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PART 1

Controlling Silica Exposures in Construction

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This publication provides a general overview of a particular standards-related topic. This publication does not alter or determine compliance responsibilities which are set forth in OSHA standards, and the *Occupational Safety and Health Act*. Moreover, because interpretations and enforcement policy may change over time, for additional guidance on OSHA compliance requirements, the reader should consult current administrative interpretations and decisions by the Occupational Safety and Health Review Commission and the courts.

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Occupational Safety and Health Administration
U.S. Department of Labor

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Cover photo courtesy of the Center for Construction Research and Training
(formerly the Center to Protect Workers' Rights (CPWR)

This guidance document is not a standard or regulation, and it creates no new legal obligations. The document is advisory in nature, informational in content, and is intended to assist employers in providing a safe and healthful workplace. The Occupational Safety and Health Act requires employers to comply with safety and health standards promulgated by OSHA or by a state with an OSHA-approved state plan. In addition, pursuant to Section 5(a)(1), the General Duty Clause of the Act, employers must provide their employees with a workplace free from recognized hazards likely to cause death or serious physical harm. Employers can be cited for violating the General Duty Clause if there is a recognized hazard and they do not take reasonable steps to prevent or abate the hazard. However, failure to implement any specific recommendations contained within this document is not, in itself, a violation of the General Duty Clause. Citations can only be based on standards, regulations, and the General Duty Clause.

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Overview

This guidance document addresses the control of employee exposures to respirable dust containing crystalline silica, which is known to cause silicosis, a serious lung disease, as well as increase the risk of lung cancer and other systemic diseases. This document provides information on the effectiveness of various engineering control approaches for several kinds of construction operations and equipment, and contains recommendations for work practices and respiratory protection, as appropriate.

Quartz is the most common form of crystalline silica. In fact, it is the second most common surface material accounting for almost 12% by volume of the earth's crust. Quartz is present in many materials in the construction industry, such as brick and mortar, concrete, slate, dimensional stone (granite, sandstone), stone aggregate, tile, and sand used for blasting. Other construction materials that contain crystalline silica are asphalt filler, roofing granules, plastic composites, soils, and to a lesser extent, some wallboard joint compounds, paint, plaster, caulking and putty. Cristobalite, a less common form of crystalline silica, is formed at high temperatures (>1,470°C) in nature and by industrial processes. The ceramic and brick lining of boilers and vessels, some ceramic tiles, and volcanic ash contain cristobalite.

The crystalline silica permissible exposure limit (PEL) for the construction industry at 29 CFR 1926.55(a) is expressed in terms of millions of particles per cubic foot (mppcf). This PEL is based on a particle count method long rendered obsolete by respirable mass (gravimetric) sampling, which yields results reported in milligrams per cubic meter (mg/m^3). In contrast with the construction PEL, the crystalline silica PEL for general industry is based on gravimetric sampling, which is the only method currently available to OSHA compliance personnel. Since the construction PEL is expressed in terms of mppcf, the results of the gravimetric sampling must be converted to an equivalent mppcf value. For more information on the conversion of gravimetric sampling results, please see Appendix E of OSHA Directive CPL 03-00-007 (January 24, 2008). It can be accessed at http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_ table=DIRECTIVES&p_id=3790.

In this guidance, OSHA uses a benchmark 8-hour time-weighted average exposure of 0.1 mg/m^3 of respirable silica dust as a point of reference in describing control measures utilized by the construction trades. This benchmark is more conservative (i.e., lower) than the current construction PEL. The benchmark is approximately equivalent to the general industry PEL, is a single easy-to-use number rather than a formula, and is expressed in terms of the current gravimetric method rather than the obsolete particle count method. Since this benchmark is generally more conservative than the construction PEL, employers who meet the benchmark will be in compliance with the construction PEL. OSHA notes that some organizations have recommended lower levels. For example, the National Institute for Occupational Safety and Health (NIOSH) recommends that respirable crystalline silica exposures be limited to 0.05 mg/m^3 as a time-weighted average for up to 10 hours (NIOSH, 2002). The American Conference of Government Industrial Hygienists (ACGIH) recommends that respirable crystalline silica exposures be limited to 0.025 as an 8-hour time-weighted average (ACGIH, 2008). OSHA is reviewing the construction and general industry PELs for silica in its ongoing silica rulemaking.

The recommendations presented in this document are based on a review of information in the published literature, NIOSH In-Depth Survey Reports and OSHA inspection data. Engineering control evaluations reported in the published literature were generally performed in controlled work environments and may not reflect actual workplace exposures experienced at construction worksites. Moreover, potential silica exposure levels will depend on the concentration of silica in materials at construction sites, as well as factors in the work environment (such as enclosed, semi-enclosed, or open spaces and/or multiple operations generating silica dust) as well as environmental conditions (such as wind direction and speed). Therefore, OSHA encourages employers to conduct periodic exposure monitoring to confirm that engineering and work practice controls are effective and that appropriate respiratory protection is being used where necessary. Controls continue to evolve and OSHA encourages equipment suppliers and contractors to work with industrial hygienists to evaluate new designs and products to obtain objective information that can be used to evaluate performance and support informed decisions on use.

If you choose to modify equipment, it is important to follow equipment manufacturers' recommendations in order to ensure that modifications do not adversely affect equipment performance and that no additional hazards are created. Furthermore, ground-fault circuit interrupters (GFCI) and watertight/sealable electrical connectors should be used with electric tools and equipment on construction sites (OSHA, 1996). These features are particularly important in areas where water is used to control dust.

The document is divided into nine sections that cover different construction operations. Eight are for specific equipment or operations: Stationary Masonry Saws, Handheld Masonry Saws, Hand-Operated Grinders, Tuckpointing/Mortar Removal, Jackhammers, Rotary Hammers and Similar Tools, Vehicle-Mounted Rock Drilling Rigs, and Drywall Finishing. The other section addresses general housekeeping operations and dust control through the use of dust suppressants. These nine sections draw heavily from OSHA's experience, as is reflected in the numerous references to "OSHA case files." These files originated primarily from OSHA's Region 5 in conjunction with a Special Emphasis Program for silica, and can be found in a report prepared for OSHA by Eastern Research Group (ERG). This report, "Technological Feasibility Study and Cost Impact Analysis of the Draft Crystalline Silica Standard for Construction", can be found in draft form in OSHA's docket H-006A, and at http://dockets.osha.gov/vg001/V037B/00/01/28.PDF.

The sections have been carefully written and compiled; they include case studies, reference lists, and technical notes. They offer information, advice and recommendations on using wet methods, vacuum dust collection (VDC) systems, and work practices to control dust emissions from construction operations. Many of these dust control systems are readily available from vendors. By implementing these recommendations, employers will more effectively minimize employee exposures to respirable dust containing crystalline silica and will provide a safer work environment for their employees.

For additional information about controlling silica exposures in construction, please see OSHA's website at http://www.osha.gov/SLTC/construction silica/index.html.

Stationary Masonry Saws

This section covers gas- and electric-powered stationary masonry saws. The term "silica" used in this document refers to respirable crystalline silica.

Introduction

Exposure to fine particles of silica has been shown to cause silicosis, a serious and sometimes fatal lung disease. Construction employees who inhale fine particles of silica may be at risk of developing this disease. Employees produce dusts containing silica when they cut, grind, crush, or drill construction materials such as concrete, masonry, tile and rock. The small particles easily become suspended in the air and, when inhaled, penetrate deep into employees' lungs.

Studies show that using a stationary masonry saw to cut bricks, concrete blocks and similar materials can result in hazardous levels of airborne silica if measures are not taken to reduce dust emissions. Stationary saws should always be used with dust control measures. At worksites without dust controls for these tools, studies have found that employee silica exposures can be as high as 20 times the Occupational Safety and Health Administration's (OSHA) benchmark of 0.1 mg/m^3 (milligrams per cubic meter of air) as an 8-hour time-weighted average (TWA), an exposure approximately equivalent to OSHA's general industry permissible exposure limit (PEL) (OSHA Case Files).[1] Short-term exposures can be even higher.

This section describes methods available to reduce employees' exposures to silica when using stationary masonry saws. OSHA encourages you to use this information to evaluate or improve system performance to reduce dust emissions. Technical notes are found at the end of this section and are referenced throughout the text.

Hazardous exposures to silica can occur when stationary saws are operated without appropriate dust controls. (Photo courtesy of the University of Washington.)

Two primary methods exist to control silica dust while operating a stationary saw: (1) wet cutting, and (2) vacuum dust collection. Ventilated booths, when properly designed, can also reduce silica dust exposure. All of these methods are easy to implement.

Wet cutting, when used properly, is an effective way to reduce employee exposures to silica dust and in most cases maintains exposures below the allowable limit. ***Vacuum dust collection*** can significantly reduce silica levels, but may not reliably keep them below 0.1 mg/m^3 as an 8-hour TWA.

Silica Dust Control Measures

Wet Cutting

Most stationary saws come equipped with a water basin that typically holds several gallons of water and a pump for recycling water for wet cutting.[2] If a saw's water supply system is not currently operating, the manufacturer may be able to supply the necessary accessories to reactivate wet cutting capability. Most suppliers stock these accessories since water cooling prolongs the life of the saw blade and tool.

Wet cutting is the most effective method for controlling silica dust generated during sawing because it controls the exposure at its source. Dust that is wet is less able to become or remain airborne. Results obtained by OSHA and the National Institute for Occupational Safety and Health (NIOSH) at five construction sites indicate that wet masonry saw operators' exposures were routinely below 0.1 mg/m^3, and usually below 0.05 mg/m^3, not only when averaged over an 8-hour shift, but also during just the period evaluated.[3]

At one jobsite, for example, NIOSH recorded a respirable silica exposure level of 0.04 mg/m^3 in the breathing zone of an employee cutting concrete blocks using a water-fed bench saw. The employee operated the saw for approximately 5 of the 8 hours sampled (NIOSH, 1999a). Even if the employee had cut block for a full 8-hour shift, his estimated exposure would have been 0.05 mg/m^3.

In comparison, OSHA reported a significantly higher exposure at another site on a day when wet methods were not used due to cold weather. The employee dry cut concrete block outdoors for a similar period of time (nearly 6 hours), but in this case experienced an 8-hour average exposure of 2 mg/m^3 (OSHA Case Files).[4]

Employee exposures associated with uncontrolled dry cutting tend to be lower for employees operating saws for a smaller percentage of their shift, as well as for jobs involving materials with lower silica content. However, among the nine results obtained by OSHA and NIOSH, the average exposure for dry cutting outdoors was 0.56 mg/m^3 (with a median of 0.25 mg/m^3) for the periods sampled.[5] These values exceed OSHA limits, and were associated with employees dry cutting for 10 to 60 percent of the time sampled. At three construction sites, employee exposures exceeded 2 mg/m^3, presumably during periods of intensive cutting lasting from 2 minutes to 6 hours (Lofgren, 1993; OSHA Case Files).

Maintenance. To minimize dust emissions from saws equipped for wet cutting, keep pumps, hoses and nozzles in excellent operating condition. Regular saw maintenance reduces silica exposures and ensures optimal operation of the equipment. Saws and dust control devices should be on a routine maintenance schedule.

