators must be stored in a convenient, clean and sanitary location.
- The respiratory protection program should be evaluated regularly (at least annually) by the employer to determine its continued effectiveness.

Many sandblasters in the precast concrete industry work with adequate respiratory protection, however, workers near the sandblaster generally wear no protection at all. Care should be taken to prevent the dust cloud from spreading to other work areas.

OSHA 1910.94 (a)(1)(ii) defines an abrasive-blast respirator as a continuous-flow air-line respirator constructed to protect the user's head, neck, and shoulders from rebounding abrasives. This was the only available equipment at the time the regulation was implemented. Positive-pressure Type CE, abrasive-blast respirators (APF of 1000 or 2000) are now available, and NIOSH recommends their use when crystalline silica is generated in abrasive blasting.

Currently, four Type CE abrasive-blasting respirators are certified by NIOSH. These four kinds of respirators and the NIOSH recommended assigned protection factors† (APF) are:

❶ A continuous-flow respirator with a loose-fitting hood and an APF of 25 is most commonly used, Fig. 1.

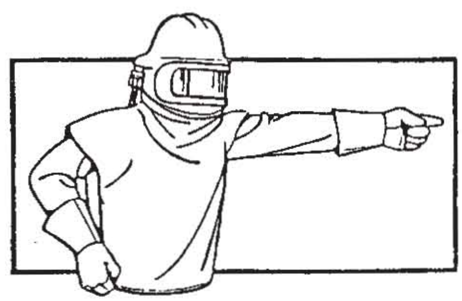

Fig. 1. Supplied air respirator, hood style, Type CE.

❷ A continuous-flow respirator with a tight-fitting facepiece and an APF of 50.

Continuous-flow, Type CE, abrasive-blast supplied-air respirators (SAR) should only be used if (a) silica sand is NOT used as the blasting agent AND (b) workplace monitoring indicates that the level of contaminant in the ambient air does not exceed 25 or 50 times the recommended exposure limit, respectively. The

† Note: OSHA has no APFs for silica therefore employers should use NIOSH selection criteria for guidance. Air purifying and powered-air purifying respirators are not recommended for abrasive blasting operations, but may be suitable for auxiliary work such as outside clean-up operations.

respirators should be operated near the upper limit of the NIOSH-approved operating pressure range (ear plugs should be used). Operation in this manner will ensure the respirator provides maximum protection to the user.

❸ A positive-pressure respirator with a tight-fitting half-mask facepiece and an APF of 1000.

❹ A pressure-demand or positive-pressure respirator containing a tight-fitting full facepiece and an APF of 2000.

Workers should wear the most protective respirator that is feasible and consistent with the tasks to be performed. At a minimum, the APF must attenuate the exposure hazard to below the PEL. However, it is recommended that the NIOSH REL (0.05 mg/m^3) be used to select respiratory protection.

Type I, Grade D respirable air meeting the requirements of the Compressed Gas Association, G-7.1, Commodity Specification for Air, must be supplied to the respirator at all times. The air quality must be monitored at regular intervals to ensure continued compliance.

The source of respirable air must be kept in a clean environment and must contain adequate filtration to prevent entry of contaminants into the respirable air. For example, care is needed not to draw carbon monoxide into air (breathing) from compressors. The respirable airstream should be separate and isolated from the abrasive-blasting airstream. The connection fittings should not be interchangeable between the respirable air and abrasive air delivery systems.

Particulate filter respirators, commonly referred to as dust-filter respirators, properly fitted, may be used for short, intermittent, or occasional dust exposures such as clean-up, dumping of dust collectors, or unloading shipments of sand at a receiving point, when it is not feasible to control the dust by enclosure, exhaust, ventilation, or other means.

Dust-filter respirators should not be used for continuous protection where silica sand is used as the blasting abrasive or where concrete is blasted.

Abrasives and Dust Control

Great Britain and the European Economic Community have restricted the use of silica sand as an abrasive blasting material since 1949, and 1966, respectively. The National Institute for Occupational Safety and Health (NIOSH) has recommended since 1974 that silica sand (or other substances containing more than one percent free silica) be prohibited as an abrasive blasting material and that less hazardous substitutes be used. However, silica sand is commonly used for abrasive blasting where reclaiming is not feasible, such as in unconfined abrasive blasting operations in a precast concrete plant. Sand has a rather high breakdown rate, which can result in substantial dust generation.

