IN-DEPTH SURVEY OF DUST CONTROL TECHNOLOGY FOR CUTTING CONCRETE BLOCK AND TUCKPOINTING BRICK

at

The International Masonry Institute Bordentown Training Center
Bordentown, NJ

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ABSTRACT

This study evaluated the performance of four commercially-available engineering controls used in dusty construction tasks. Two controls for hand-held abrasive cutters and two controls for tuckpointing grinders were examined at a bricklayers training center. A local exhaust ventilation (LEV) control and a water spray control for hand-held abrasive cutters were evaluated during concrete-block cutting. Compared with the use of no control during block cutting, the LEV shroud and vacuum cleaner reduced both quartz and respirable dust exposures by 95 percent, while the water-spray attachment reduced quartz exposures by 90 percent and respirable dust exposures by 88 percent. Both of the control measures were significantly different from the use of no control during block cutting ($p < 0.05$), but the exposure reductions achieved by the controls were not significantly different from each other. A local exhaust ventilation control and a water spray control for tuckpointing grinders were tested while a brick wall was tuckpointed. Reductions in respirable quartz concentrations were 98 percent with the LEV control and 84 percent with water spray control. The differences in mean quartz concentrations during tuckpointing were statistically significant between use of no control and either the water control or local exhaust control ($p<0.05$). There was not a statistically significant difference between the two control methods. Respirable dust concentrations while tuckpointing were reduced by 99 percent with the use of the LEV control, versus 81 percent by the water spray control. Mean levels of respirable dust measured during tuckpointing were statistically significantly different ($p<0.05$) between control and no control, and also between the two control methods.

INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) is located in the Centers for Disease Control and Prevention (CDC), part of the Department of Health and Human Services (DHHS). NIOSH was established in 1970 by the Occupational Safety and Health Act, when the Occupational Safety and Health Administration (OSHA) was created concurrently in the Department of Labor (DOL). The OSH Act legislation mandated NIOSH to conduct research and education programs separate from the standard-setting and enforcement functions conducted by OSHA. An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemical and physical hazards.

The Engineering and Physical Hazards Branch (EPHB) of the Division of Applied Research and Technology (DART) has been given the lead within NIOSH to study and develop engineering controls and assess their impact on reducing occupational illness. Since 1976, EPHB (and its predecessor, the Engineering Control Technology Branch) has conducted a large number of studies to evaluate engineering control technology based upon industry, process, or control technique. The objective of each of these studies has been to evaluate and document control techniques and to determine their effectiveness in reducing potential health hazards in an industry or for a specific process.

Many construction tasks have been associated with overexposure to crystalline silica [Chisholm 1999, Flanagan et al. 2003, Rappaport et al. 2003, Valiante et al. 2004, Woskie et al. 2002]. Among these tasks are tuckpointing, concrete cutting, concrete grinding, abrasive blasting, and road milling [Nash and Williams 2000, Thorpe et al. 1999, Akbar-Kanzadeh and Brillhart 2002, Glindmeyer and Hammad 1988, Linch 2002, Rappaport et al. 2003].

Nash and Williams [2000] and Yasui et al. [2003] have previously described tuckpointing engineering controls. The engineering control evaluated by Nash and Williams [2000] was capable of a 92.5% reduction in respirable silica exposure, from 4.08 mg/m^3 to 0.306 mg/m^3, while the control evaluated by Yasui et al. [2003] reduced respirable dust exposures by greater than 97% when either an angle grinder or a mortar rake were used for tuckpointing. In that study [Yasui et al. 2003], use of an engineering control reduced respirable quartz exposures by about 98% when an angle grinder was used. The mortar rake tests by Yasui et al. [2003] were conducted in a lime mortar, while the angle grinder tests were performed in a conventional mortar. Thorpe et al. [1999] described exposure reductions of at least 90% for cutting concrete slabs with cut-off saws using water to suppress dust and cutting concrete slabs with a grinder using local exhaust ventilation (LEV). Croteau et al. [2002] examined the use of LEV for reducing exposures from several construction tasks, including tuckpointing and block cutting, with exposure reductions ranging from 80 to 95% at the higher of two ventilation rates tested. In a recent study of tuckpointing controls, Heitbrink and Bennett [2006] concluded that an exhaust ventilation flow rate of 20-25 cubic feet per minute (cfm) per inch of grinding wheel diameter was a reasonable specification to achieve dust control. The present study evaluated the use of a novel water spray control to suppress dust during block cutting and tuckpointing, the use of a LEV system to control dust from cutting block, and the use of a new tuckpointing grinder with LEV.

OCCUPATIONAL EXPOSURE TO CRYSTALLINE SILICA

Silicosis, a fibrotic disease of the lungs, is an occupational respiratory disease caused by the inhalation and deposition of respirable crystalline silica dust [NIOSH 1986]. Silicosis is irreversible, often progressive (even after exposure has ceased), and potentially fatal. Because no effective treatment exists for silicosis, prevention through exposure control is essential. Exposure to respirable crystalline silica dust occurs in many occupations, including construction. Crystalline silica refers to a group of minerals composed of silicon and oxygen; a crystalline structure is one in which the atoms are arranged in a repeating three-dimensional pattern [Bureau of Mines 1992]. The three major forms of crystalline silica are quartz, cristobalite, and tridymite; quartz is the most common form [Bureau of Mines 1992]. Respirable refers to that portion of airborne crystalline silica that is capable of entering the gas-exchange regions of the lungs if inhaled; this includes particles with aerodynamic diameters less than approximately 10 :m [NIOSH 2002].

When proper practices are not followed or controls are not maintained, respirable crystalline silica exposures can exceed the NIOSH Recommended Exposure Limit (REL), the OSHA Permissible Exposure Limit (PEL), or the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) [NIOSH 2002, 29 CFR 1926.55, ACGIH 2004]. NIOSH recommends an exposure limit of 0.05 mg/m^3 to reduce the risk of developing silicosis, lung cancer, and other adverse health effects.