Maintaining a Water-Feed System

- Check the pump to ensure that it is working properly and make sure that hoses are securely connected and not cracked or broken.
- Adjust nozzles to ensure that water is directed so that the maximum amount reaches the cutting area while still cooling the blade.
- Rinse or replace water filters at appropriate intervals to ensure that the flow of clean water is not restricted and to prevent damage to the pump.
- Replace basin water when it gets gritty or begins to silt up with dust. Depending on use, this step may need to be repeated several times per day to prevent the nozzle from clogging and to ensure that mist generated during cutting does not carry extra dust from the recycled water.
- Dispose of water containing silica in a way that prevents the silica from becoming resuspended in the air. If the silica is allowed to become airborne, it can contribute to employee exposures.
- Consult the manufacturer for equipment operating specifications and recommendations that apply to the specific saw model including electrical fault protection, such as a ground-fault circuit interrupter (GFCI).

Freezing Temperatures. Freezing temperatures complicate the use of water.[6] Consider heating the local work area, if practical, to prevent ice from forming in the water-feed system. Drain the system when not in use. Large portable heating units are commonly used to heat commercial and sometimes road and highway projects. If water freezes on the ground, chip away the ice or use deicing compounds or sand to control the slipping hazard.

Electrical Safety. Use ground-fault circuit interrupters (GFCIs) and watertight, sealable electrical connectors for electric tools and equipment on construction sites (OSHA, 1996). These features are particularly important to employee safety in wet or damp areas, such as where water is used to control dust. Although an assured equipment grounding conductor program is an acceptable alternative to GFCIs, OSHA recommends that employers use GFCIs where possible because they afford better protection for employees. (See 29 CFR 1926.404(b)(1) for OSHA's ground-fault protection requirements.)

Visible and Respirable Dust

Visible dust contains large particles that are easy to see. The tiny, respirable-sized particles (those that can get into the deep lung) containing silica pose the greatest hazard and are not visible. Most dust-generating construction activities produce a mixture of visible and respirable particles.

Do use visible dust as a general guide for improving dust suppression efforts. If you see visible dust being generated, emissions of respirable silica are probably too high. Measures that control tool-generated dust at the source usually reduce all types of particle emissions, including respirable particles.

Do not rely only on visible dust to assess the extent of the silica hazard. There may be more airborne respirable dust present that is not visible to the naked eye.

Vacuum Dust Collection Systems

When wet methods cannot be implemented, one alternative is the use of vacuum dust collection (VDC) systems. Stationary masonry saws with VDC systems are commercially available and have the ability to capture a substantial amount of dust.

With these systems, a vacuum pulls dust from the cutting point through special fittings connected directly to the saw (fixed-blade saws) or, alternatively, through a dust collection device connected to the back of the saw (plunge-cut saws) (Croteau, 2000). A dust collector (exterior hood) mounted to the back of a saw requires a high exhaust airflow to ensure good dust capture between the saw blade and dust collector.

Under experimental conditions, a VDC system for a fixed-blade saw reduced short-term (15-minute) exposures by 80 to 95 percent when compared to uncontrolled masonry cutting. Because the saw produced unusually high levels of dust in the enclosed, ventilated test area, the operators' silica exposure levels exceeded OSHA limits by a wide margin, even with the VDC system equipment activated. However, the authors of the study reported that uncontrolled silica exposure levels in the study were considerably greater than those observed in actual construction industry exposure assessment studies. Consequently, use of the VDC system in an actual construction setting could reduce silica exposure levels below OSHA limits (Croteau, 2000; Croteau et al., 2002). Even when operators' silica exposure still exceeds OSHA limits, the level of exposure could be substantially reduced through the use of the VDC system.

Recommendations for Vacuum Dust Collection Systems. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends airflow of 25 cubic feet per minute (CFM) per inch of blade diameter (ACGIH, 2007). If airflow is too low, the hose may clog with particulate matter. A study by Croteau et al. (2002), which tested an abrasive wheel saw, indicated that a ventilation flow rate of 75 CFM and an air velocity of 3440 feet per minute (FPM) should be considered the minimum ventilation rate for a 2-inch diameter vacuum hose. If the system provides a higher flow rate, then it is acceptable to use a larger hose.

VDC systems can be purchased as a kit. These kits should include a dust collector (exterior hood), vacuum, vacuum hose, and filter(s). The components of a VDC system are discussed below.

- *Dust collector (exterior hood)*: Be sure to use the appropriate sized dust collector for the wheel and if it is a retrofit on the saw, be sure to follow the manufacturer's instructions when installing the device.
- *Vacuum*: Choose a vacuum with the appropriate power and capacity for your job. Obtaining a flow rate on a VDC system of 80 CFM or better will give the best results while performing mortar removal (Heitbrink and Watkins, 2001).
- *Vacuum hose*: A flow rate of 80 CFM is best maintained with a 1½- to 2-inch diameter hose. If the diameter is larger, the airflow velocity will be reduced. If the diameter is smaller, airflow resistance will be higher. Airflow resistance also increases with hose length; excessively long hoses should be avoided.
- *Filters*: Double filtration is important. The use of a high-efficiency particulate air (HEPA) filter is critical to prevent the escape of respirable silica dust from the vacuum exhaust. HEPA filters are at least 99.97 percent efficient in removing fine dust particles from the air. A prefilter or cyclonic separator in addition to a HEPA filter will improve vacuum efficiency and extend the service life of the more costly HEPA filter. A cyclonic separator removes large particles that are capable of overloading or clogging the filter (Heitbrink and Collingwood, 2005).[7]
- *Systematic cleaning*: Choose a vacuum equipped with a back-pulse filter cleaning cycle. Such auto-cleaning mechanisms will reduce the time required for vacuum maintenance and improve the overall efficiency of the dust collection system. If the vacuum does not have an auto-cleaning mechanism, the employee can periodically turn the vacuum cleaner on and off. This allows the bag to collapse and causes the prefilter cake to dislodge from the filter.
- *Monitoring VDC efficiency*: Purchasing a dust collection system equipped with a static pressure gauge allows the employee to monitor the system's efficiency. Systems lacking a static pressure gauge can be monitored visually. If a dust plume increases and becomes more visible where the dust collector meets the working surface, the system is not working efficiently (Heitbrink and Collingwood, 2005).

Tips for Operating a Vacuum Dust Collection System

- Make sure that all hoses are clean and free of cracks.
- Ensure that appropriate filters and dust bags are in good condition and changed or emptied as needed (may be necessary several times per shift under some circumstances).
- Check the entire system daily for signs of poor dust capture or dust leaks.
- Use high-efficiency (HEPA) filters for maximum dust control.
- Erect baffles on either side of the saw to improve dust capture by rear-mounted dust collection devices (exterior hoods).
- Review manufacturers' operating specifications and recommendations for your equipment.

Work Practice Controls to Enhance Vacuum Effectiveness. Studies have shown that the effectiveness of VDC systems is enhanced by the use of proper work practices (NIOSH, 1999; Croteau et al., 2002). However, use of these work techniques without a dust collection system will not substantially reduce dust exposures.

With any type of vacuum system, employee protection from respirable dust is only as good as the filter in the vacuum. The less efficient the filter, the more respirable dust will pass through with the vacuum exhaust air. Locating the vacuum as far from employees as possible is one way to help limit exposure.

For optimal dust collection, the following measures are recommended:

- Keep the vacuum hose clear and free of debris, kinks and tight bends. Maintain the vacuum at peak performance to ensure adequate airflow through the dust collector and vacuum hoses.
- On vacuums with manual back-pulse filter cleaning systems, activate the system frequently (several times per day). Empty collection bags and vacuums as frequently as necessary. Dispose of collected dust in a way that prevents it from becoming resuspended in the air.
- For best results, set up a regular schedule for filter cleaning and maintenance. For example, institute a rule to clean the filter or change the bag at each break. This will prevent pressure loss and ensure that exhaust airflow stays constant on the VDC system.
- Remember, the absence of visible dust does not necessarily mean that employees are adequately protected from silica exposure.

Ventilation Booths

A booth (with fan) erected around a saw can help reduce dust, but may require some experimentation.[8] For example, one employer built a plywood booth around the saw and installed a large exhaust fan at the rear wall to pull dust away from the employee, who operated the saw through an opening in the front of the booth.[9] Initial air sampling results indicated that the operators' exposures to silica while cutting brick were between 0.07 and 0.1 mg/m^3. By modifying the booth interior to better capture the plume of dust released by the saw, the employer was able to reduce exposures further, to 0.02 mg/m^3 during the period evaluated (OSHA Case Files).[10]

Tips for Designing an Effective Booth[3]

- Minimize the size of the operator opening to reduce the chance of dust escaping into the operator's breathing area.
- Use a fan large enough to provide an average of 250 feet per minute air velocity across the face of the operator opening.
- Do not let the saw blade protrude beyond the open face of the booth.
- Build a trapdoor into the lower back of the booth to access the interior for cleaning and to remove debris.
- Always position the booth so that the exhaust fan does not blow dusty air on other employees. When possible, have the booth exhaust downwind.

Fans

Fans are not effective dust control devices when used as the sole control method and should not be used as the primary method for managing dust.[11] Fans can, however, be useful as a supplement to other control methods. Use fans in enclosed areas, such as bathrooms, where dust would build up due to poor air circulation.

For the best effect, set an exhaust fan (the bigger, the better) in an open window or external doorway. Position the saw nearby, so that the fan captures dust and blows it outside. Avoid positioning employees between the saw and the fan. Also, avoid positioning employees near the exhausted air. An exhaust fan works best if a second window or door across the room is open to allow fresh air to enter.

Considerations

While dust control using vacuum dust collection may be an attractive option in some circumstances, it is not as effective as wet cutting for controlling respirable dust. Respiratory protection may still be needed to reduce employee exposures to levels of 0.1 mg/m^3 or less when using vacuum dust collection.

Provide employees with respiratory protection until air sampling indicates that their exposure is adequately controlled.

Compressed Air

The use of compressed air to clean surfaces or clothing is strongly discouraged. Using compressed air to clean work surfaces or clothing can significantly increase employee exposure, especially in enclosed and semi-enclosed spaces. Cleaning should be performed with a HEPA-filtered vacuum or by wet methods.

Respiratory Protection and Engineering Control Evaluation

Using a stationary saw without engineering controls can cause exposure to respirable silica to reach 2.0 mg/m^3 or higher. Therefore, it is important to utilize effective controls to reduce employee exposures. Wet methods present the best choice for suppressing dust while cutting with stationary saws. Studies indicate that effective wet methods can reduce exposures below 0.05 mg/m^3, as an 8-hour TWA. Stationary saws can be purchased with water-fed equipment, or existing saws can be retrofitted with water-fed attachments. Respiratory protection should not be necessary when using effective wet methods.