The American National Standard titled *ANSI/AIHA Z9.4 – 1997, American National Standard for Abrasive Blasting Operations – Ventilation and Safe Practices for Fixed Location Enclosures,* in a strongly worded statement under the Selection of Abrasive and Equipment section states: "The health hazard to abrasive blasting operators posed by silica sand is sufficiently severe to prohibit its use since feasible alternatives are available." The forward further elaborates, stating: "The ANSI Z9 Committee chose to prohibit the use of silica sand as an abrasive blasting agent for the following reasons: (1) NIOSH continues to document serious health effects due to crystalline silica overexposure, many of which are attributable to ineffective respiratory protection programs; and (2) the committee could not document an abrasive blasting application which required the use of silica sand to achieve the desired result." This voluntary consensus standard applies to all fixed location abrasive blast enclosures in which an abrasive comes in contact with a surface by pneumatic or hydraulic pressure or centrifugal force.

Some silica sand suppliers will not sell sand to persons engaged in sandblasting and some insurance companies are requiring plants to use an alternate blasting abrasive.

Among some of the alternatives to silica sand are wet bottom boiler (coal) slag ("Black Beauty" type), and copper slag, both of which generally contain less than 1% of free silica. These materials are less fragile than silica sand and, as a result, do not fracture on impact. This results in less dust. On the negative side, it must be recognized that these abrasives will tend to give the blasted concrete an appearance different from what would have been obtained with silica sand. Also, some employees are reluctant to use the abrasives due to their black coloration. Some employees feel it is necessary to shower after working with them, whereas white sand generally is considered "clean." A variety of other materials are available as alternative blasting media, Table 2. Producers have investigated some of these abrasives, however, the architectural nature of the precast concrete product may prevent use of

TABLE 2. Alternative Abrasive Materials

ABRASIVE	PRICE*	SPECIAL EQUIPMENT AND PROPERTIES
ALUMINUM OXIDE	$660/Ton	Closely Sized, Very Hard (MOH 8.5-9)
BAKING SODA (Sodium Bicarbonate) or Trona (Natural Sodium Carbonate/Sodium Bicarbonate)	$900/Ton	Special Equipment Required (Meters Less Product/Min and Dries Air), Low Nozzle Pressures (35-90 PSI), Less than 1% Free Silica, Water Soluble/Less Cleanup, Non-Sparking, Non-Flammable
COAL SLAG	$44/Ton	May Contain Toxic Metals, Less Than 0.1% Free Silica, Inert, Fast Cutting, Hard (MOH 6-7), Angular, Uniform Density, Low Friability
COPPER SLAG	$50/Ton	May Contain Toxic Metals, Blocky, Hard (MOH 7-8), Sharp Edged
CORN COB GRANULES	$350/Ton	Special Ventilation May Be Required in Enclosed Areas to Control Combustion, Medium Hardness (MOH 4.5), Non-Sparking, Low Dust Levels, Biodegradable
DRY ICE (Carbon Dioxide)	$60-80/Ton	Dry Air Required, No Residue Remains, Natural Gas in Solid State, Minimal Cleanup
GARNET	$325/Ton	Low Dust Levels, Fast Blasting Rates, Low Free Silica <0.5%, Very Hard (MOH 7.5 to 8), Very Heavy (S.G. 4.1), Subangular, Low Nozzle Pressures (60-70 PSI)
GLASS BEADS	$500/Ton	Manufactured of Soda Lime, Uniform Size and Shape
NICKEL SLAG	$70/Ton	Very Hard (MOH 7-8), Blocky, Sharp Edged, Poor Visibility, May Contain Toxic Materials
NUT SHELLS	$360/Ton	Special Ventilation May Be Required in Enclosed Areas to Control Combustion, Soft, Non-Sparking
OLIVINE	$76/Ton	Natural Mineral, Hard (MOH 6.5-7), High Specific Gravity, Angular
PLASTIC MEDIA (Polyester, Urea, Melamine Varieties)	$3000-4000/Ton	Soft, Non-Abrasive, Inert, Low Nozzle Pressures (20-40 PSI)
STAUROLITE	$75-140/Ton	May Contain Up to 5% Free Silica, Rounded to Subangular Grains, Hard (MOH 6.5-7.5), Irregular Shape, Low Dust Levels
STEEL GRIT & SHOT	$425-475/Ton	Uniform Size, Uniform Hardness, Creates Anchor Profile, Low Dust Levels, Superior Visibility