The current OSHA permissible exposure limit (PEL) for respirable dust containing crystalline silica (quartz) for the construction industry is measured by impinger sampling. The PEL is expressed in millions of particles per cubic foot (mppcf) and is calculated using the following formula [29 CFR 1926.55]:

$$\text{Respirable PEL} = \frac{250 \text{ mppcf}}{\% \text{ Silica} + 5}$$

Since the PELs were adopted, the impinger sampling method has been rendered obsolete by gravimetric sampling [OSHA 1996]. OSHA currently instructs its compliance officers to apply a conversion factor of 0.1 mg/m^3 per mppcf when converting between gravimetric sampling and particle count standard when characterizing construction operation exposures [OSHA 2001].

The ACGIH® TLV®s for cristobalite, quartz, and tridymite are all 0.05 mg/m^3 [ACGIH 2004]. The ACGIH® has published a notice of their intent to change the TLV® for α-quartz and cristobalite (respirable fraction) to 0.025 mg/m^3 and to withdraw the documentation and adopted TLV® for tridymite [ACGIH 2004].

METHODS

Experimental design

The aim of this study was to estimate the reduction in dust produced by the units with controls compared to that produced by those without controls. Percent reduction was estimated by:

Estimated % Reduction = 100 x [1 - (control mean/no-control mean)]

In order to measure this reduction, trials of the block-cutting controls were conducted in 5 rounds consisting of 3 trials in each round. The order of the trials was randomized within each round (see Tables 1 and 2 for the order in which the trials were performed). Each trial where a control was used lasted approximately 10 minutes. The no-control trials lasted approximately 5 minutes. Real-time and filter samples were collected during each trial.

Each block-cutting trial consisted of using a hand-held electric abrasive cutter to make cuts through concrete blocks laid on their side on a plank laid across two stacks of two blocks (the plank was 17 in above the ground) in the outdoor training area behind the IMI training facility located in Bordentown, NJ (Figure 1).

Trials for evaluating the tuckpointing controls were performed in 6 rounds of 3 trials each. The order of the trials was randomized within each round (see Tables 3 and 4 for the order in which the trials were conducted). The duration of each control trial was 10 minutes, while the no-control trials were halted after 5 minutes. These times were selected in order to obtain a quantifiable silica sample during the control trials and avoid overloading with respirable dust during a no-control trial. Real-time and filter samples were collected during each trial.

Each tuckpointing trial consisted of using an electric angle grinder to remove mortar from a brick wall of a building on the training center site. Both head (vertical) joints and bed (horizontal) joints were ground during the trials. The tasks described during this site visit were performed by experienced journeyman bricklayers at the IMI apprentice training center. Both workers wore ear plugs, work gloves, work boots, and a 3M GVP-series belt-mounted helmet-type (model L-501 bump cap) powered air purifying respirator (PAPR) with a GVP-440 high efficiency (HEPA) filter (3M Occupational Health & Environmental Safety, St. Paul, MN).

Exposure assessment

The effectiveness of the engineering controls examined in this study was evaluated by measuring the reduction in the respirable dust and silica exposures in the breathing zone of the construction worker when the dust control device was used compared to the exposure when no dust control device was used. Respirable dust exposure was measured in real time using a portable laser photometer (DUSTTRAK™ Aerosol Monitor, TSI Inc., St. Paul, MN) connected via flexible tubing to a respirable dust pre-selector (a 10-mm Dorr-Oliver nylon cyclone) placed in the employee's breathing zone. In addition, personal breathing zone samples were collected at a flow rate of 4.2 liters/minute using a GK 2.69 respirable/thoracic cyclone (BGI Inc., Waltham, MA) and a pre-weighed, 37-mm diameter, 5-micron (µm) pore-size polyvinyl chloride filter supported by a backup pad in a three-piece filter cassette sealed with a cellulose shrink band in accordance with NIOSH Methods 0600 and 7500 connected via Tygon tubing to battery-operated sampling pump [NIOSH 1994, HSE 1997]. Bulk samples of settled dust were also collected in accordance with NIOSH Method 7500 [NIOSH 1994].

Gravimetric analysis for respirable particulate collected on personal breathing zone filter samples was carried out with the following modifications to NIOSH Method 0600: 1) the filters and backup pads were stored in an environmentally controlled room (20±1 °C and 50±5% relative humidity) and were subjected to the room conditions for at least two hours for stabilization prior to tare and gross weighing, and, 2) two weighings of the tare weight and gross weight were performed. NIOSH Method 0600 recommends that the user equilibrate the filters in an environmentally controlled weighing area while the modification gives the specific temperature and humidity. The second weighing was added for precision and accuracy control. The difference between the average gross weight and the average tare weight was the result of the analysis. The limit of detection for this method was 0.02 mg.

Crystalline silica analysis of personal breathing zone filter samples and bulk samples was performed using X-ray diffraction. NIOSH Method 7500 was used with the following modifications: 1) filters were dissolved in tetrahydrofuran rather than being ashed in a furnace; and 2) standards and samples were run concurrently and an external calibration curve was prepared from the integrated intensities rather than using the suggested normalization procedure. These changes reflect the evolution of silica analysis since the method was published. Both methods of eliminating the PVC filters are widely used, the laboratory that performed the analyses preferred the use of tetrahydrofuran. The normalization procedure essentially uses a single standard and draws a line through the origin. DART established a standard operating procedure where the limit of detection/limit of quantitation values and the quantitative calibration curve are determined by the analysis of standards over the range of interest. This compensates for any variation of the calibration curve especially over the lower range. It also compensates for the differences in diffraction due to different size particles of silica. These samples were analyzed for quartz and cristobalite. The limits of detection for quartz and cristobalite on filters were 0.01 and 0.02 mg, respectively. The limit of quantitation is 0.03 mg for both quartz and cristobalite. The limits of detection in bulk samples were 0.8% for quartz and 1% for cristobalite. The limit of quantitation was 2% for both forms of crystalline silica in bulk samples.

Water flow measurements

Water flow through the spray attachment was measured (when the tools were not being used to cut block or grind mortar) using a stopwatch and a measuring cup. The water hose was detached from the shroud where it joined the fitting for the nozzle(s) and water flow to the shroud was measured at that point. The stopwatch and water flow were started simultaneously and the amount of water dispensed in one minute was recorded. Three measurements were performed in order to obtain an average flow rate.