In situations where wet methods may not be appropriate or feasible, vacuum dust collection may be an alternative control option. However, data indicate that vacuum dust collection alone can only reduce exposures to 0.4 mg/m^3. Therefore, to supplement this control option, employees need to wear a properly fitted, NIOSH-approved half-facepiece or disposable respirator equipped with an N-, R-, or P-95 filter. A half-facepiece or disposable respirator can be used for exposures up to 1.0 mg/m^3.

In any workplace where respirators are necessary to protect the health of the employee, or whenever respirators are required by the employer, the employer must establish and implement a written respiratory protection program with worksite-specific procedures and elements, including the selection of respirators, medical evaluations of employees, fit testing, proper usage, maintenance and care, cleaning and disinfecting, proper air quality/quantity and training (see 29 CFR 1926.103).

Other employees in close proximity to the work operations where silica dust is generated may also need respiratory protection if effective controls are not implemented. The level of respiratory protection is dependent on the employee's silica exposure, which varies depending on factors in the work environment (such as enclosed, semi-enclosed, or open spaces and/or multiple operations generating silica dust), environmental conditions (such as wind direction and speed), and the percentage of silica found in the material.

Construction sites often involve many operations occurring simultaneously that can generate respirable silica dust. Therefore, it is important and necessary to utilize effective controls (such as wet methods and/or vacuum dust collection) in order to minimize total exposures to silica-exposed tool operators or potential exposures to other employees.

Employers should conduct exposure monitoring periodically while controls are being used to ensure that the controls are working properly and that the appropriate level of respiratory protection is being used.

For more information on how to determine proper respiratory protection, visit OSHA's Web site at www.osha.gov. NIOSH's Web site also provides information on respirators at www.cdc.gov/niosh.

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Technical Notes

[1] Laboratories have not used particle counting for crystalline silica analysis for many years. Exposure data is now reported gravimetrically. However, OSHA's construction PEL for crystalline silica, established in 1971, is still listed as a particle-count value. (See Appendix E to OSHA's National Emphasis Program for Crystalline Silica, CPL 03-00-007, for a detailed discussion of the conversion factor used to transform gravimetric measurements to particle-count values). In this guidance, OSHA is using the general industry PEL (0.1 mg/m^3 of respirable quartz as an 8-hour time-weighted average) as a benchmark to describe the effectiveness of control measures. The benchmark is approximately equivalent to the general industry silica PEL. Other organizations suggest more stringent levels. For example, the National Institute for Occupational Safety and Health (NIOSH) recommends that respirable crystalline silica exposures be limited to 0.05 mg/m^3 as a 10-hour time-weighted average (NIOSH, 2002). The American Conference of Governmental Industrial Hygienists (ACGIH) recommends that respirable crystalline silica exposures be limited to 0.025 mg/m^3 as an 8-hour time-weighted average (ACGIH, 2008).

[2] Some employers use a hose connected to an external water source to provide a continuous flow of fresh water in place of recirculated water. This eliminates the need for pumps and filters, but requires substantially more water and produces more runoff.

[3] Nine results contained in NIOSH, 1999a and 1999b; Shields, 2000; ERG, 2000; and OSHA Case Files. The one exception was a result of 0.1 mg/m^3.

[4] The respirable silica concentration in the employee's breathing zone during the period monitored was 2.8 mg/m^3.

[5] Two results associated with exceptionally short sampling periods (a 56-minute result of 7.5 mg/m^3 and a 2-minute result of 3.1 mg/m^3) were excluded from this average, but included in the subsequent text on periods of intensive cutting.

[6] Some saws come set up for both water-feed and vacuum dust collection for better employee protection in all situations.

[7] For the system tested by Croteau et al. (2002), an airflow of 70 cubic feet per minute (CFM) through the vacuum controlled respirable dust better than 30 CFM. ACGIH (2007) recommends a still higher airflow of 25 CFM per inch of blade diameter (equivalent to 236 CFM for the saw tested). Low airflow can cause ducts to clog. For abrasive wheel saws with vacuum dust collection, ACGIH recommends a minimum airflow velocity of 4,000 feet per minute (FPM) through ducts to prevent dust from settling. For a typical 2-inch diameter vacuum hose, 75 to 90 CFM will achieve that duct velocity. Larger hoses are acceptable for larger vacuums that draw more CFM of air. For example, 350 CFM of airflow would create the recommended air velocity in a 4-inch duct.

[8] With careful experimentation, it is possible to construct a booth that controls exposures to levels below OSHA's limits. First, make adjustments to control visible dust escaping from the front of the booth. Then, conduct air sampling (preferably under a variety of cutting conditions) to confirm that the booth will also protect the operator from respirable sized particles.

[9] Booth dimensions were approximately 6 feet by 6.5 feet by 3.5 feet, with a 36-inch fan. Air moved through the open face of the booth at an average velocity of 250 feet per minute (FPM), consistent with ACGIH's recommendation for abrasive cut-off saw booths.

[10] Sampling periods at this site were of 318 to 462 minutes duration.

Handheld Masonry Saws

This section covers gas-, air-, electric- and hydraulic-powered handheld masonry saws. The term "silica" used in this document refers to respirable crystalline silica.

Employee operating a handheld masonry saw without the use of appropriate dust controls. (Photo courtesy of OSHA.)

Introduction

Exposure to fine particles of silica has been shown to cause silicosis, a serious and sometimes fatal lung disease. Construction employees who inhale fine particles of silica may be at risk of developing this disease. Employees produce dusts containing silica when they cut, grind, crush, or drill construction materials such as concrete, masonry, tile and rock. The small particles easily become suspended in the air and, when inhaled, penetrate deep into employees' lungs.

Studies show that using a handheld masonry saw to cut bricks, concrete blocks and similar materials can result in hazardous levels of airborne silica if measures are not taken to reduce dust emissions. Operating a handheld masonry saw outdoors without dust controls can produce silica exposures as high as 14 times the Occupational Safety and Health Administration's (OSHA) benchmark of 0.1 mg/m^3 (milligrams per cubic meter of air) as an 8-hour time-weighted average (TWA), an exposure approximately equivalent to OSHA's general industry permissible exposure limit (PEL) for construction (OSHA Case Files).[1] Short-term exposures or exposures from operating saws indoors can be significantly higher (up to 10 mg/m^3).

Visible and Respirable Dust

Visible dust contains large particles that are easy to see. The tiny, respirable-sized particles (those that can get into the deep lung) containing silica pose the greatest hazard and are not visible. Most dust-generating construction activities produce a mixture of visible and respirable particles.

Do use visible dust as a general guide for improving dust suppression efforts. If you see visible dust being generated, emissions of respirable silica are probably too high. Measures that control tool-generated dust at the source usually reduce *all* types of particle emissions, including respirable particles.

Do not rely *only* on visible dust to assess the extent of the silica hazard. There may be airborne respirable dust present that is not visible to the naked eye.

This section describes methods available to reduce employees' exposures to silica when using handheld masonry saws. Walk-behind saws are addressed in a separate section for walk-behind surface preparation tools. OSHA encourages you to use this information to evaluate or improve system performance to reduce dust emissions. Technical notes are found at the end of this section and are referenced throughout the text.

Two main methods exist to control silica dust while operating a handheld masonry saw: (1) wet cutting and (2) vacuum dust collection.

Wet cutting, when used properly, is an effective way to reduce employee exposures to silica dust and in most cases maintains exposures below the allowable limit. ***Vacuum dust collection*** can significantly reduce silica levels, but may not reliably keep them below 0.1 mg/m^3 as an 8-hour TWA.

When applying water to the blade, exposures of handheld saw operators to silica are considerably reduced. (Photo courtesy of OSHA.)

Silica Dust Control Measures

Wet Cutting

Water-fed handheld saws that are gasoline-powered, air-powered, electric-powered and hydraulic-powered are commercially available (Stihl, 2001; Diamond Products, 2001; Partner Industrial Products, 2001). Water can be supplied to the saws either with a pressurized portable water supply or with a constant water source, for example, a hose connected to a municipal water supply.

Wet cutting is the most effective method for controlling silica dust generated during sawing because it controls the exposure at its source. Dust that is wet is less able to become or remain airborne. The effectiveness of both a pressurized portable water supply and a constant water supply was evaluated by Thorpe et al. (1999). They found that respirable dust levels were reduced by up to 94 percent for pressurized portable water supply systems and up to 96 percent for a constant supplying water source. NIOSH reported that an employee dry cutting on concrete outdoors was exposed to 1.5 mg/m^3 of silica as an 8-hour TWA (NIOSH, 1999c). A reduction of 96 percent in respirable dust for this employee would have resulted in exposure around 0.06 mg/m^3 if the employee switched to a wet method.

Maintaining a Water-Feed System

- Check to ensure that hoses are securely connected and not cracked or broken.
- Adjust nozzles to ensure that water is directed so that the maximum amount reaches the cutting area while still cooling the blade.
- Dispose of water containing silica in a way that prevents the silica from becoming resuspended in the air. If the silica is allowed to become airborne, it can contribute to employee exposures.
- Consult the manufacturer for equipment operating specifications and recommendations that apply to the specific saw model including electrical fault protection, such as a ground-fault circuit interrupter (GFCI).

Maintenance. To minimize dust emissions from saws equipped for wet cutting, keep hoses and nozzles in excellent operating condition. Regular saw maintenance reduces silica exposures and ensures optimal operation of the equipment. Saws and dust control devices should be on a routine maintenance schedule.

Freezing Temperatures. Freezing temperatures complicate the use of water.[2] Consider heating the local work area, if practical, to prevent ice from forming in the water-feed system. Large portable heating units are commonly used to heat commercial and sometimes road and highway projects. Drain the system when not in use. If water freezes on the ground, chip away the ice or use deicing compounds or sand to control the slipping hazard.

Electrical Safety. Use ground-fault circuit interrupters (GFCIs) and watertight, sealable electrical connectors for electric tools and equipment on construction sites (OSHA, 1996). These features are particularly important to employee safety in wet or damp areas, such as where water is used to control dust. Although an assured equipment grounding conductor program is an acceptable alternative to GFCIs, OSHA recommends that employers use GFCIs where possible because they provide better protection for employees. (See 29 CFR 1926.404(b)(1) for OSHA's ground-fault protection requirements.)

Vacuum Dust Collection Systems

Handheld saws can also be equipped with vacuum dust collection (VDC) systems. Saws equipped with VDC systems can be effective in controlling respirable silica exposure. One study by Thorpe et al. (1999) found that a VDC system on the handheld saw reduced mean respirable concrete dust concentrations from 8 mg/m^3 to 0.7 mg/m^3. This represents an 88 percent reduction in respirable concrete dust. However, this study used a dust collection device (exterior hood) that may not be commercially available.

Other studies have shown that handheld VDC-equipped saws do not offer a reliable reduction in exposure to dust. Two studies, Croteau (2000) and Croteau et al. (2002), tested a handheld saw equipped with a VDC system exhausting at 70 cubic feet per minute (CFM). Unfortunately, this system did not reduce respirable silica exposure. The studies concluded that the shape of the opening on the dust collection device was not effective in capturing the dust being emitted from the rotating blade. In some cases, handheld saw and VDC system combinations might require the rotation of the blade to be reversed to optimize dust collection (USF Surface Preparation Group, 2002). However, such modifications generally must be performed by the manufacturer.