* Prices are estimates based on 1994 data.

abrasives such as coal slag and steel grit because of discoloration problems. Corn cob granules, nutshells, plastic media, Staurolite (Star Blast), olivine, baking soda, and dry ice are not aggressive enough to provide the desired finishes. Aluminum oxide and stainless steel grit are prohibitive from an economical standpoint. Also no comprehensive studies have been conducted to evaluate the health effects of these silica substitute materials, see Appendix A. Media without any silicosis or cancer hazard include natural zircon Barton sands and synthetic olivine Olimag sands. However, finely fractured particles of silica will still be emitted from the concrete surfaces even if the blast abrasive has no crystalline silica

It is therefore important to remember that no matter what abrasive blasting material is used, appropriate control measures (e.g., containment, ventilation, and filtration) should be employed as well as providing workers with training and effective personal protective equipment (e.g., respirators and clothing).

The key to preventing silicosis is to keep dust out of the air. One method is the use of silica sand treated with a dust suppressant. The suppressant is available applied to silica sand from most sand suppliers or as a liquid concentrate for blending by the precaster. It is claimed that respirable dust is reduced by 65 to 90 percent and visible dust by 30 to 40 percent. Remaining dust settles more quickly and closer to the concrete being blasted. Long-term effectiveness appears to keep treated sand low-dusting indefinitely.

NIOSH conducted a site survey in 1997 to measure and compare respirable crystalline silica concentrations at a controlled abrasive blasting operation using untreated silica sand and sand treated with the dust suppressant. The results of this survey indicated that sand treated with dust suppressant produced, on average, lower respirable dust and respirable quartz dust levels when compared to blasting with untreated sand. The results were quite variable, and are not necessarily representative of all conditions that may be encountered in the abrasive blasting industry. Since most research was performed in "worse-case" conditions, the test results generally did not indicate the reduced quartz concentrations to be lower than the NIOSH recommended exposure limit (REL). Additional industrial hygiene surveys should be conducted to determine the level of dust reduction when using sand treated with a dust suppressant in other abrasive blasting conditions. Additional studies need to be conducted to determine whether the dust suppressants alter the toxic properties of the parent material. NIOSH is currently conducting research to answer these questions about dust suppressants used in the abrasive blasting industry.

To combat the dust problem, manufacturers offer attachments for abrasive blasting equipment that introduce water to the blast stream at the nozzle, greatly reducing the amount of dust produced, but not necessarily below the OSHA PEL. Wet blasting may impact the ability of the blaster to produce a uniform finish by producing a film on the concrete surface. Also, winter usage may be limited by ice formation.

The simplest form of wet blasting uses a circular ring that fastens to the end of the blast nozzle. Used for light dust suppression, it directs streams of water on the outside of the air and abrasive as it leave the nozzle, Fig. 2. The operator can vary the water volume using a control valve at the nozzle. Most precasters have found this method greatly reduces visibility of the concrete surface because of wet mud deposits on the surface during blasting.