Ventilation measurements

Air flow measurements were made by replacing the vacuum cleaner hose used in the control testing with an identical hose that had been cut approximately 48-in from the inlet and 72-in from the outlet. The tool to be tested was connected to the inlet of the 48-in length of hose. The other end was connected to a 16¼-in length of 2-in diameter galvanized pipe using a 1½-in to 2-in flexible pipe coupling (American Valve, Greensboro, NC). A Sierra Instruments, Inc. (Monterey, CA) model 730-N5-1 fast response in-line mass flow meter (range 0-100 cfm) was attached to the pipe (the flow meter and pipe end are threaded, Teflon™ tape was wrapped around the threads). The other end of the mass flow meter was attached to an 8½-in length of 2-in diameter galvanized pipe. This was connected via another 1½-in to 2-in flexible pipe coupling to the 72-in length of vacuum cleaner hose, which was connected to the vacuum cleaner. Duct tape was wrapped around both vacuum cleaner hose-to-flexible pipe coupling connections. This arrangement (tool-vacuum cleaner hose-flexible coupling–galvanized pipe-mass flow meter-galvanized pipe-flexible coupling-vacuum cleaner hose-vacuum cleaner) is shown in Figure 2. A Sierra Instruments, Inc. Model 904M Flo-Box was used to read the signal from the meter (Sierra Instruments, Monterey, CA).

Static pressure was measured through a fitting threaded into a hole in the side of the 16¼-in length of galvanized pipe. The fitting was placed 12-in downstream of the inlet end of the pipe and 4-in upstream of the flow meter to satisfy the minimum distances from disturbances recommended by the ACGIH (2001). An Airflow model PVM100 micromanometer (Airflow Technical Products, Inc., Netcong, NJ) was used to measure static pressure.

Following the work at IMI, the vacuum cleaner was shipped to the University of Iowa for evaluation. The relationship between vacuum cleaner air flow and static pressure measured between the final filter and the inlet to the vacuum cleaner motor serves the same purpose as a fan curve: air flow through a hose, hoods, and filters can be estimated based upon pressure loss**.** The apparatus for determining the "fan curve" for a vacuum cleaner is shown in Figure 3. The vacuum cleaner is probed and a manometer (u-tube type slack manometer, Dwyer, Michigan City, IN) was used to measure the static pressure in the vacuum cleaner canister between the final filter and the vacuum cleaner motor. This is essentially the pressure in the vacuum cleaner tank when the filters are removed. Holes were drilled in the vacuum cleaner to gain access to the space between the vacuum cleaner motor and final filter. One end of a length of flexible tubing was passed through these holes and into that space. The other end of the tubing was attached to the manometer. The space around the tubing where it entered the holes was sealed with silicone caulk. The inlet of the vacuum cleaner was attached by flexible tubing to a rigid 2-inch diameter PVC pipe that contains a gate valve and a venturi meter (2 HVT-FV, Primary Flow Signal, Inc., Cranston, RI). The gate valve is used to change the resistance to flow and the static pressure between the vacuum cleaner final filter and the vacuum cleaner motor.

Figure 4 describes the venturi meter. In a venturi meter, the air flows through a gradual, nearly frictionless reduction in diameter. For this venturi meter, the diameter is reduced from 2.067 to 1.088 inches at an angle of 30 degrees. As the diameter is reduced, the air velocity is increased, producing a static pressure difference between the 2.067 inch section and the throat of the venturi meter. Because of the angle of the flow restriction and smoothness of the interior surfaces of the venturi meter, the conversion of static pressure to velocity pressure is nearly frictionless. As a result, the air flow measured by a venturi meter is a direct function of the diameters of the pipe and throat, the measured pressure differential, fluid density, and the venturi meter discharge coefficient. The discharge coefficient accounts for the energy lost in compressing the fluid flow. Uncertainty in the discharge coefficient is a source of the uncertainty in measuring fluid flow rates with a venturi meter. The venturi meter coefficient is between 0.98 and 0.99 when the pipe Reynolds number is larger than 75,000. In this study, the venturi meter is used to measure air flows in the range of 20 to 120 cfm. As flow rate decreases from 100 cfm to 20 cfm, the Reynolds number decreases from 75,000 to 20,000 and the venturi meter coefficient decreases from 0.99 to 0.94 [Munson et al. 1990]. Thus, as flow rate decreases from 100 to 20 cfm, the error in ignoring the reduction in the venturi meter coefficient increases from 0 to 5%. At 20 cfm, this bias is 1 cfm. Formulas relating the pressure differential produced by the venturi meter to air flow, $q_{v,}$ are presented in fluid mechanics text books, chemical engineering text books and an engineering standard published by the American Society of Mechanical Engineers. The air flow measured by the venturi meter was computed as specified by an ASME standard [ASME 1989].

Statistical methods

All data were found to follow a lognormal distribution, so values were transformed by the logarithm. One-way analysis of variance was performed to determine if there was a statistically significant difference between the means of the treatments, where the type of control used was considered as the treatment. Observations included means of measurements taken in runs using both exposure assessment methods – real time and cassette. Bonferroni tests were used to test differences between results from each control. All calculations were done using the Statistical Analysis System (SAS Institute, Inc., Cary, NC) V. 9.1. Average reductions were calculated using averages of the results for the control treatment and no control treatments. Sample results below the LOD were replaced by the value LOD/sqrt2 [Hornung and Reed 1990].

Video Exposure Monitoring

A digital video camera was paired with the direct reading instrument, and video exposure monitoring techniques were used to characterize exposure [NIOSH 1992]. In the laboratory, the data collected with the personal dust monitor were overlaid onto the video recording to observe the effects of factors such as work practices on exposure.