NIOSH obtained 8-hour TWA respirable silica results between 0.117 and 0.388 mg/m^3 for six employees at two separate construction sites (NIOSH, 1999a; NIOSH, 1999b). The employees used no dust controls on this worksite. However, they worked outdoors and used the handheld saw intermittently. The rest of the time on the worksite was spent on activities that did not generate respirable crystalline silica. If the handheld saw that was used intermittently had been equipped with a VDC system, dust levels could have been reduced 75 percent, resulting in exposures between 0.03 mg/m^3 and 0.01 mg/m^3.

Although data on VDC-equipped handheld saws used indoors were not available, one measurement obtained from an employee cutting indoors without a VDC system yielded a silica exposure of 10.3 mg/m^3. The employee was a plumber cutting concrete floors around drains in a 16-story building. Even if the employee achieved an 88 percent reduction in dust exposure using the VDC system described by Thorpe et al. (1999), exposure still would have exceeded 1.0 mg/m^3.

Compressed Air

The use of compressed air to clean surfaces or clothing is strongly discouraged. Using compressed air to clean work surfaces or clothing can significantly increase employee exposure, especially in enclosed and semi-enclosed spaces. Cleaning should be performed with a HEPA-filtered vacuum or by wet methods.

Recommendations for Vacuum Dust Collection Systems. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends airflow of 25 CFM per inch of blade diameter. If airflow is too low, the hose may clog with particulate matter. A study by Croteau et al. (2002), which tested an abrasive wheel saw, found a 2-inch diameter vacuum hose and a flow rate of 75 to 90 CFM achieved an air velocity of 4,000 feet per minute (FPM). Achieving this air velocity prevented particulate matter from settling in the hose. If the VDC provides a higher flow rate, then it is acceptable to use a larger hose.

VDC systems can be purchased as a kit. These kits should include a dust collector (exterior hood), vacuum, vacuum hose and filter(s). The components of a VDC system are discussed below.

- *Dust collector (exterior hood)*: In most cases, this is a retrofit on the saw; therefore, be sure to follow the manufacturer's instructions when installing the device.
- *Vacuum*: Choose a vacuum with the appropriate power and capacity for your job.
- *Vacuum hose*: A flow rate of 80 CFM is best maintained with a 1½- to 2-inch diameter hose. If the diameter is larger, the airflow velocity of the vacuum will be reduced. If the diameter is smaller, airflow resistance will be higher. Airflow resistance also increases with hose length; excessively long hoses should be avoided. Many HEPA-filtered vacuum system kits include a variety of hose sizes for different tool applications.
- *Filters:* Double filtration is important. The use of a high-efficiency particulate air (HEPA) filter is critical to prevent the escape of respirable silica dust from the vacuum exhaust. HEPA filters are at least 99.97 percent efficient in removing fine dust particles from the air. A prefilter or cyclonic separator in addition to a HEPA filter will improve vacuum efficiency and extend the service life of the more costly HEPA filter. A cyclonic separator removes large particles that are capable of overloading or clogging the filter. (Heitbrink and Collingwood, 2005).[3]
- *Systematic cleaning*: Choose a vacuum equipped with a back-pulse filter cleaning cycle. Such auto-cleaning mechanisms will reduce the time required for vacuum maintenance and improve the overall efficiency of the dust collection system. If the vacuum does not have an auto-cleaning mechanism, the employee can periodically turn the vacuum cleaner on and off. This allows the bag to collapse and causes the prefilter cake to dislodge from the filter.
- *Monitoring VDC efficiency*: Purchasing a dust collection system equipped with a static pressure gauge allows the employee to monitor the system's efficiency. Systems lacking a static pressure gauge can be monitored visually. If a dust plume increases and becomes more visible where the dust collector (exterior hood) meets the working surface, the system is not working efficiently. When relying on this technique to monitor the efficiency of the dust collection system, try to locate the vacuum as far away from adjacent employees as possible to help limit their exposure to silica (Heitbrink and Collingwood, 2005).

Work Practice Controls to Enhance Vacuum Effectiveness. Studies have shown that the effectiveness of vacuum dust collection systems is enhanced by the use of proper work practices (NIOSH, 1999a; NIOSH, 1999b; NIOSH 1999c; Croteau et al., 2002). However, use of these work techniques without a dust collection system will not substantially reduce dust exposures.

With any type of vacuum system, employee protection from respirable dust is only as good as the filter in the vacuum. The less efficient the filter, the more respirable dust will pass through with the vacuum exhaust air. Locating the vacuum as far from employees as possible is one way to help limit exposure.

For optimal dust collection, the following measures are recommended:

- Keep the vacuum hose clear and free of debris, kinks and tight bends. Maintain the vacuum at peak performance to ensure adequate airflow through the dust collector (exterior hood) and vacuum hoses.
- On vacuums with back-pulse filter cleaning systems, activate the system frequently (several times per day). Empty collection bags and vacuums as frequently as necessary. Dispose of collected dust in a way that prevents it from becoming resuspended in the air.
- For best results, set up a regular schedule for filter cleaning and maintenance. For example, institute a rule to clean the filter or change the bag at each break. This will prevent pressure loss and ensure that exhaust airflow stays constant on the VDC system.
- Remember, the absence of visible dust does not necessarily mean that employees are adequately protected from silica exposure.

Fans

Fans are not effective dust control devices when used as the sole control method and should not be used as the primary method for managing dust. Fans can, however, be useful as a supplement to other control methods. Use fans in enclosed areas, such as bathrooms, where dust may build up due to poor air circulation.

For the best effect, set an exhaust fan (the bigger, the better) in an open window or external doorway. Position the saw nearby, so that the fan captures dust and blows it outside. Avoid positioning employees between the saw and the fan. Also, avoid positioning employees near the exhausted air. An exhaust fan works best if a second window or door across the room is opened to allow fresh air to enter.

Considerations

While dust control using VDC may be an attractive option in some circumstances, it is not as effective as wet cutting for controlling respirable dust. Respiratory protection may still be needed to reduce employee exposures below 0.1 mg/m^3 as an 8-hour TWA when using VDC.

Provide employees with respiratory protection until air sampling demonstrates that their exposure is adequately controlled.

Respiratory Protection and Engineering Control Evaluation

Using a handheld saw without engineering controls can cause exposures to respirable crystalline silica to reach 1.5 mg/m^3 during outdoor operations, with indoor exposures being significantly higher (up to 10 mg/m^3). Therefore, effective controls are needed to reduce employee exposures below 0.1 mg/m^3 as an 8-hour TWA.

Effective wet methods provide the most reliable control for silica dust and are invaluable in keeping silica levels below 0.1 mg/m^3 as an 8-hour TWA. Most handheld saws are manufactured with water-fed equipment. Employees who use saws that do not include water-fed equipment should apply water directly to the cutting point. Water should be applied at a minimum rate of ***0.13 gallons per minute*** to ensure adequate dust suppression outdoors. When effective wet methods are used outdoors, it is unlikely that supplemental respiratory protection will be needed (Thorpe et al., 1999).

The use of wet methods during indoor operations can reduce silica exposures, but may not reduce exposures below 0.1 mg/m^3. However, when wet methods are used, exposures will not likely exceed 1.0 mg/m^3. When wet methods cannot reduce exposures below 0.1 mg/m^3, employees should supplement them with a NIOSH-approved half-facepiece or disposable respirator equipped with an N-, R-, or P-95 filter.

In situations where wet methods may not be appropriate or feasible, VDC systems may be an alternative control option. Current data suggest that the reduction in silica offered by VDC systems is variable. For outdoor operations, using effective VDC may reduce exposures below 1.0 mg/m^3, but not necessarily below 0.1 mg/m^3. Therefore, employees may need to wear a properly fitted, NIOSH-approved half-facepiece or a disposable respirator equipped with an N-, R- or P-95 filter (see 29 CFR 1926.103).

In any workplace where respirators are necessary to protect the health of the employee, or whenever respirators are required by the employer, the employer must establish and implement a written respiratory protection program with worksite-specific procedures and elements. These should include the selection of respirators, medical evaluations of employees, fit testing, proper usage, maintenance and care, cleaning and disinfecting, proper air quality/quantity and training (see 29 CFR 1926.103).

Exposure control data are limited regarding the use of a VDC system during indoor sawing operations. A handheld saw equipped with a VDC system cannot be relied upon solely to reduce exposures below 0.1 mg/m^3; therefore, employees may need to wear a full-facepiece respirator equipped with an N-, R-, or P-95 filter (see 29 CFR 1926.103).

Other employees in close proximity to the work operations where silica dust is generated may also need respiratory protection if effective controls are not implemented. The level of respiratory protection is dependent on the employee's silica exposure, which varies depending on factors in the work environment (such as enclosed, semi-enclosed, or open spaces and/or multiple operations generating silica dust), environmental conditions (such as wind direction and speed) and the percentage of silica found in the material.

Construction sites often involve many operations occurring simultaneously that can generate respirable silica dust. Therefore, it is important and necessary to utilize effective controls (such as wet-methods and/or vacuum dust collection) in order to minimize total exposures to silica-exposed tool operators or potential exposures to other employees.

Employers should conduct exposure monitoring periodically while controls are being used to ensure that the controls are working properly and that the appropriate level of respiratory protection is being used.

For more information on how to determine proper respiratory protection, visit OSHA's Web site at www.osha.gov. NIOSH's Web site also provides information on respirators at www.cdc.gov/niosh.

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Technical Notes

[1] Laboratories have not used particle counting for crystalline silica analysis for many years. Exposure data is now reported gravimetrically. However, OSHA's construction PEL for crystalline silica, established in 1971, is still listed as a particle-count value. (See Appendix E to OSHA's National Emphasis Program for Crystalline Silica, CPL 03-00-007, for a detailed discussion of the conversion factor used to transform gravimetric measurements to particle-count values). In this guidance, OSHA is using 0.1 mg/m^3 of respirable quartz as an 8-hour time-weighted average as a benchmark to describe the effectiveness of control measures. The benchmark is approximately equivalent to the general industry silica PEL. Other organizations suggest lower levels. For example, the National Institute for Occupational Safety and Health (NIOSH) recommends that respirable crystalline silica exposures be limited to 0.05 mg/m^3 as a 10-hour time-weighted average (NIOSH, 2002). The American Conference of Governmental Industrial Hygienists (ACGIH) recommends that respirable crystalline silica exposures be limited to 0.025 mg/m^3 as an 8-hour time-weighted average (ACGIH, 2008).

[2] Some saws come set up for both water-feed and vacuum dust collection for better employee protection in all situations.

[3] For the system tested by Croteau et al. (2002), an airflow of 90 cubic feet per minute (CFM) through the vacuum controlled respirable dust better than 70 CFM. ACGIH (2001) recommends a still higher airflow of 25 CFM per inch of blade diameter (equivalent to 236 CFM for the saw tested). Low airflow can cause ducts to clog. For abrasive wheel saws with vacuum dust collection, ACGIH recommends a minimum airflow velocity of 4,000 feet per minute (FPM) through ducts to prevent dust from settling. For a typical 2-inch diameter vacuum hose, 75 to 90 CFM will achieve that duct velocity. Larger hoses are acceptable for larger vacuums that draw more CFM of air. For example, 350 CFM of airflow would create the recommended air velocity in a 4-inch duct.