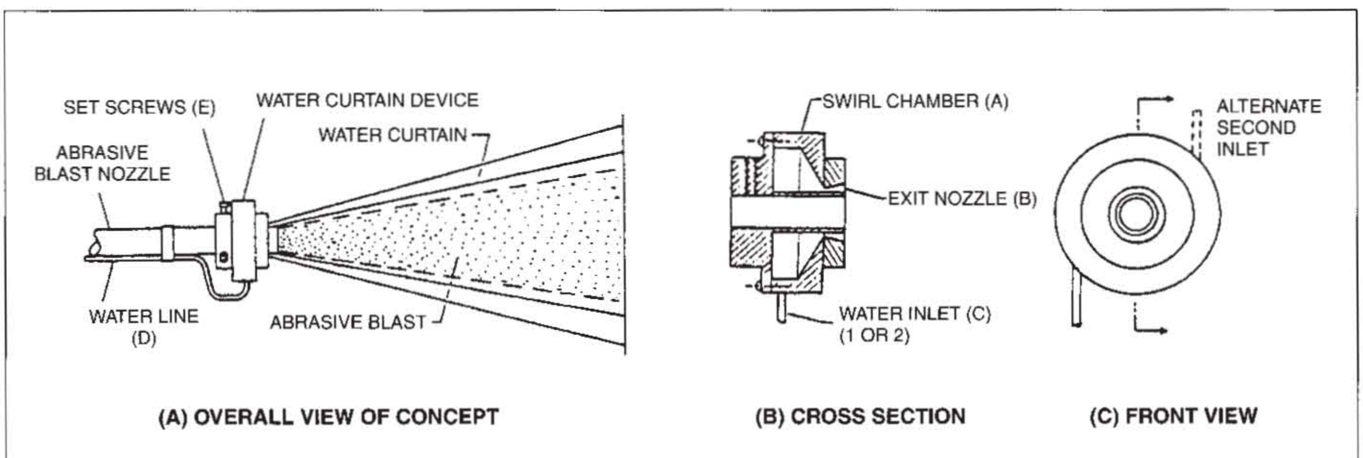

Fig. 2. Water ring device for abrasive blast nozzle.

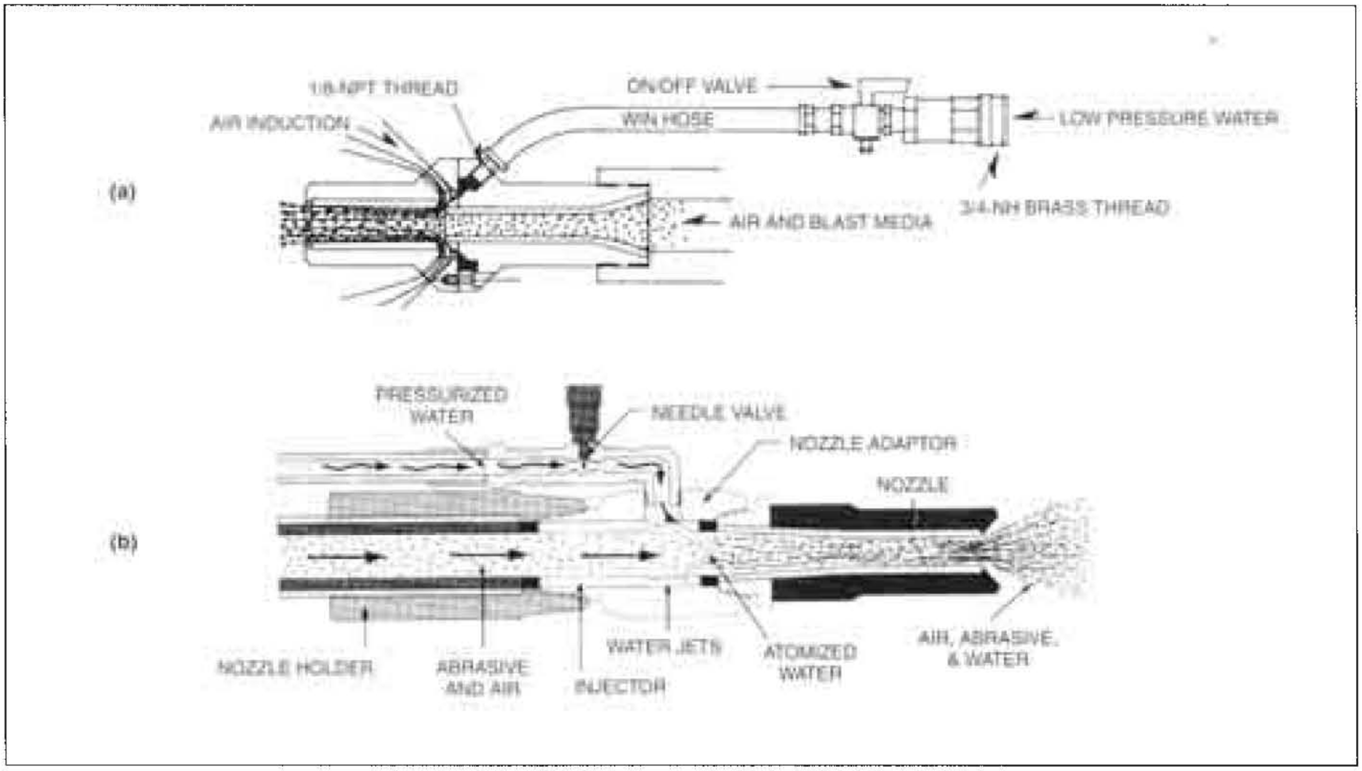

Fig. 3. (a) Water Induction Nozzle available from Fister Quarries Group and (b) Wetblast Injector System available from Clemco Industries Corp.