Description of tools and controls

Block cutting

The block cutting tools and controls tested included a hand-held electric abrasive cutter equipped with a LEV shroud and a hand-held electric abrasive cutter equipped with a water-spray attachment. The tool equipped with the LEV shroud (Figure 5) was a Bosch model 1364 12-in abrasive cutter equipped with a Bosch model 1605510215 dust extraction guard connected via 3 meters (9.84 ft) of 35-mm (1.38 inches) diameter hose to a Bosch model 3931 Airsweep 13 gallon wet/dry local exhaust cleaner with "pulse clean" and high-efficiency particulate air (HEPA) filters (Robert Bosch Tool Corp., Mt. Prospect, IL). The tool with the water-spray attachment (Figure 6) was a Partner model K3000 EL 12-in 110 volt electric cutter (Partner Industrial Products, Partille, Sweden) with a Bronco 1111B300-004-QR back pack unit water system[a] with quick release and a Bronco model BJP-A Dex mounting kit QR (Bronco Construction Equipment Ltd., Tel Aviv, Israel) suitable for the K3000 EL12-in cutter. Exposure measurements were also made during the use of a cutter without dust controls (a no-control tool) for the purpose of this study. For the no-control tool, either the vacuum cleaner hose was removed from the Bosch dust extraction guard and the ventilation take-off was plugged (rounds 2 and 4) or the water hose was disconnected from the Bronco water attachment on the Partner cutter (rounds 1, 3, and 5). A Target wet/dry cutting high speed diamond blade, 12-in x .110-in x 1-in (part no. 580889) was used for all of the block cutting trials (Target, Olathe, KS).

Tuckpointing

The tuckpointing tools and controls evaluated included an LEV-equipped tuckpointing grinder and a grinder equipped with a water-spray attachment. The LEV-equipped grinder was a Bosch model 1775E 5-in Tuckpointer paired with the same Bosch model 3931 Airsweep 13 gallon wet/dry vacuum cleaner with "pulse clean" and high-efficiency particulate air (HEPA) filters (Robert Bosch Tool Corp., Mt. Prospect, IL) and 3 meters of 35-mm diameter hose. The water-spray equipped grinder (Figure 7) was a Metabo model we-14-125 plus angle grinder (Metabowerke GmbH, Nürtingen, Germany) paired with a Bronco 1111B300-004-QR back pack unit water system with quick release and a Bronco model BCT 4.5-in DEX mounting kit QR (Bronco Construction Equipment Ltd., Tel Aviv, Israel). For the no-control grinder, either the local exhaust port on the Bosch tuckpointer was blocked (round 1), the water hose was disconnected from the Bronco attachment on the Metabo grinder (round 2), or a Milwaukee model 6148 angle grinder

[a] Since the worker wore a PAPR, sampling pump, and direct reading instrument, the backpack unit water system was placed near his work station in an upright position.

(Milwaukee Electric Tool Corporation, Brookfield, WI) was used with no dust control (rounds 3-6). A 4.5-in diameter wheel was used with the Milwaukee grinder, while 5-in diameter wheels were used with the Metabo and Bosch grinders.

RESULTS AND DISCUSSION

Effectiveness of controls on respirable quartz exposures in block cutting

The results of the quartz analyses of filter samples collected during the evaluation of block-cutting controls are presented in Table 1. The LEV shroud and vacuum cleaner reduced quartz exposures by an average of 95 percent, while the water-spray attachment reduced quartz exposures by an average of 90 percent. Both of the control measures were significantly different from the use of no control ($p < 0.05$), but the exposure reductions achieved by the controls were not significantly different from each other.

Effectiveness of controls on respirable dust exposures in block cutting

Table 2 presents the results of the analyses of filter samples for respirable dust collected during the block-cutting control evaluation. The use of the LEV attachment resulted in an average exposure reduction of 95 percent, while the use of water resulted in an average exposure reduction of 88 percent. Both control measures resulted in exposure reductions that were statistically significantly different from the use of no control ($p<0.05$) when measured using either air sampling cassettes or the real time instrument. There was not a statistically significant difference between the effectiveness of the two control measures.

Effectiveness of controls on respirable quartz exposures during tuckpointing

Table 3 lists the results of the quartz sampling and analyses during the tuckpointing tests. Reductions in respirable quartz concentrations were 98 percent with the LEV control and 84 percent with water control. The differences in mean quartz concentrations were statistically significant between use of no control and either the water control or local exhaust control ($p<0.05$). There was not a statistically significant difference between the two control methods.

Effectiveness of controls on respirable dust exposures during tuckpointing

Table 4 gives the results of respirable dust sampling during tuckpointing. Respirable dust concentrations were reduced by 99 percent with the use of the LEV control, versus 81 percent by the water control. Mean levels of respirable dust measured using either air sampling cassettes or the real time instrument were statistically significantly different ($p<0.05$) between control and no control and between both control methods. Table 5 provides the summary statistics for the air sampling data collected during all of the tests. The use of water during tuckpointing deposited a mixture of water, mortar, and brick dust on the brick wall (Figure 8).

Results of Water Flow Measurements

Table 6 provides the results of water flow measurements. The reductions in exposures noted above were achieved using a backpack system that supplied 1.4 L/min to the shrouds used for cutting block (the flow divided between two nozzles) and tuckpointing brick (the water supplied to one nozzle). This is almost three times the flow noted by Thorpe et al. [1999], where effective control during concrete-slab cutting with gasoline-powered hand-held cut-off saws was achieved with a water flow of 0.5 L/min. However, the flow rate for the device tested was set by the manufacturer, and we were unable to determine the effectiveness of different water flow rates.

Results of Ventilation Measurements

Air flow and static pressure were measured with the Bosch Tuckpointer grinder and Bosch cutter running and not running, with a new vacuum cleaner bag. Air flow with the grinder running was 55 cfm, with a static pressure of -5.9-in water gauge (w.g.). With the grinder not running, the air flow was 74 cfm, with a static pressure of -11.5 in w.g. The air flow with the cutter running was 56 cfm; the static pressure was -5.2 in w.g. When the cutter was not running, the air flow was 76 cfm; static pressure was -11 in w.g. The fan curve for this vacuum cleaner is presented in Figure 9, and ranges from 4 inches of water at about 125 cfm to 74 inches of water at 0 cfm.

Video Exposure Monitoring Results

An interesting finding revealed by reviewing the recording of the use of the Bosch saw to cut block was the effect of adjusting the depth of the blade guard/hood on dust generation. Dust generation was minimized when the guard/hood was adjusted so that blade exposure was limited to depth necessary to cut the block. During tuckpointing, it was noted that better dust control was achieved during bed-joint grinding than during head-joint grinding with the Bosch tuckpointer.