Hand-Operated Grinders

This section covers electric- and pneumatic-hand-operated grinders used for surface finishing and cutting slots. Angle grinders used for tuckpointing are addressed in a separate section. The term "silica" used in this document refers to respirable crystalline silica.

Introduction

Employees produce dusts containing silica when they grind on concrete and similar materials. The grinders' abrasive action generates fine particles that easily become suspended in the air and, when inhaled, penetrate deep into employees' lungs. Exposure to fine particles of silica has been shown to cause silicosis, a serious and sometimes fatal lung disease. Construction employees who inhale fine particles of silica may be at risk of developing this disease This section discusses the methods available to reduce employee exposures to silica during grinding activities.

Data compiled by the Occupational Safety and Health Administration (OSHA) indicate that, among employees who grind concrete, most are exposed to silica at levels that exceed OSHA's benchmark of 0.1 mg/m^3 (milligrams of silica per cubic meter of air) as an 8-hour time-weighted average (TWA), an exposure approximately equivalent to OSHA's general industry permissible exposure limit (PEL).[1] In fact, on average, grinder operators' silica exposures (along with those of tuckpointers) are among the highest in the construction industry.[2] More than half of all grinder operators experience silica exposures above 0.2 mg/m^3 (milligrams per cubic meter of air).[3] During periods of intensive grinding, concrete finishers' exposures can exceed 1.2 mg/m^3 outdoors and 4.5 mg/m^3 indoors (Lofgren, 1993; OSHA Case Files).[4]

Vacuum dust collection systems are used to reduce silica dust during concrete grinding operations. Vacuum methods can significantly reduce dust emissions, but thus far have not been shown to reliably keep silica levels below 0.1 mg/m^3 as an 8-hour time-weighted average (TWA).

Wet grinding is highly effective in reducing silica exposures. Handheld water-fed grinding equipment is commercially available for concrete applications, granite grinding, and polishing operations. Conventional grinding equipment can be retrofitted to add a water-feed capability.[5]

Using a grinder in poorly controlled conditions. (Photo courtesy of the University of Washington.)

Adjustments in work methods and equipment, when possible, can lower exposure levels. For example, the use of jigs to increase the distance between the employee and the point of work can reduce exposure levels. Modifications in construction work methods for pouring, casting, finishing and installing concrete can reduce the amount of grinding required, which, in turn, can lower exposures.

Visible and Respirable Dust

Visible dust contains large particles that are easy to see. The tiny, respirable-sized particles (those that can get into the deep lung) containing silica pose the greatest hazard and are not visible. Most dust-generating construction activities produce a mixture of visible and respirable particles.

Do use visible dust as a general guide for improving dust suppression efforts. If you see visible dust being generated, emissions of respirable silica are probably too high. Measures that control tool-generated dust at the source usually reduce *all* types of particle emissions, including respirable particles.

Do not rely *only* on visible dust to assess the extent of the silica hazard. There may be airborne respirable dust present that is not visible to the naked eye.

Silica Dust Control Measures

Vacuum Dust Collection Systems

Vacuum dust collection (VDC) systems for grinders include a shroud, which surrounds the grinding wheel, hose, filters and a vacuum to pull air through the shroud. Many manufacturers offer grinders with dust collection options. Employers may also purchase equipment to retrofit grinders for vacuum dust collection. The effectiveness of vacuum systems depends on several factors, including the user's technique, the surfaces being finished, and the efficiency of the dust collection system.

The addition of the shroud and vacuum hose may make it more difficult to work effectively while reaching overhead.

Recommendations for Vacuum Dust Collection Systems. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends airflow of 25 cubic feet per minute (CFM) per inch of blade diameter (for example, a 4-inch grinder would need a vacuum with airflow of 100 CFM). If airflow is too low, the hose may clog with particulate matter. However, employers should be aware that rated airflows provided by manufacturers may be different from actual airflow once attached to the tool. A study by Croteau et al. (2002), which tested an abrasive wheel saw, found a 2-inch diameter vacuum hose and a flow rate of 75 CFM achieved an air velocity of 4,000 feet per minute (FPM). Achieving this air velocity prevented particulate matter from settling in the hose.

VDC systems can be purchased as a kit. These kits should include a grinder shroud (exterior hood), vacuum, vacuum hose, and filter(s). The components of a VDC system are discussed below.

- Grinder shroud (exterior hood): Employees should use a shroud appropriate for the grinder and wheel size.
- Vacuum: Choose a vacuum with the appropriate power and capacity for your job. Croteau et al. (2002) found a flow rate greater than 70 CFM to be effective.
- Vacuum hose: A 1½- to 2-inch diameter hose is usually best for smaller vacuums. If the diameter is larger, the airflow velocity of the vacuum will be reduced. If the diameter is smaller, airflow resistance will be higher. Airflow resistance also increases with hose length; excessively long hoses should be avoided.
- Filters: Double filtration is important. The use of a high-efficiency particulate air (HEPA) filter is critical to prevent the escape of respirable silica dust from the vacuum exhaust. HEPA filters are at least 99.97 percent efficient in removing fine dust particles from the air. A prefilter or cyclonic separator in addition to a HEPA filter will improve vacuum efficiency and extend the service life of the more costly HEPA filter. A cyclonic separator removes large particles that are capable of overloading or clogging the filter (Heitbrink and Collingwood, 2005).
- Systematic cleaning: Regular cleaning of the filter is critical to maintaining high airflow. Choose a vacuum equipped with a back-pulse filter cleaning cycle. Such auto-cleaning mechanisms will reduce the time required for vacuum maintenance and improve the overall efficiency of the dust collection system. If the vacuum does not have an auto-cleaning mechanism, the employee can periodically turn the vacuum cleaner on and off. This allows the bag to collapse and causes the prefilter cake to dislodge from the filter.
- Monitoring VDC efficiency: Purchasing a dust collection system equipped with a static pressure gauge allows the employee to monitor the system's efficiency. Systems lacking a static pressure gauge can be monitored visually. If a dust plume increases and becomes more visible where the shroud meets the working surface, the system is not working efficiently. When relying on this technique to monitor the efficiency of the dust collection system, try to locate the vacuum as far away from adjacent employees as possible to help limit their exposure to silica (Heitbrink and Collingwood, 2005).

System Maintenance. For optimal dust collection, the following measures are recommended:

- Keep the vacuum hose clear and free of debris, kinks and tight bends. Maintain the vacuum at peak performance to ensure adequate airflow through the shroud and ducts.
- On vacuums with back-pulse filter cleaning systems, activate the system frequently (several times per day). Empty collection bags and vacuums as frequently as necessary. Dispose of collected dust in a way that prevents it from becoming resuspended in the air.
- For best results, set up a regular schedule for filter cleaning and maintenance. For example, institute a rule to clean the filter or change the bag at each break. This will prevent pressure loss and ensure that exhaust airflow stays constant on the VDC system.
- Remember, the absence of visible dust does not necessarily mean that employees are adequately protected from silica exposure.

Grinder with attached VDC system. (Photo courtesy of the University of Washington.)

Fans

Fans are not effective dust control devices when used as the sole control method and should not be used as the primary method for managing dust. Fans can, however, be useful as a supplement to other control methods. Use fans in enclosed areas, such as bathrooms, where dust may build up due to poor air circulation.

For the best effect, set an exhaust fan (the bigger, the better) in an open window or external doorway. Position the grinder nearby, so the fan captures dust and blows it outside. Avoid positioning employees between the grinder and the fan. Also, avoid positioning employees near the exhausted air. An exhaust fan works best if a second window or door across the room is opened to allow fresh air to enter.

Example: A four-foot square fan is placed in a window exhausting to outside the building at maximum fan speed. The fan will have the strongest capture capability directly in front of the fan face, but this quickly drops off. At two feet away from the fan the capture capability is reduced to 50 percent and at four feet the capture capability is reduced to 7 percent of the capture capability at the fan face. If the distance between the grinding point and fan face is greater than the length of the fan side (4 feet), dust capture would probably not be effective (ACGIH, 2001).

Wet Grinding

Water provides excellent dust control during tasks involving abrasive action on concrete. When applied at the point where dust is generated, water wets the dust particles before they can become airborne.

Water-fed equipment is regularly used to control dust during granite and concrete grinding and polishing operations, as well as during concrete and masonry cutting with abrasive wheels. The wet methods consistently keep employee exposures below OSHA limits (Simcox et al., 1999; NIOSH, 1999). These tools include a nozzle or spout that provides a stream of water to the grinding wheel. For example, some equipment provides water through a hole in a hollow shaft or a nozzle at the edge of the wheel.

The National Institute for Occupational Safety and Health (NIOSH) reported that an employee reduced respirable dust levels by fitting an automatic water feed to a conventional handheld grinder and exhaust shroud system used for tuck-pointing (NIOSH, 2000a). Alternatively, a helper can apply water by hand using a spray nozzle (NIOSH, 1998). To be effective, the source must constantly supply water to the point of operation.

The use of water systems on similar tools used in the cut stone and stone products manufacturing industry has shown a reduction of exposures well below 0.1 mg/m^3 (NIOSH, 2000d and 2000e; and OSHA Case Files). It is reasonable to assume that such reductions can be achieved in the construction industry while using similar tools and control methods.

Wet methods have advantages, but require advance planning. The stone processing industry has shown that water-fed grinders function well to control dust even on uneven surfaces and near corners and edges (problem areas for vacuum dust collection equipment). Employees need training, however, to become comfortable working with water-fed grinders. A wet surface looks different from a dry one, and visibility during grinding may be obscured by water spray and slurry (OSHA Case Files). Slurry removal also requires an extra step in the cleaning process (for example, use of a wet-dry shop vacuum or rinsing the surface).[6] Nevertheless, wet methods offer reliable dust control during grinding.

Some surfaces might require extra cleaning (for example, with a pressure washer or hose and brush) after employees use wet methods. Avoid splashing concrete slurry on vehicles or other objects with specialty finishes.

Freezing Temperatures. Freezing temperatures complicate the use of water. Consider heating the local work area, if practical, to prevent ice from forming in the water-feed system. Large portable heating units are commonly used to heat commercial and sometimes road and highway projects. Drain the system when not in use. If water freezes on the ground, chip away the ice or use deicing compounds or sand to control the slipping hazard.

Electrical Safety. Use ground-fault circuit interrupters (GFCIs) and watertight, sealable electrical connectors for electric tools and equipment on construction sites (OSHA, 1996). These features are particularly important to employee safety in wet or damp areas, such as where water is used to control dust. Although an assured equipment grounding conductor program is an acceptable alternative to GFCIs, OSHA recommends that employers use GFCIs where possible because they afford better protection for employees. (See 29 CFR 1926.404(b)(1) for OSHA's ground-fault protection requirements.)