For greater dust suppression, another type of attachment can be installed just behind the nozzle (see Fig. 3). These systems inject water into the air and abrasive stream, more thoroughly wetting the abrasive.

A different type of wet blasting equipment is also available. This system uses 80% abrasive and 20% water mixed in a pressure vessel. Water pressure from an onboard pump forces the mixture from the vessel into a compressed airstream, where it is accelerated to the nozzle. Although to the best of our knowledge this is not used in the industry, possibly because of a thick film being deposited on the concrete surface.

If wet blasting is employed, an airborne dust hazard from the concrete surface and abrasive residue may exist after evaporation of water.

Dust should not be permitted to accumulate on the floor or on ledges outside of an abrasive-blasting area, and abrasive blast residue should be cleaned up promptly. This is particularly critical, if dispersed the dust would result in airborne concentrations in excess of the permissible exposure limit. Also, the abrasive blasting residue is a significant source of pollutant loading to stormwater. Minimize dust by following good work practices, such as removing dust with a water hose (wet sweeping instead of dry sweeping) or vacuum with a high-efficiency particulate air (HEPA) filter rather than blowing it clean with compressed air.

Air monitoring data have revealed that the dust exposure problems in yards is typically a total dust problem and not a respirable dust problem. Except in extreme cases, silica exposures are not expected to be a problem although the exposures usually exceed the OSHA limits for total dust. Over months and years the amount of dust which settles on the yard accumulates and soon enough, passing mobile equipment or gusts of wind billow up a perpetual dust cloud which eventually settles, only to be continually re-used in future dust clouds. This dust becomes pulverized, by foot traffic or heavy mobile equipment, which reduces the dust particle size, which in turn may create a future silica exposure problem. The plant should carefully evaluate the type and quantity of dust control agents being used on the yard and roads. Many forestry product dust control agents, such as lignin, are excellent for dust control but they will runoff and increase the Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) loading of stormwater runoff. An acceptable product is Coherex dust retardant which is a virgin petroleum oil with an emulsifier made by Golden Bear Oil Specialties, Chandler, AZ, (602) 963-2267.

Personal Hygiene and Protective Measures

The following personal hygiene practices are important elements of any program for protecting workers from unnecessary exposure to crystalline silica during abrasive blasting operations:

- Be aware of the health effects of crystalline silica and that smoking adds to the damage.
- Participate in any medical examinations, air monitoring, or training programs offered by the employer.
- Substitute less hazardous abrasive-blasting materials for those containing crystalline silica.
- If substitution is not possible, use engineering controls such as dust collectors, wet methods, and local exhaust ventilation to minimize or control the hazard and protect adjacent workers from exposure.
- Always use the dust control systems and keep them well maintained.
- Be aware that the highest silica concentrations may occur inside enclosed areas during concrete sawing or abrasive blasting.
- Enter and exit blast area with blast respirator on and working. Respirator should not be removed in blast area even after dust has cleared to the naked eye.
- Use Type CE pressure-demand or positive-pressure, abrasive-blasting respirators when sandblasting.
- Sandblasters should practice good personal hygiene to prevent unnecessary exposure; and should park their cars where they will not be contaminated.
- Wash hands and face before eating, drinking, smoking, or applying cosmetics outside of the exposure area.
- If possible, change into disposable or washable protective work clothes at the plant; shower (where available) and change into clean clothing before leaving the plant to prevent contamination of cars, homes, and other work areas. Change rooms should be provided in accordance with 1910.141. Work clothing should be vacuumed before removal unless it is wet. Clothes should not be cleaned by blowing or shaking.
- Do not eat, drink, use tobacco products, or apply cosmetics in areas where there is dust containing crystalline silica.