Bulk Sample Results

Two bulk samples were collected on July 26; both were taken from the slurry of water and concrete block dust that collected on the mud flap on the Partner saw. One of these contained 24% quartz, the other contained 41% quartz. A single bulk sample was collected on July 27, from settled dust on top of the backpack water reservoir. That sample contained 54% quartz. No compounds that would interfere with the quartz analyses were identified in the bulk samples. The presence of interfering compounds would have necessitated additional analyses.

Employee exposures resulting from the use of these controls

Tables 7 and 8 compare the sampling results for block cutting and tuckpointing with the OSHA Construction PEL for respirable dust that contains quartz and the NIOSH REL for crystalline silica. During block cutting, the respirable dust exposures measured with sampling cassettes using the local exhaust control ranged from 1.9 mg/m^3 to 3.6 mg/m^3 (19 to 36 mppcf), or from about 4 to 5 times the PEL. Quartz exposures during block cutting with the local exhaust control ranged from 0.79 to 1.1 mg/m^3, or 16 to 22 times the REL. The use of the water-spray control during block cutting resulted in respirable dust exposures that ranged from 2.9 mg/m^3 to 11 mg/m^3 (29 to 115 mppcf), or about 5 to 12 times the PEL. Quartz exposures during block cutting using the water-spray control ranged from 1.1 to 2.4 mg/m^3, or 22 to 48 times the REL.

Review of Table 7 indicates that during tuckpointing with the local exhaust control, respirable dust concentrations ranged from 0.34 mg/m^3 to 1.3 mg/m^3 (3.4 to 13 mppcf), from less than the PEL to about twice the PEL. Use of the water-spray control resulted in respirable dust exposures from 0.34 mg/m^3 to 26 mg/m^3 (3.4 to 263 mppcf), from less than the PEL to 36 times the PEL. Table 8 shows that quartz exposures while tuckpointing with the local exhaust control ranged from 0.15 mg/m^3 to 0.48 mg/m^3, or from 3 times the REL to almost 10 times the REL. Quartz exposures while tuckpointing with the water-spray control ranged from 0.17 mg/m^3 to 7.6 mg/m^3, or from more than 3 times the REL to more than 150 times the REL. When reviewing the tuckpointing results, it is important to note that analyses for silica were not carried out for five of the samples (four when the local exhaust control was evaluated and one water-spray trial) because the respirable dust results were below the silica limit of quantitation (LOQ). In other words, the analyses were not performed because even if all of the respirable dust in those samples was silica, the results would have been below the silica (quartz and cristobalite) LOQ of 0.03 mg. The values for three other samples (two local exhaust tests and one water-spray evaluation) were between the silica limit of detection (LOD) and LOQ. Values between the LOD and LOQ are semi-quantitative estimates only. Undetectable values occur in industrial hygiene work, and several methods have been suggested to handle them [NIOSH 1977]. One method is to use the laboratory LOD to determine the least detectable concentration in the amount of air the pump sampled; another widely used method, suggested by Hornung and Reed [1990] is to use the value of the LOD/sqrt 2. That method was used in the analyses in this study. However, the use of the value LOD/sqrt 2 in place of quartz masses for the samples that were not analyzed may overestimate the silica results for those samples.

CONCLUSIONS AND RECOMMENDATIONS

The results of these tests showed that exposures to respirable dust and quartz can be significantly reduced through the use of LEV or wet methods during block cutting and tuckpointing with hand-held electric tools. However, even with the reductions seen here, exposures exceeded applicable exposure limits in some cases, if this work were carried out for a full shift. This means that appropriate respiratory protection will have to be used in the context of a comprehensive respiratory protection program. Alternatively, the amount of time these tasks can be performed could be restricted. For example, the use of the local exhaust control while cutting block resulted in brief silica exposures of 16 to 22 times the REL. Under these conditions, a worker could cut block for up to 22 minutes in an 8-hour day with no additional quartz exposures without exceeding the REL.[b]

The next step in the evaluation of these tools should be exposure monitoring during their use while performing these tasks on actual construction jobs to confirm their performance. Workers using these tools made a few recommendations to improve their acceptability. One suggested that a spirit level bubble should be added to the shroud on the Bosch tuckpointer to guide the use of the tool on bed joints. That worker also suggested that a handle be added to the Bosch grinder at a right angle to the shroud and pointing down to permit better control of the tool. The use of a larger diameter vacuum hose and take-off from both shrouds may also improve performance. The workers noted that the use of the water-spray attachment while tuckpointing required that the tool be used so that the grinder is above the shroud in order to keep water from entering the motor; this is not the way a grinder is usually oriented when tuckpointing.[c] While this study demonstrated that the use of these controls resulted in substantial and significant reductions in personal exposures to respirable dust and quartz, work remains to be done to achieve compliance with occupational exposure limits through the use of engineering controls without resorting to the supplemental use of respiratory protection or administrative controls.

[b] (1.1 mg/m^3 quartz x 22 minutes)/480 minutes = 0.05 mg/m^3 quartz, the NIOSH REL

[c] the instructions that accompanied the water spray kit state, “Do not work with the grinder while the blade cover is upside down to avoid the water of [sic] flowing to the motor. It is dangerous!”