Adjustments in Work Methods

Employee Positioning

Where possible, exposures can be reduced if employees work at a greater distance from the grinding point. These reductions have been demonstrated for employees grinding on ceilings and for employees sanding drywall. Dust falls on employees who stand directly below the grinding point. If the grinder is attached to an adequately supported pole, the employee can manipulate the grinder at a distance from one side where the dust is less concentrated. While this method does not eliminate exposure, it can help reduce the amount of dust in the employee's breathing area (NIOSH, 1995; OSHA Case Files).

Grinding Wheel Size

A study comparing construction employees' respirable silica exposure at nine construction sites found that short-term exposure levels were about 30 percent higher for employees operating grinders with 7-inch wheels than for operators grinding with 4.5-inch wheels. Additionally, diamond wheels used for rougher, more aggressive grinding were associated with exposure levels approximately 60 percent higher than those associated with abrasive wheels used for fine finishing (Flanagan et al., 2003). Therefore, whenever possible, use a smaller rather than a larger wheel, and use the least aggressive tool that will do the job.

Construction Work Methods

Where practical, employers can reduce employees' silica exposures by utilizing construction methods and techniques that minimize the amount of grinding required. Examples include taking steps to minimize pouring/casting flaws and defects by ensuring tighter fitting forms, improved finishing, grinding on pre-cast panels outdoors before installation inside, or using factory installed chase and grooves on pre-cast structural concrete (ERG, 2002; OSHA Case Files). Silica exposures may also be reduced if grinding is done while the concrete is still "green" (NIOSH, 2000b, NIOSH, 2000c). Additionally, for a given amount of material removed from a surface, less airborne dust will be generated if some of the material can be removed as larger chips instead of finely ground particles. An employee might use a hammer and chisel or power chipping equipment to remove most of the mass before using a grinder to smooth the surface.

Case Studies

The following case studies indicate silica exposure levels found under certain uncontrolled conditions, and show the effectiveness of controls in reducing silica exposures.

Case Studies - Silica Exposure Levels

Studies have shown that employees grinding concrete are exposed to potentially harmful levels of silica unless dust levels are controlled.

Indoors. *Case Study I:* Among data obtained by OSHA, grinder operators' silica exposures exceeded 1.0 mg/m^3 during OSHA inspections reported for indoor construction sites. NIOSH reported an exposure level of 2.8 mg/m^3 for a grinder operator finishing the walls, columns and floor inside an open-sided parking garage (NIOSH, 2001).

Some of the highest indoor results are associated with overhead work (grinding on ceilings). For example, OSHA reported exposures of 4.5, 4.5, 5.9, and 7.3 mg/m^3 for four construction employees grinding slots and smoothing the ceiling of a mostly enclosed building (OSHA Case Files).

Outdoors. *Case Study II:* Exposures are somewhat lower outdoors, where dust can disperse more quickly, but results still indicate potentially harmful employee exposures. For example, data compiled by OSHA included results for three construction employees who primarily performed concrete grinding during the evaluation. The results indicate that the employees' silica exposures ranged from nearly 0.4 to 1.2 mg/m^3 during the air sampling period. Even when results were averaged over their full shift, exposures were still 0.15 mg/m^3 to 0.3 mg/m^3 (Lofgren, 1993; OSHA Case Files).[7]

Other Employees in the Area. *Case Study III:* Silica dust released during uncontrolled grinding can affect other employees in the area. NIOSH collected area samples in the center of a room measuring 13 feet by 23 feet, while an employee used a grinder on the concrete walls. The area samples indicated that, over the course of a shift, a person (for example, an employee from another trade) could experience a silica exposure level of nearly 0.2 mg/m^3 by simply standing in the center of the room (NIOSH, 1998).[8]

Fortunately, bystander exposure can generally be reduced to levels well below OSHA limits by managing the dust. NIOSH found that when the grinder operator's exposure is reduced, bystander exposure drops as well. At the site mentioned above, the silica concentration in the middle of the room fell below the limit of detection when grinder operator exposures were reduced using either vacuum dust collection or wet-grinding methods (NIOSH, 1998).

Case Studies - Vacuum Dust Collection

Several case studies provide insights about employees' silica exposure when VDC systems are used to control dust emissions. These examples show that such systems significantly lower levels of airborne silica, but may not reliably reduce the grinder operator's exposures to levels below allowable limits.

Case Study IV: OSHA evaluated employees grinding on outdoor concrete pier structures for about 3 hours during bridge construction. Without controls, their daily average exposures to silica were 0.16 and 0.30 mg/m^3 as 8-hour TWAs.[9] OSHA then tested a shrouded grinder connected to a backpack vacuum with a HEPA filter. The silica exposure dropped to 0.02 mg/m^3 as an 8-hour TWA[10] (OSHA Case Files).

Case Study V: At another construction site, an employee operated a 7-inch grinder fitted with a dust collection shroud connected to a drum vacuum. Full-shift air samples collected on two days indicated a silica exposure level of 0.06 mg/m^3 on the first day and 0.11 mg/m^3 on the second day (OSHA Case Files). Exposure levels typically exceed these values when dust controls are not used.

Case Study VI: Researchers collected air samples for five days while one employee used various grinders fitted with a vacuum dust-collection shroud. The shroud was connected to a portable electric vacuum, which included a high-efficiency filter.[11] While the operator performed grinding on concrete walls inside a parking garage, breathing area exposure levels ranged from 0.06 to 0.2 mg/m^3 (Echt and Sieber, 2002; NIOSH, 2002b).

NIOSH (2001) obtained similar results from another employee testing various grinders, shrouds, and vacuums while smoothing concrete at a parking garage site. The three 6-hour samples collected on separate days indicated employee exposure levels of 0.17, 0.18, and 0.26 mg/m^3.[12]

The results reported in these case studies are notably lower than the exposure levels typically associated with uncontrolled concrete grinding. However, even when using a vacuum dust collection system, grinder operators' exposures often exceed 0.1 mg/m^3.

Case Studies - Fans

Case Study VII: A fan set up in the doorway of a small room was not adequate to remove the dust generated during grinding. No other methods were used to control dust. As a result, the grinder operator's exposure to silica was 1.4 mg/m^3 during a 2-hour period. In another indoor space where employees on a scaffold were grinding on a concrete wall, fans helped keep exposures at around 0.5 mg/m^3 for the periods evaluated (1.5 to 4 hours) (Lofgren, 1993).

Case Studies - Wet Methods

Case Study VIII: The results from two air samples for a grinder operator and helper showed that employees had low silica exposure when using water spray while smoothing concrete walls. The helper applied a spray of water from a hand-pump garden sprayer can filled with tap water. The investigators concluded that by constantly spraying the concrete just ahead of the grinder wheel, the employees reduced their exposure levels by 90 percent (NIOSH 1998).[13]

Case Studies - Employee Repositioning

Two studies suggest that employee positioning is an important determinant of silica exposure levels. The following examples show a tenfold difference in exposure recorded for employees using grinders attached to poles while grinding concrete ceilings at two (mostly enclosed) building sites. While employee position was a large factor, the type of work and the silica content of the concrete also accounted for some of the difference.

Case Study IX: At the first site, two grinder operators smoothed seams in a concrete ceiling using grinders on long extension jigs. The jigs were supported at an angle on rolling scaffolds. The operators manipulated the grinders from the bottom end of the jigs and were exposed to silica at levels of 0.184 and 0.415 mg/m^3 (OSHA Case Files).[14]

Case Study X: Four operators at the second site ground utility slots and smoothed junctions in concrete ceilings, holding the grinders above their heads on short extensions fabricated from PVC pipe. The employees' exposure was exceptionally high, ranging from 4.5 to 7.2 mg/m^3. In this case, the operators were removing more material (making more dust) and were positioned so that most of the dust fell directly onto them (OSHA Case Files).[15]

Compressed Air

The use of compressed air to clean surfaces or clothing is strongly discouraged. Using compressed air to clean work surfaces or clothing can significantly increase employee exposure, especially in enclosed and semi-enclosed spaces. Cleaning should be performed with a HEPA-filtered vacuum or by wet methods.

Respiratory Protection and Engineering Control Evaluation

Using a hand-operated grinder without engineering controls can cause exposures to respirable crystalline silica to reach 1.2 mg/m^3 or higher while working outdoors and 4.5 mg/m^3 or higher while working indoors. Effective wet methods are invaluable in keeping silica levels below 0.1 mg/m^3 as an 8-hour TWA. When using effective wet methods, it is unlikely that respiratory protection will be needed.

In situations where wet methods may not be appropriate or feasible, VDC systems may be an alternative control option. Current data suggest that most grinding operations that utilize VDC systems usually exceed 0.1 mg/m^3, but generally do not exceed 1.0 mg/m^3. Therefore, to supplement the use of a VDC system, employees should wear a properly fitted, NIOSH-approved half-facepiece or disposable respirator equipped with an N-, R- or P-95 filter. A half-facepiece or disposable respirator can be used for protection at silica concentrations up to 1.0 mg/m^3.

In any workplace where respirators are necessary to protect the health of the employee, or whenever respirators are required by the employer, the employer must establish and implement a written respiratory protection program with worksite-specific procedures and elements. These should include the selection of respirators, medical evaluations of employees, fit testing, proper usage, maintenance and care, cleaning and disinfecting, proper air quality/quantity and training (see 29 CFR 1926.103).

Where VDC systems and/or wet methods are not feasible, the employee may be subject to wearing a full-facepiece respirator equipped with an N-, R- or P-95 filter in conjunction with a respiratory protection program, which is also outlined in and must correspond with 29 CFR 1926.103. A full-facepiece respirator equipped with an N-, R- or P-95 is adequate for silica concentrations up to 5.0 mg/m^3.

Other employees in close proximity to the work operations where silica dust is generated may also need respiratory protection if effective controls are not implemented. The level of respiratory protection is dependent on the employee's silica exposure, which varies depending on factors in the work environment (such as enclosed, semi-enclosed, or open spaces and/or multiple operations generating silica dust), environmental conditions (such as wind direction and speed), and the percentage of silica found in the material.

Construction sites often involve many operations occurring simultaneously that can generate respirable silica dust. Therefore, it is important and necessary to utilize effective controls (such as wet methods or VDC systems) in order to minimize total exposures to silica-exposed tool operators or potential exposures to other employees.

Employers should conduct exposure monitoring periodically while controls are being used to ensure that the controls are working properly and that the appropriate level of respiratory protection is being used.

For more information on how to determine proper respiratory protection, visit OSHA's Web site at www.osha.gov. NIOSH's Web site also provides information on respirators at www.cdc.gov/niosh.

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Technical Notes

[1] Laboratories have not used particle counting for crystalline silica analysis for many years. Exposure data is now reported gravimetrically. However, OSHA's construction PEL for crystalline silica, established in 1971, is still listed as a particle-count value. (See Appendix E to OSHA's National Emphasis Program for Crystalline Silica, CPL 03-00-007, for a detailed discussion of the conversion factor used to transform gravimetric measurements to particle-count values). In this guidance, OSHA is using the general industry PEL (0.1 mg/m^3 of respirable quartz as an 8-hour time-weighted average) as a benchmark to describe the effectiveness of control measures. The benchmark is approximately equivalent to the general industry silica PEL. Other organizations suggest more stringent levels. For example, the National Institute for Occupational Safety and Health (NIOSH) recommends that respirable crystalline silica exposures be limited to 0.05 mg/m^3 as a 10-hour time-weighted average (NIOSH, 2002c). The American Conference of Governmental Industrial Hygienists (ACGIH) recommends that respirable crystalline silica exposures be limited to 0.025 mg/m^3 as an 8-hour time-weighted average (ACGIH, 2008).