Warning Signs

Warning signs should be posted to mark the boundaries of work areas contaminated with respirable crystalline silica. These signs should warn employees about the hazard and specify any protective equipment required (for example, respirators). The sample sign in Fig. 4 contains the information needed for a silica work area where respirators are required.

WARNING!

CRYSTALLINE SILICA WORK AREA

Improper handling or exposure to the dust may cause silicosis (a serious lung disease) and death.

RESPIRATOR REQUIRED

Fig. 4. Sample of warning sign for work areas contaminated with crystalline silica.

Environmental Regulations

A number of precasters have been cited for air pollution caused by sandblasting. Dust concentrations in areas adjacent to sandblast operations can be excessive as far as 75 ft from the operator, even with only a light wind. Silica particles may remain airborne for up to 20 minutes.

A number of plants are required to have permits for sandblasting. Permit limitations include panels/year, sq. footage, and tons of sand used.

A retarder has been used as a blasting aid by some plants, however, a larger plume of dust results. In order to avoid a dust plume it may be desirable to use a light retarder and high pressure water washing and then abrasive blast to dull the surface.

The Environmental Protection Agency (EPA) requires permits for "PM-10" emissions, or particulate matter in which the individual particles are 10 microns or less in size. An even newer standard further regulates particles at 2.5 micron size and smaller. The new PM-2.5 standard is 15 micrograms per cu meter, measured over a year, with a daily limit of 65 micrograms per cu m.

EPA will not impose the guidelines for "PM-2.5" for five years, while a new regional monitoring network is set up. It then will allow three years for non-complying areas to submit plans to meet guidelines, followed by an 18-month review period. And EPA says it will be several more years before many regions have to comply. EPA estimates that about 150 counties will be out of compliance with the PM-2.5 standards. Under current standards, 41 counties exceed limits for particulate matter (PM-10).

Many plants would be surprised to learn that the activities or equipment in their facilities could label them as "major sources" of air pollution under the Clean Air Act (CAA) Amendments of 1990. Even more surprising might be the realization that some chemicals routinely released from their sites for decades are now classified as hazardous, or toxic, air pollutants that need state or federal emission permits. Plants located in unacceptably high pollution zones or non-attainment areas are especially likely to warrant an examination of their status relative to regulations emerging as a direct result of the CAA. As a result, many plants should anticipate costs associated with inventorying, permitting and controlling their air pollution sources.

The maximum opacity of visible particulate emissions is controlled by the states or counties. Areas with ambient air quality problems often have tighter visible emissions limits than other areas. In order to determine potential emission limits for abrasive blasting, or for emissions from roadways or material storage piles, a plant needs to contact their state EPA. The plant should have the average opacity of the emissions from any fugitive dust source determined to ensure compliance. Plant personnel may receive certification as a qualified observer by meeting the requirements of U.S. EPA Method 9 – Visual – "Determination of the Opacity of Emissions from Stationary Sources."

CAA and Title V. With the changes to the Clean Air Act (CAA) in 1990, the very nature of permitting for air pollution sources was overhauled. Under the new requirements spelled out in Title V (Permits) of the CAA, states must develop a comprehensive operating permit system for sources.

At the federal level, these clean air compliance laws have been codified by the U.S. Environmental Protection Agency regulations contained primarily in 40 Code of Federal Regulations (CFR) Parts 52, 60, 61, 63, and 70. Most State Implementation Plans (SIPs) are based on these regulations, although critical differences can and do exist. Depending on the state, additional permitting requirements may also apply.

All stationary point sources, all fugitive emissions, all air pollution control equipment, most mobile sources and many work practices should be evaluated for inclusion in an emissions inventory. Many sources may ultimately be considered insignificant or "de minimis" and therefore exempt from Title V reporting – depending on the language of the state's own program rules – but all should be included in at least an initial emissions listing.