REFERENCES

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Table 1: Results of Personal Breathing Zone Samples
For Quartz While Cutting Block
Bordentown, NJ - July 26, 2004

Round	Treatment	Respirable Quartz (mg/sample)	Sample Time (minutes)	Sample Flow avg (L/min)	Sample Volume (L)	Respirable Quartz Concentration (mg/m^3)	Exposure Reduction (percent)
1	no control	0.11	4	4.2	17	6.6	0
	water spray	0.082	11	4.2	46	1.8	73
	local exhaust	0.040	10	4.2	42	0.95	85
2	no control	0.20	5	4.2	21	9.5	0
	water spray	0.044	10	4.2	42	1.0	89
	local exhaust	0.033	10	4.2	42	0.79	92
3	local exhaust	0.043	10	4.2	42	1.0	96
	water spray	0.047	10	4.2	42	1.1	95
	no control	0.51	5	4.2	21	24	0
4	water spray	0.094	10	4.2	42	2.2	61
	local exhaust	0.037	10	4.2	42	0.88	85
	no control	0.12	5	4.2	21	5.7	0
5	no control	0.80	5	4.2	21	38	0
	local exhaust	0.047	10	4.2	42	1.1	97
	water spray	0.10	10	4.2	42	2.4	94

mg = milligrams, min = minutes, L = liters, m^3 = cubic meters
The limit of detection for quartz on filters was 0.01mg.
The limit of quantitation was 0.03 mg for quartz on filters.
No control means either the local exhaust hose was removed from the Bosch dust extraction guard and the ventilation take-off was plugged (rounds 2 and 4) or the water hose was disconnected from the Bronco water attachment on the Partner cutter (rounds 1, 3, and 5).
Water spray means the Partner K3000 cutter plus Bronco water spray kit.
Local exhaust means the Bosch 1264 was plus the dust extraction guard and vacuum cleaner

Table 2: Results of Personal Breathing Zone Samples
For Respirable Dust While Cutting Block
Bordentown, NJ - July 26, 2004

Round	Treatment	Respirable Dust (mg/sample)	Sample Time (minutes)	Sample Flow avg (L/min)	Sample Volume (L)	Respirable Dust Concentration (mg/m^3)	Reduction (percent)
1	no control	0.39	4	4.2	17	23	0
	water spray	0.25	11	4.2	46	5.4	77
	local exhaust	0.10	10	4.2	42	2.4	90
2	no control	0.57	5	4.2	21	27	0
	water spray	0.12	10	4.2	42	2.9	89
	local exhaust	0.089	10	4.2	42	2.1	92
3	local exhaust	0.14	10	4.2	42	3.3	97
	water spray	0.16	10	4.2	42	3.8	96
	no control	2.0	5	4.2	21	95	0
4	water spray	0.38	10	4.2	42	9.1	58
	local exhaust	0.15	10	4.2	42	3.6	83
	no control	0.45	5	4.2	21	21	0
5	no control	2.4	5	4.2	21	115	0
	local exhaust	0.079	10	4.2	42	1.9	98
	water spray	0.48	10	4.2	42	11	90

mg = milligrams, min = minutes, L = liters, m^3 = cubic meters
The limit of detection for respirable particulate on filters was 0.02 mg.
No control means either the local exhaust hose was removed from the Bosch dust extraction guard and the ventilation take-off was plugged (rounds 2 and 4) or the water hose was disconnected from the Bronco water attachment on the Partner cutter (rounds 1, 3, and 5).
Water spray means the Partner K3000 cutter plus Bronco water spray kit.
Local exhaust means the Bosch 1264 cutter plus the dust extraction guard and vacuum cleaner

Table 3: Results of Personal Breathing Zone Samples
For Respirable Quartz While Tuckpointing Brick
Bordentown, NJ - July 27, 2004

Round	Treatment	Respirable Quartz (mg/sample)	Sample Time (minutes)	Sample Flow avg (L/min)	Sample Volume (L)	Quartz Concentration (mg/m^3)	Reduction (percent)
1	local exhaust	**	10	4.2	42	0.17‡	98
	no control	0.18	5	4.2	21	8.6	0
	water spray	0.04	10	4.2	42	0.91	89
2	water spray	(0.02)	10	4.2	42	0.48	88
	no control	0.08	5	4.2	21	3.9	0
	local exhaust	**	10	4.2	42	0.17‡	96
3	water spray	**	10	4.2	42	0.17‡	99
	local exhaust	**	10	4.2	42	0.17‡	99
	no control	0.53	5	4.2	21	25	0
4	no control	0.68	5	4.2	21	32	0
	local exhaust	(0.03)	10	4.2	42	0.72	98
	water spray	0.21	10	4.2	42	5.0	85
5	water spray	0.21	10	4.2	42	5.0	61
	no control	0.27	5	4.2	21	13	0
	local exhaust	**	11	4.2	46	0.15	99
6	water spray	0.32	10	4.2	42	7.6	77
	local exhaust	(0.02)	10	4.2	42	0.48	99
	no control	0.71	5	4.2	21	34	0

mg = milligrams, min = minutes, L = liters, m^3 = cubic meters
The limit of detection (LOD) for quartz on filters was 0.01mg.
The limit of quantitation (LOQ) was 0.03 mg for quartz on filters.
**had dust values less than the quartz LOQ of 0.03 mg/sample, and were not analyzed for quartz.
Results in parentheses are between the LOD and LOQ; semi-quantitative estimates reported only to one significant digit.
‡these concentrations were determined by using the value LOD/sqrt2 in place of the quartz mass and dividing that value by the sample volume [Hornung and Reed 1990]
Local exhaust means the Bosch Tuckpointer and vacuum cleaner
No Control means either the local exhaust port on the Bosch tuckpointer was blocked (round 1), the water hose was disconnected from the Bronco attachment on the Metabo grinder (round 2), or a Milwaukee angle grinder was used with no dust control (rounds 3-6).
Water spray means the Metabo grinder and Bronco water spray kit

Table 4: Results of Personal Breathing Zone Samples
For Respirable Dust While Tuckpointing Brick
Bordentown, NJ - July 27, 2004