[2] Among data obtained by OSHA for common construction jobs, tuckpointers' mean and median respirable silica exposures are the highest, with concrete surface grinder operators second highest. Flanagan et al. (2003) found that, at the nine construction sites evaluated, concrete surface grinder operators had the highest average exposure, with tuckpointers next highest. Other groups evaluated included jackhammer operators, rock drillers, concrete saw operators, crusher operators and employees performing cleaning activities at construction sites.

[3] For data compiled by OSHA, the median exposure level for handheld grinder operators exceeded 0.2 mg/m^3.

[4] Assuming exposure continued at the same level for the entire shift, as is the case for some grinder operators.

[5] NIOSH (2000a) reported that an employee retrofitted grinding equipment used for tuckpointing. Simcox et al. (1999) reported that several employers retrofit the grinders and polishers their employees used on granite.

[6] Using more water will help keep the slurry thin and unobtrusive, but can result in runoff if not controlled.

[7] Results for the period evaluated were 0.39, 0.78, and 1.2 mg/m^3. If no additional exposure had occurred, the associated 8-hour time-weighted average (TWA) would have been 0.16, 0.31, and 0.34 mg/m^3 for samples of 191 to 135 minutes duration. However, it is not uncommon for grinder operators to work at the same task for a full shift.

[8] The average of four general area silica levels (0.14, 0.16, 0.16, and 0.27 mg/m^3) in the middle of the room was 0.18 mg/m^3. As expected, the grinder's exposure was higher (0.66 mg/m^3) during the same 3-hour period.

[9] The TWA is calculated by averaging the measured exposure over a specific period of time (in this case a full 8-hour shift).

[10] Consultant provided only an 8-hour TWA result. The construction firm did not continue use of the backpack vacuum because its weight was considered too awkward (for bridge construction work).

[11] The filter was rated as 99.99 percent efficient when tested with respirable-sized particles in accordance with European Standard DIN 24184.

[12] The employee primarily operated the grinder, but performed concrete chipping for a brief period on one day. The result of 0.18 mg/m^3 suggests the period of chipping had little impact on his total exposure for the period sampled.

[13] The sample pump worn by the operator faulted; however, a high volume sample in the area indicated airborne concentration of 0.02 mg/m^3, the same as the operator's reported exposure level and much lower than results for area samples during uncontrolled grinding. The result associated with the helper was below the limit of detection for the 342-minute sampling period. The grinder was operated for about 80 percent of the time as the employee smoothed walls in a room open to the outdoors on one end and to an atrium on the other. During uncontrolled grinding at the same site, NIOSH obtained a result of 0.66 mg/m^3 (grinding 75 percent of the time). During this sampling period, the quick-interrupt electrical circuit breaker cut the power off several times, possibly because water caused an electrical short in this grinder.

[14] These samples of 212 and 431 minutes in duration resulted in 8-hour TWAs of 0.08 and 0.36 mg/m^3.

[15] The bulk silica concentration (30 percent) at the first site was lower than at the second site (50 percent). However, the difference in silica content can only account for roughly 40 percent of the large difference between exposure values for the two processes. Results are associated with 8-hour TWA values between 2.4 and 3.8 mg/m^3 (if the employees had not had additional exposures) for samples collected over 4 hours.

Tuckpointing/Mortar Removal

This section covers the use of handheld angle grinders for renovation of deteriorating mortar in brick, stone and concrete block buildings (tuckpointing/mortar removal). The term "silica" used in this document refers to respirable crystalline silica.

Introduction

Exposure to fine particles of silica has been shown to cause silicosis, a serious and sometimes fatal lung disease. Construction employees who inhale fine particles of silica may be at risk of developing this disease. Employees who use handheld angle grinders to remove deteriorating mortar between brick, stone and concrete block units generate significant amounts of silica-containing dusts. During this operation, referred to as tuckpointing, small silica particles become suspended in the air and, when inhaled, penetrate deep into employees' lungs. Brick and building renovation masons have been diagnosed with silicosis (Lyons et al., 2007).[1]

Air monitoring shows that typical silica exposure levels for employees using angle grinders without dust collection controls are in excess of the Occupational Safety and Health Administration's (OSHA) benchmark of 0.1 mg/m^3 (milligrams of silica per cubic meter of air) as an 8-hour time-weighted average (TWA), an exposure approximately equivalent to OSHA's general industry permissible exposure limit (PEL).[2] In fact, on average, tuckpointers' silica exposures (along with those of surface grinder operators) are among the highest in the construction industry.[3] Among data collected by OSHA, more than half of employee exposures exceed 1.0 mg/m^3 during tuckpointing activities, and frequently reach 2.4 mg/m^3. Even higher levels are not uncommon (OSHA Case Files).[4]

This document describes methods available to reduce employees' exposures to silica when performing tuckpointing operations.

Although not widely used, vacuum dust collection systems are the most readily available means for controlling silica dust during tuckpointing. With careful work practices, this form of dust control can lower silica exposures substantially. Nevertheless, this method generally will not reduce dust levels below regulatory limits and employers must take additional steps to protect employees. Wet methods are not generally used for tuckpointing because they deposit a slurry of mortar dust and water on the brick, and the water used may penetrate the building envelope.

Grinders who perform tuckpointing without dust controls are frequently exposed to extremely high silica levels. (Photo courtesy of CPWR.)

Silica Dust Control Measures

Vacuum Dust Collection Systems

Vacuum dust collection (VDC) systems for grinders include a shroud, which surrounds the grinding wheel, and a vacuum to pull air through the shroud. Many manufacturers offer grinders with dust collection options. Employers may also purchase equipment to retrofit grinders for vacuum dust collection. The effectiveness of vacuum systems depends on several factors, including the user's technique, the surfaces being finished and the efficiency of the dust collection system.

The addition of the shroud and vacuum hose may make it more difficult to work effectively while reaching above the shoulder, but improved visibility due to reduced dust levels contributes to increased efficiency.

Visible and Respirable Dust

Visible dust contains large particles that are easy to see. The tiny, respirable-sized particles (those that can get into the deep lung) containing silica pose the greatest hazard and are not visible. Most dust-generating construction activities produce a mixture of visible and respirable particles.

Do use visible dust as a general guide for improving dust suppression efforts. If you see visible dust being generated, emissions of respirable silica are probably too high. Measures that control tool-generated dust at the source usually reduce *all* types of particle emissions, including respirable particles.

Do not rely *only* on visible dust to assess the extent of the silica hazard. There may be airborne respirable dust present that is not visible to the naked eye.

Recommendations for Vacuum Dust Collection Systems. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends airflow of 25 cubic feet per minute (CFM) per inch of blade diameter (for example, a 4-inch grinder would need a vacuum with airflow of 100 CFM) (ACGIH, 2007). If airflow is too low, the hose may clog with particulate matter. A study by Croteau et al. (2002), which tested an abrasive wheel saw, indicated that a ventilation flow rate of 75 CFM and an air velocity of 3440 feet per minute (FPM) should be considered the minimum ventilation rate for a 2-inch diameter vacuum hose.

VDC systems can be purchased as a kit. These kits should include a grinder shroud, vacuum, vacuum hose and filter(s). The components of a VDC system are discussed below.

- *Grinder shroud:* Use a shroud appropriate for the grinder and wheel size that provides adequate visibility.
- *Vacuum:* Choose a vacuum with the appropriate power and capacity for your job. A flow rate of 80 CFM or better on a vacuum dust collection system will give the best results while performing mortar removal (Heitbrink and Watkins, 2001).
- *Vacuum hose:* Use the vacuum hose recommended by the manufacturer or that comes with the equipment. Airflow resistance increases with hose length; hoses more than 10 to 15 feet in length should be avoided.
- *Filters:* Double filtration is important. The use of a high-efficiency particulate air (HEPA) filter is critical to prevent the escape of respirable silica dust from the vacuum exhaust. HEPA filters are at least 99.97 percent efficient in removing fine dust particles from the air. A prefilter or cyclonic separator in addition to a HEPA filter will extend the service life of the more costly HEPA filter. A cyclonic separator removes large particles that are capable of overloading or clogging the filter (Heitbrink and Collingwood, 2005).
- *Systematic cleaning:* Choose a vacuum equipped with a back-pulse filter cleaning cycle. Such auto-cleaning mechanisms will reduce the time required for vacuum maintenance and improve the overall efficiency of the dust collection system. If the vacuum does not have an auto-cleaning mechanism, the employee can periodically turn the vacuum cleaner on and off. This allows the bag to collapse and causes the prefilter cake to dislodge from the filter.
- *Monitoring VDC efficiency:* Purchasing a dust collection system equipped with a static pressure gauge allows the employee to monitor the system's efficiency. Systems lacking a static pressure gauge can be monitored visually. If a dust plume increases and becomes more visible where the shroud meets the working surface, the system is not working efficiently (Heitbrink and Collingwood, 2005).

System Maintenance. For optimal dust collection, the following measures are recommended:

- Keep the vacuum hose clear and free of debris, kinks and tight bends. Maintain the vacuum at peak performance to ensure adequate airflow through the shroud and vacuum hoses.
- For vacuums with back-pulse filter cleaning systems, activate the system frequently (several times per day). Empty collection bags and vacuums as frequently as necessary. Dispose of collected dust in a way that prevents it from becoming resuspended in the air.
- For best results, set up a regular schedule for filter cleaning and maintenance. For example, institute a rule to clean the filter or change the bag at each break. This will prevent pressure loss and ensure that exhaust airflow stays more constant on the VDC system.
- Remember, the absence of visible dust does not necessarily mean that employees are adequately protected from silica exposure.

Work Practice Controls to Enhance Vacuum Effectiveness. Studies have shown that the effectiveness of vacuum dust collection systems is enhanced by the use of proper work practices (NIOSH, 1999; Croteau et al., 2002). However, use of these work techniques without a dust collection system will not substantially reduce dust exposures.

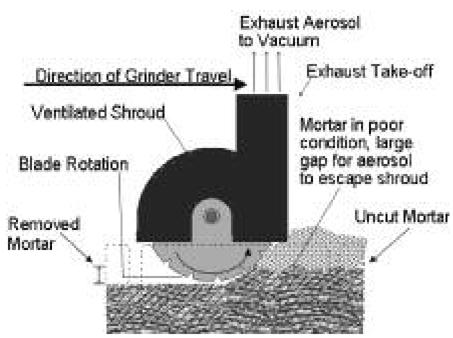
- *Blade insertions:* Place the left-hand side of the shroud against the working surface before blade insertion.[5] This directs the dust into the shroud as the blade cuts into the mortar joint.
- *Blade depth:* Per job specification, maintain the full depth of the cut into the mortar. This allows the shroud to remain flush against the working surface and minimizes the dust that escapes from the collection system.
- *One-way movement:* Avoid moving the grinder back and forth along the slot as this will create an open space ahead of the grinder and increase dust escape. For better results, move the grinder

in one direction, making a second pass only if necessary.