Air emissions permits are required for almost all existing plants, modifications to existing pants and for new concrete production plants. It is impossible within the scope of this article to do more than mention key aspects of the Clean Air Act that should be considered in trying to ascertain if a Title V permit is required. Some of the more important questions to be answered are:

- Does the sum of all the sources of all air pollutants at the site constitute a major source (i.e., in an attainment area, does the operation have the potential to emit 100 tons per year for attainment areas (areas which meet national ambient air quality standards), or 25 tons per year for non-attainment areas, of any criteria air pollutant, or 10 tons per year of any of 188 listed "hazardous" air pollutants)? These levels exceed most precast concrete plant emissions rates which will typically vary from 3 to 20 tons per year. However, if plant is in a severe particulate or ozone non-attainment area, thresholds will vary (see 40 CFR Part 70.3).
- Is the facility located in a non-attainment area for one or more specific air pollutants (e.g., ozone or carbon monoxide)? Different timelines and control technologies (e.g., maximum achievable control technology versus best available control technology or reasonably available control technology) are in effect for attainment versus non-attainment areas, with lower emission limits requiring permits being applicable in non-attainment areas.
- If in a non-attainment area, what is the non-attainment areas classification: "marginal," "moderate," "serious," "severe" or "extreme." And are changes to the current attainment status pending with the EPA? Depending on the classification, different emission limits for compliance exist.
- What governmental entity is responsible for CAA compliance, and what is the status of implementation plans? In some states, responsibility for CAA compliance rests with a county governmental office or specially designated airshed district. Some state implementation plans have elected to defer for the maximum five years any regulation of nonmajor sources.

Liabilities. The civil and criminal liability portions of the CAA should be considered carefully. Civil penalties can be as high as $5,000 a day per violation. The CAA makes provision for direct legal action by private parties and, perhaps more importantly, enables the EPA to pay bounties to individuals of up to $10,000 for information leading to civil or criminal penalties. Finally, like other environmental regulations, the CAA has criminal enforcement provisions for senior management personnel of up to $250,000 a day per violation and five years in jail. A maximum of two years jail time is permitted for simply failing to file CAA records or maintain CAA reports.

Conclusion

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

Producers should recognize the adverse potential health effects of silica exposure and investigate other means of abrasive finishing including possible mechanization of the process and the use of low silica content abrasives. However, there is not any currently available alternate technologies in use by any producer which are more effective in reducing dust exposure levels than the methods currently being used.

Since producers currently are not aware of an alternate technology, sandblasters should participate in a Respiratory Protection Program. Producers should provide and require sandblasters to use Type CE respirators which provide a level of protection greater than their exposure. They should be properly trained in both Respiratory Protection and Hazard Communication. They should also be required to undergo annual physicals for medical surveillance purposes.

In all likelihood, the concrete material removed (by any type of abrasive) will by itself generate crystalline silica dust levels in excess of the exposure limits. Without a radical change in available technology, the industry does not believe that we will ever be able to reduce the levels of crystalline silica to the point where the sandblasters will not be required to use respiratory protection. The industry should, however, continue to explore other methods to reduce exposure to sandblasters.

If your plant has not yet examined compliance with Title V of the CAA of 1990, it should do so soon. In the worst case, an operation may find itself out of compliance with permitting requirements of Title V, and therefore subject to both civil and criminal provisions of the Clean Air Act. The use of a Title V Environment Air Permit Specialist is recommended due to the cumbersome, detailed and lengthy permit process.

If the issue of Title V compliance has not been conclusively addressed, efforts toward that end should begin soon. Given the considerable confusion about certain aspects of control technologies, such as what constitutes a process modification as opposed to what changes may legitimately be accomplished under existing approvals, it may be advantageous to accelerate certain plant upgrades ahead of schedule to make unnecessary or simplify permitting requirements.

APPENDIX A: RELATIVE TOXICITY OF SUBSTITUTES

Specular Hematite (Iron Oxide)

Specular hematite is composed of 985 iron oxide, trace amounts of manganese, chromium, and nickel, and no quartz. The National Research Council (NRC) and American Conference of Governmental Industrial Hygienists (ACGIH) have classified iron oxide as inert and nonfibrogenic [National Research Council 1979]. Many researchers use iron oxide as the negative control in toxicity studies. The International Agency for Research on Cancer (IARC) and ACGIH classify iron oxide as "not carcinogenic to humans" [International Agency for Research on Cancer (IARC) 1987a, b, c]. These classifications are supported by numerous studies. Iron oxide does cause siderosis, a benign form of pneumoconiosis, after years of exposure at 15 mg/m^3. It is also considered to be a cocarcinogenic carrier with quartz, diesel exhaust, and the radioactivity in the ore in which it is mined. Quartz will be in the surfaces to be blasted.