Round	Treatment	Respirable Dust (mg/sample)	Sample Time (minutes)	Sample Flow avg (L/min)	Sample Volume (L)	Respirable Dust Concentration (mg/m^3)	Reduction (percent)
1	local exhaust	ND	10	4.2	42	0.34*	99
	no control	0.70	5	4.2	21	33	0
	water spray	0.17	10	4.2	42	4.1	88
2	water spray	0.15	10	4.2	42	3.6	73
	no Control	0.28	5	4.2	21	13	0
	local exhaust	ND	10	4.2	42	0.34*	97
3	water spray	ND	10	4.2	42	0.34*	100
	local exhaust	ND	10	4.2	42	0.34*	100
	no control	1.5	5	4.2	21	72	0
4	no control	2.1	5	4.2	21	100	0
	local exhaust	0.035	10	4.2	42	0.84	99
	water spray	0.73	10	4.2	42	17	83
5	water spray	0.72	10	4.2	42	17	53
	no control	0.76	5	4.2	21	36	0
	local exhaust	ND	11	4.2	46	0.31*	99
6	water spray	1.1	10	4.2	42	26	75
	local exhaust	0.056	10	4.2	42	1.3	99
	no control	2.2	5	4.2	21	105	0

mg = milligrams, min = minutes, L = liters, m^3 = cubic meters
The limit of detection for respirable particulate was 0.02 mg.
*these concentrations were determined by using the value LOD/sqrt2 in place of the respirable dust mass and dividing that value by the sample volume [Hornung and Reed 1990]
Local exhaust means the Bosch Tuckpointer and vacuum cleaner
No control means either the local exhaust port on the Bosch tuckpointer was blocked (round 1), the water hose was disconnected from the Bronco attachment on the Metabo grinder (round 2), or a Milwaukee angle grinder was used with no dust control (rounds 3-6).
Water spray means the Metabo grinder and Bronco water spray kit

Table 5: Summary Statistics - Air Sampling Data
Bordentown, NJ - July 26-27, 2004

Control Treatment	Sampling Method	Number of Samples	Analyte	Geometric Mean (mg/m^3)	Geometric Standard Deviation
Cutting Block					
None	Real-time	1251	Respirable dust	15.7	9.92
None	Filter Cassette	5	Respirable dust	43.2	2.26
None	Filter Cassette	5	Respirable quartz	12.7	2.30
Local Exhaust	Real-time	2460	Respirable dust	1.57	4.92
Local Exhaust	Filter Cassette	5	Respirable dust	2.58	1.32
Local Exhaust	Filter Cassette	5	Respirable quartz	0.95	1.15
Water spray	Real-time	2359	Respirable dust	5.95	3.64
Water spray	Filter Cassette	5	Respirable dust	5.73	1.78
Water spray	Filter Cassette	5	Respirable quartz	1.62	1.47
Tuckpointing Brick					
None	Real-time	1894	Respirable dust	31.4	5.81
None	Filter Cassette	6	Respirable quartz	12.0	2.19
None	Filter Cassette	6	Respirable dust	48.0	2.21
Local Exhaust	Real-time	3798	Respirable dust	0.32	4.59
Local Exhaust	Filter Cassette	6	Respirable quartz	0.41	4.97
Local Exhaust	Filter Cassette	6	Respirable dust	0.49	1.87
Water spray	Real-time	3670	Respirable dust	4.42	6.89
Water spray	Filter Cassette	6	Respirable quartz	1.58	4.79
Water spray	Filter Cassette	6	Respirable dust	5.81	5.06

Table 6: Results of Water Flow Measurements
Bordentown, NJ - July 27, 2004

TRIAL	VOLUME (cups)	TIME (sec)	FLOW RATE ml/min
1	1	11.36	1320.42
2	1	11.02	1361.16
3	1	10.42	1439.54
mean	1	10.93	1373.71

1 cup=250ml

Table 7: Comparison of Sampling Results from Cutting Block with Occupational Exposure Limits
Bordentown, NJ - July 26, 2004

Round	Condition	Quartz Concentration	Respirable Dust Concentration		% Quartz	PEL	REL
		(mg/m^3)	(mg/m^3)	(mppcf)	(percent)	(mppcf)	(mg/m^3)
1	no control	6.6	23	233	28	7.5	0.05
	water spray	1.8	5.4	54	33	6.6	0.05
	local exhaust	0.95	2.4	24	40	5.6	0.05
2	no control	9.5	27	272	35	6.2	0.05
	water spray	1.1	2.9	29	37	6.0	0.05
	local exhaust	0.79	2.1	21	37	5.9	0.05
3	local exhaust	1.0	3.3	33	31	7.0	0.05
	water spray	1.1	3.8	38	29	7.3	0.05
	no control	24	95	954	26	8.2	0.05
4	water spray	2.2	9.1	91	25	8.4	0.05
	local exhaust	0.88	3.6	36	25	8.4	0.05
	no control	5.7	21	215	27	7.9	0.05
5	no control	38	115	1145	33	6.5	0.05
	local exhaust	1.1	1.9	19	59	3.9	0.05
	water spray	2.4	11	115	21	9.7	0.05

mg means milligrams, L means liters, m^3 means cubic meters, mppcf means millions of particles per cubic foot.

Table 8: Comparison of Sampling Results from Tuckpointing with Occupational Exposure Limits
Bordentown, NJ - July 27, 2004

Round	Condition	Quartz Concentration	Respirable Dust Concentration		% Quartz	PEL	REL
		(mg/m^3)	(mg/m^3)	(mppcf)	(percent)	(mppcf)	(mg/m^3)
1	local exhaust	0.17‡	0.34	3.4	**	**	0.05
	no control	8.6	33	334	26	8.1	0.05
	water spray	0.91	4.1	41	22	9.1	0.05
2	water spray	0.48	3.6	36	13	14	0.05
	no control	3.9	13	134	29	7.4	0.05
	local exhaust	0.17‡	0.34	3.4	**	**	0.05
3	water spray	0.17‡	0.34	3.4	**	**	0.05
	local exhaust	0.17‡	0.34	3.4	**	**	0.05
	no control	25	72	716	35	6.2	0.05
4	no control	32	100	1003	32	6.7	0.05
	local exhaust	0.72	0.84	8.4	86	2.8	0.05
	water spray	5.0	17	174	29	7.4	0.05
5	water spray	5.0	17	172	29	7.3	0.05
	no control	13	36	363	36	6.2	0.05
	local exhaust	0.15‡	0.34	3.4	**	**	0.05
6	water spray	7.6	26	263	29	7.3	0.05
	local exhaust	0.48	1.3	13	36	6.1	0.05
	no control	34	105	1050	32	6.7	0.05

mg means milligrams, L means liters, m^3 means cubic meters, mppcf means millions of particles per cubic foot.

Figure 1: Experimental setting for block cutting

Figure 2: Experimental setting for measuring air flow and static pressure. The duct tape has not yet been applied to the flexible couplings.