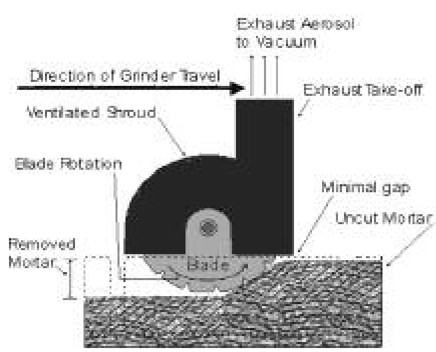
- *Grinding direction:* Grind counter to the direction of blade rotation to minimize escaping dust.
- *Blade removal:* Backing off the blade a few inches (2 to 4 inches) before removing it from the slot will permit the vacuum to clear accumulated dust.
- *Force:* Use normal (not excessive) force when operating the tool to help keep the leading tool edge flush against the working surface.

Leaving a large gap between the shroud and uncut mortar (see Figure 1a) and not utilizing a high enough airflow exhaust rate will allow dust to escape and may expose employees to high levels of respirable silica (Collingwood and Heitbrink, 2007). Reducing the size of the gap significantly (see Figure 1b) and maintaining a high exhaust airflow rate ensures that most of the dust generated from tuckpointing is captured.

Fiqure 1. Mortar Removal



1a. A large gap between the shroud and uncut mortar permits air containing pulverized mortar to escape.



1b. Minimizing the gap between the shroud and uncut mortar allows for good capture of pulverized mortar coming off the blade.

(Illustration courtesy of S. Collingwood and W.A. Heitbrink.)

Case Studies

The following case studies indicate silica exposure levels found under certain uncontrolled conditions, and show the effectiveness of controls in reducing silica exposures.

Uncontrolled Exposures

Case Study I: Several silica samples were collected at two unrelated building renovation sites. Neither group of tuckpointers used dust controls. At the first site, respirable silica exposures for all four employees evaluated were greater than 1.4 mg/m^3. Exposure results were even higher at the second location, where all tuckpointer exposure results exceeded 2.4 mg/m^3. At both sites, the highest tuckpointer exposures ranged from 7.0 mg/m^3 to 8.0 mg/m^3 (OSHA Case Files).

Case Study II: A foreman and a mason were evaluated while they performed tuckpointing on a humid day with variable wind. Their respirable silica exposures were between 1.0 mg/m^3 and 1.5 mg/m^3. These levels exceeded regulatory limits and might have been even higher had it not been for the windy and humid weather conditions (OSHA Case File).[7]

Controlled Exposures

Case Study III: NIOSH collected 13 respirable silica samples for tuckpointers using angle-grinders equipped with a VDC system consisting of a shroud, hose and vacuum. Although exposures were less than those uncontrolled exposures previously discussed, more than half of the employees had exposures above 0.5 mg/m^3 (NIOSH, 1999).

Case Study IV: A study showed the benefits of using dust controls by comparing tuckpointers' exposures with and without the use of vacuum dust collection equipment. The dust collection system consisted of a shroud on the grinder and a hose attachment leading to a dust collection bag. Initial tests showed that silica exposures with controls were 37 to 47 percent lower than when controls were not used, even though employees had difficulty using the shroud properly. Subsequently, the manufacturer adjusted the shroud and rearranged the handle and hose attachment to make the equipment easier to handle. In a follow-up test, the modified equipment reduced the employees' respirable silica exposure by 93 percent, from 4.0 mg/m^3 (uncontrolled) to 0.3 mg/m^3. While this reduction is significant, the authors concluded that respiratory protection is still required in order to provide employees using dust collection equipment with adequate protection (Nash and Williams, 2000).[8]

Case Study V: Wet methods are not commonly used for tuckpointing because they may deposit a slurry consisting of mortar dust and water on the brick. The applied water may also penetrate the structure and damage the interior. However, in some cases, wet methods can be used in tuckpointing operations. For example, in this case study, an employee modified a tuckpointing grinder with both a ventilation shroud and a small water application nozzle. During one hour of mortar grinding, the employee's respirable dust exposure (0.38 mg/m^3) was less than 3 percent of the median value for five results obtained for uncontrolled mortar grinding in this study (13.3 mg/m^3) (NIOSH, 2000).

In this case study, the employee used a hand-pump garden sprayer to pressurize the water, which was applied to the blade at a rate slightly less than a quart per minute through a nozzle made of 1/16-inch copper tubing. A wet/dry shop vacuum connected to the shroud removed the damp mortar debris as it was generated. A 10-foot vacuum hose extension (PVC pipe) allowed the employee to stand an extra 10 feet away from the vacuum for added protection from dust escaping from the vacuum.

This study was performed using an electric grinder, which introduces electrical safety issues because it is an electric tool being used in a wet environment. One way to avoid possible electrical safety issues related to the introduction of water is to switch to a pneumatic grinder (NIOSH, 2000).

Compressed Air

The use of compressed air to clean surfaces or clothing is strongly discouraged. Using compressed air to clean work surfaces or clothing can significantly increase employee exposure, especially in enclosed and semi-enclosed spaces. Cleaning should be performed with a HEPA-filtered vacuum or by wet methods.

Respiratory Protection and Engineering Control Evaluation

It is not uncommon for respirable crystalline silica exposures to reach 2.4 mg/m^3 or higher while tuckpointing without engineering controls. Tuckpointing is often conducted in situations or on materials that do not permit the use of wet methods as an engineering control.

In these situations, VDC systems are recommended. A VDC system attached to the angle grinder will lower silica exposures; however, since exposures may still exceed 0.1 mg/m^3 with controls, respiratory protection will be required to supplement the VDC system. When working in an open or semi-enclosed area with a properly functioning VDC system, the employee may be able to wear a properly fitted, NIOSH-approved half-facepiece or disposable respirator equipped with an N-, R- or P-95 filter.

In any workplace where respirators are necessary to protect the health of the employee, or whenever respirators are required by the employer, the employer must establish and implement a written respiratory protection program with worksite-specific procedures and elements. These should include the selection of respirators, medical evaluations of employees, fit testing, proper usage, maintenance and care, cleaning and disinfecting, proper air quality/quantity and training (see 29 CFR 1926.103).

When tuckpointing in enclosed areas or when environmental conditions, such as wind, concentrate mortar particles in an employee's breathing zone, exposures may exceed 1.0 mg/m^3 even with effective controls. When working in enclosed areas, the employer should supplement the VDC system by providing a properly fitted NIOSH-approved full-facepiece respirator with an N-, R- or P-95 filter. A powered air-purifying respirator (PAPR) offers alternative protection for those who cannot wear a full-facepiece air-purifying respirator. Such respiratory protection is effective for exposures to silica up to 5 mg/m^3 for a full-facepiece respirator and up to 10 mg/m^3 for a PAPR with a fitted facepiece.

Construction sites often involve many operations occurring simultaneously that can generate respirable silica dust. Therefore, it is important and necessary to utilize effective controls (such as wet methods and/or a VDC system) in order to minimize total exposures to silica-exposed tool operators or potential exposures to other employees.

Since tuckpointing even under controlled conditions can result in silica exposures in excess of 0.1 mg/m^3, adjacent employees may need to wear respirators as well. The level of respiratory protection is dependent on the employee's silica exposure, which varies depending on factors in the work environment (such as enclosed, semi-enclosed, or open spaces and/or multiple operations generating silica dust), environmental conditions (such as wind direction and speed), and the percentage of silica found in the material.

Employers should conduct exposure monitoring periodically while controls are being used to ensure that the controls are working properly and that the appropriate level of respiratory protection is being used.

For more information on how to determine proper respiratory protection, visit OSHA's Web site at www.osha.gov. NIOSH's Web site also provides information on respirators at www.cdc.gov/niosh.

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Technical Notes

[1] These employees performed a variety of activities involving silica-containing materials, including abrasive blasting and work with fire brick (NIOSH, 1996).

[2] Laboratories have not used particle counting for crystalline silica analysis for many years. Exposure data is now reported gravimetrically. However, OSHA's construction PEL for crystalline silica, established in 1971, is still listed as a particle-count value. (See Appendix E to OSHA's National

Emphasis Program for Crystalline Silica, CPL 03-00-007, for a detailed discussion of the conversion factor used to transform gravimetric measurements to particle-count values). In this guidance, OSHA is using 0.1 mg/m^3 of respirable quartz as an 8-hour time-weighted average as a benchmark to describe the effectiveness of control measures. The benchmark is approximately equivalent to the general industry silica PEL. Other organizations suggest more stringent levels. For example, the National Institute for Occupational Safety and Health (NIOSH) recommends that respirable crystalline silica exposures be limited to 0.05 mg/m^3 as a 10-hour time-weighted average (NIOSH, 2002). The American Conference of Governmental Industrial Hygienists (ACGIH) recommends that respirable crystalline silica exposures be limited to 0.025 mg/m^3 as an 8-hour time-weighted average (ACGIH, 2008).

[3] Among data obtained by OSHA for common construction jobs, tuckpointers' mean and median respirable silica exposures are the highest, with concrete surface grinder operators the second highest. Flanagan et al. (2003) found that, at nine construction sites evaluated, concrete surface grinder operators had the highest average exposure, with tuckpointers next highest. Other groups evaluated included jackhammer operators, rock drillers, concrete saw operators, crusher operators, and employees performing cleaning activities at construction sites.

[4] Among data obtained by OSHA, more than half of employee exposures exceeded 1.0 mg/m^3 during tuckpointing and the average exposure level was 2.2 mg/m^3. Due to the high levels of dust, many of the samples were collected for a period less than a full shift. However, tuckpointers often work at this task 8 hours per day. Thus, a similar level of exposure is assumed for the unsampled portion of the shift. Even if employees had no further silica exposure beyond the period sampled, the median 8-hour time-weighted average crystalline silica result would exceed 0.5 mg/m^3 and the average level would be 1.5 mg/m^3.

[5] Assumes typical counter-clockwise blade rotation (or whatever blade direction ensures that the dust will be captured within the shroud).

[6] Results from the two sites include 6 full and 2 partial shift samples. Employees at both sites indicated they typically performed tuckpointing 8 hours per day. Bulk samples showed that the mortar contained 20 to 40 percent silica at the first site and 30 percent silica at the second site (OSHA Case Files).

[7] Bulk samples associated with these results indicate that the mortar contained 50 to 70 percent silica (OSHA Case File).

[8] Initially, employees at two sites were monitored for 5 to 7 hours each; in the follow-up test, sample times were 1 to 2 hours. All results were reported as 8-hour time-weighted averages. In the final test, the respirable silica exposure without dust controls was 4.08 mg/m^3, compared to 0.31 mg/m^3 with the modified dust collection system (Nash and Williams, 2000).