Garnet

Garnet is composed of 36-38% silicon dioxide, and according to suppliers, less than 0.3% quartz. However, quartz in the range of 2.2 – 7.7% was found in 5 of 12 bulk samples analyzed by NIOSH. Manganese in the range of 100-700 μg/gm was found in all 4 bulks used for elemental analysis. 50-60% of garnet is composed of iron oxide and aluminum oxide, which were classified earlier by ACIGH, NRC, and IARC as being nonfibrogenic and noncarcinogenic.

Staurolite

Staurolite is composed of 29% silicon dioxide, and according to suppliers, less than 2% quartz. About 1.0% quartz was found in 2 of 4 bulk samples analyzed by NIOSH. 59% of staurolite is composed of aluminum oxide and iron oxide, which were classified earlier by ACIGH, NRC, and IARC as being nonfibrogenic and noncarcinogenic.

Coal Slag

Coal slag is composed of 45-50% silicon dioxide and no quartz. The gamma range is 15-20 pCi/g. Eighteen bulk samples analyzed for 28 elements contained the following: arsenic in 8, beryllium in 12, chromium in 9, nickel in 14, manganese in 12. Three NIOSH studies by Stettler indicated coal slag to cause moderate pulmonary fibrosis, but much less fibrogenic potential than silica sand [Stettler 1981,1982, 1988].

Copper Slag

Copper slag is composed of 45% silicon dioxide and no quartz. Seven bulk samples analyzed for 28 elements contained the following: arsenic in 3 (up to 1450 μg/gm), beryllium in 2 (up to 180 μg/gm), chromium in 5 (up to 2400 μg/gm), nickel in 4 (up to 2240 μg/gm), manganese in 6 (up to 2900 μg/gm), lead in 6 (up to 8900 μg/gm), and copper in 7 (up to 6400 μg/gm). Three NIOSH studies by Stettler indicated copper slag to cause minimal pulmonary fibrosis, with much less fibrogenic potential than silica sand [Stettler 1981, 1982, 1988]. However, copper slag was suggested to be carcinogenic to rats [Stettler 1981, 1982, 1988]. The NIOSH DBBS in vivo assays by Stettler were the only toxicity studies regarding copper slag.

Nickel Slag

Nickel slag is composed of 37-50% silicon dioxide and no quartz. Three bulk samples analyzed for 28 elements contained the following: arsenic in 2 (up to 180 μg/gm), chromium in all 3 (up to 3700 μg/gm), nickel in all 3 (up to 2400 μg/gm), manganese in all 3 (up to 1100 μg/gm) and lead in 2 (up to 700 μg/gm). Two NIOSH studies by Stettler indicated nickel slag to cause minimal pulmonary fibrosis, with much less fibrogenic potential than silica sand [Stettler 1981, 1982, 1988]. Nickel slag was suggested to be noncarcinogenic to rats [Stettler 1981, 1982, 1988]. The NIOSH DBBS in vivo assays by Stettler were the only toxicity studies regarding nickel slag.

Steel Grit

Steel grit is composed of 95-99% iron oxide. Therefore, one may refer to specular hematite for the toxicity of steel grit. Steel grit contains no quartz.

Aluminum Oxide

Aluminum oxide is composed of 92-97% aluminum oxide. Aluminum oxide contains no quartz, and is classified to be inert and nonfibrogenic by NRC and ACGIH and not classified as a human carcinogen by IARC and ACGIH [National Research Council 1979, IARC 1987a, b, c]. These classifications are supported by numerous studies. Over 20 toxicity studies (references) suggest the potential of neurotoxicity due to aluminum oxide exposure. Aluminum oxide is often not considered a potential substitute for silica sand in abrasive blasting since it's hardness of 10 MOHS often makes it too aggressive for many blasting tasks (it can erode expensive tungsten carbide nozzles out quickly) and the initial per ton price range of $600 to $800 dollars often makes it economically noncompetitive with silica sand.

Olivine

Olivine is composted of 39-46% silicon dioxide, but no quartz, Ten toxicity studies (references) suggest olivine to be inert and nonfibrogenic. Three toxicity studies (references) suggest olivine to be noncarcinogenic. The synthetic olivine marketed as an abrasive blasting agent out of Quebec, Canada has been found to contain little to no asbestos fibers. Asbestos fibers have been found in natural olivine as suggested by three references.

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