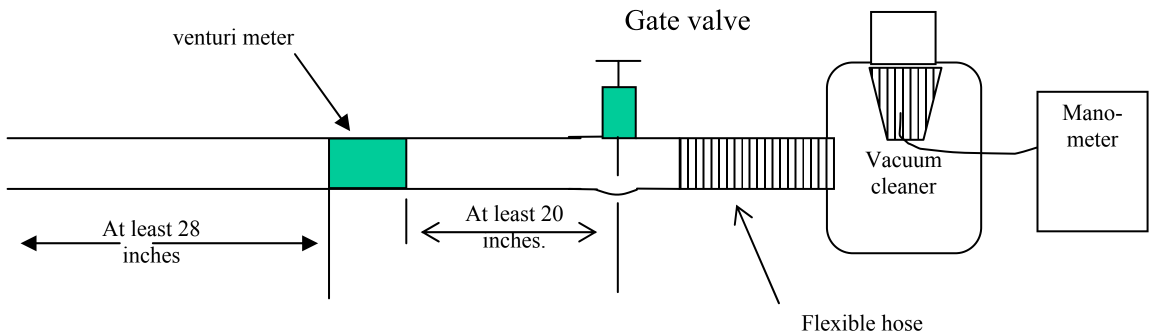

Figure 3: Experimental measurement of pressure loss as a function of airflow rate for commercially available vacuum cleaners. The pipes used in this study are 2 inch diameter schedule 40 PVC pipe. The vacuum cleaner static pressure is measured between the final filter and the inlet to the vacuum cleaner motor.

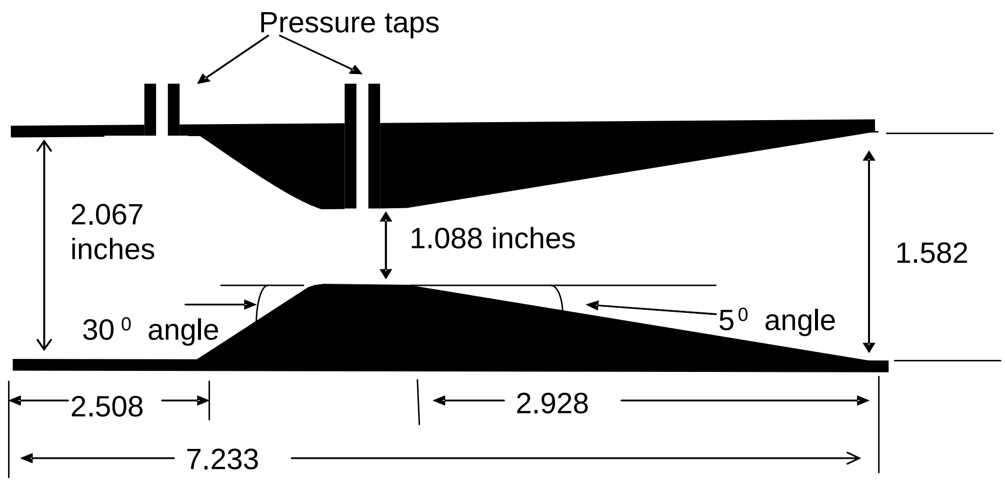

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Figure 4: Description of venturi meter with dimensions measured in inches and angles from supplier's drawings. All dimensions are in inches. The venturi meter was machined from type 304 stainless steel. Wall thickness is 0.23 in. The exterior shape is a nominal schedule 40 pipe with national pipe threads on the ends.

Figure 5: The Bosch cutter with shroud. Note the close contact between the shroud and block surface, essential to effective dust control.

Figure 6: Partner cutter with Bronco Control

Figure 7: Grinder with Bronco control

Figure 8: Mixture of mortar, water and brick dust on wall following use of Bronco control

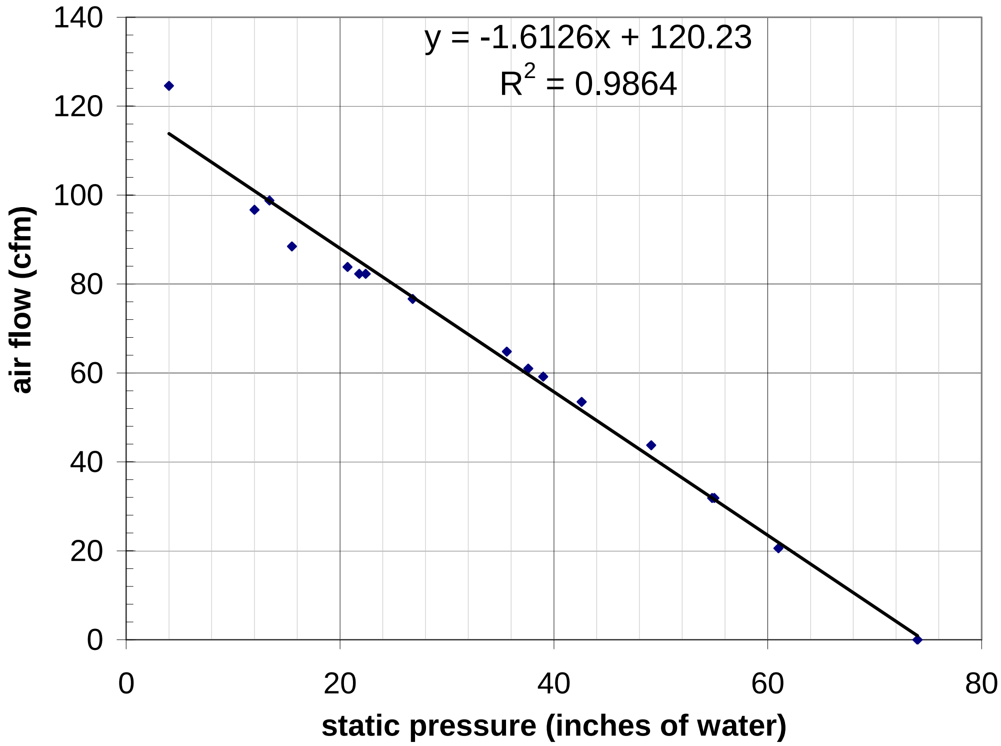

Figure 9: Fan curve for Bosch vacuum cleaner