IN-DEPTH SURVEY REPORT OF CONTROL OF RESPIRABLE DUST AND CRYSTALLINE SILICA FROM GRINDING CONCRETE

at

Messer Construction
Newport, Kentucky
and
Baker Concrete Construction
Dayton, Ohio

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SITES SURVEYED	Parking Garage (New Construction), Newport, KY Performing Arts Center (New Construction), Dayton, OH
SIC CODE	1771 (Concrete Work)
SURVEY DATES	February 2 and 13, 2001, and April 12, 2001
SURVEYS CONDUCTED BY	Alan Echt William A Heitbrink Stanley A Shulman Daniel S Watkins Ronald L Kovein
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ABSTRACT

When construction workers use hand-held grinders to smooth poured concrete surfaces after forms are removed, they risk overexposure to respirable dust and crystalline silica A previous study at a stadium construction site revealed TWA respirable crystalline silica exposures that ranged from 56 to 830 $\mu g/m^3$ (the NIOSH REL is 50 $\mu g/m^3$) and TWA respirable dust concentrations ranging from 0 38 to 6 9 mg/m^3 Silicosis is an occupational respiratory disease caused by inhaling respirable crystalline silica dust Silicosis is irreversible, often progressive (even after exposure has ceased), and potentially fatal Exposure to crystalline silica dust occurs in many occupations, including construction Because no effective treatment exists for silicosis, prevention through exposure control is essential The study described here compared the exposures during the use of off-the-shelf local exhaust ventilation shrouds with that of no shroud The aim was to quantify the exposure reduction that could be achieved through the use of shrouds, and to compare shroud effectiveness

Two grinders from different manufacturers were studied, at three study sites Two shrouds were evaluated for each type of grinder for a total of four shrouds The grinder with no control varied from site to site, since this was furnished by the employer The same vacuum cleaner was used to provide exhaust air flow at both sites An aerosol photometer was paired with an SKC aluminum cyclone to measure respirable dust exposures in the cement mason's breathing zone

With 95% confidence, the results indicated at least 90% reduction due to the controls for each of the four shrouds at an average flow rate of 122 cfm Results indicate little difference between the reductions in the different grinder/shroud pairings This study demonstrated effective control can be achieved for hand held grinding of concrete

INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) is located in the Centers for Disease Control and Prevention (CDC), under the Department of Health and Human Services (DHHS) NIOSH was established in 1970 by the Occupational Safety and Health Act, at the same time that the Occupational Safety and Health Administration (OSHA) was established 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 forerunner, 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 the effectiveness of the control techniques in reducing potential health hazards in an industry or for a specific process

This is the report of a project that involved visits to three sites where construction workers were using hand-held grinders to finish the surface of poured concrete walls by removing form lines, smoothing patches, and removing other surface irregularities This study sought to quantify the exposure reduction that could be achieved through the use of local exhaust ventilation during grinding In this case, the local exhaust ventilation consisted of a variety of commercially available shrouds or hoods mounted on the grinder and connected via a flexible corrugated hose to an industrial vacuum cleaner

OCCUPATIONAL EXPOSURE TO CRYSTALLINE SILICA

Silicosis is an occupational respiratory disease caused by inhaling respirable crystalline silica dust 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 [1] Crystalline means the oxygen and silicon atoms are arranged in a repeating three-dimensional pattern [1] Crystalline silica can be found in many forms The three major forms of crystalline silica are quartz, cristobalite, and tridymite [1] Quartz is the most common form of crystalline silica [1] Respirable means that the dust particles are small enough to reach the region of the human lung where gas exchange occurs [1]

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) [2-4] The NIOSH REL for all forms of respirable crystalline silica is a 10-hour, time-weighted average level of 0 05 milligrams per cubic meter (mg/m^3) NIOSH has classified crystalline silica as a potential occupational carcinogen Therefore, NIOSH recommends that employers make efforts to reduce exposures below the REL

The OSHA PEL for respirable dust containing 1% quartz or more is expressed as an equation

$$\text{Respirable PEL} = \frac{10}{(\%\ \text{Silica}) + 2}$$

Thus, if the dust contains no crystalline silica, the PEL is 5 mg/m^3, and if the dust is 100% crystalline silica, the PEL is 0 1 mg/m^3 For tridymite and cristobalite (two other forms of crystalline silica), OSHA uses half the value calculated using the formula for quartz The ACGIH TLVs for cristobalite, quartz, and tridymite are all 0 05 mg/m^3

METHODS

Exposure Assessment

The extent of the reduction in the breathing zone respirable dust exposure of the construction worker when local exhaust ventilation (LEV) was used compared to the exposure when no LEV was used served as the measure of the effectiveness of the controls evaluated in this study Respirable dust exposure was measured using an aerosol photometer (Hazdust II, Environmental Devices Corporation, Haverhill, MA) with a respirable dust pre-selector (SKC aluminum cyclone, SKC, Inc , Eighty-four, PA) placed before the sensor A 37-mm diameter 5-µm pore-size filter in a two-piece cassette in line after the sensor was analyzed for crystalline silica to determine the percent crystalline silica in the dust as an aggregate over the sampling period This enabled an estimate of the reduction of crystalline silica exposure due to the use of the controls, since crystalline silica exposure could not be measured in real time The aerosol photometer was modified by the manufacturer, including the installation of a new internal pump to allow sampling at a flow rate of 2 5 liters per minute, the flow rate required for the pre-selector to meet the ACGIH/ISO/CEN curve for respirable dust (50% sampling efficiency (cut-point) = 4 0 µm) The aerosol photometer samples at 1-second intervals and provides results in terms of concentration (mg/m^3) The pre-selector/sensor/filter unit was clipped to the employee's lapel, connected via flexible tubing and cable to the unit housing the pump and electronics This unit was worn on a belt around the employee's waist Bulk samples of settled dust were collected and analyzed in order to determine whether substances were present which would interfere with the crystalline silica analyses

Gravimetric analysis for respirable particulate was carried out with the following modifications to NIOSH Method 0600 1) The filters and backup pads were stored in an environmentally controlled room (21±3 °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 [5] 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 filter and bulk samples was done 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 [5] These samples were analyzed for two forms of crystalline silica 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

Vacuum Cleaner Performance Evaluation

Vacuum cleaner performance was measured in terms of the static pressure and air flow through the shroud-hose-vacuum cleaner system Static pressure was measured by inserting a smooth-walled metal tube the same diameter as the vacuum cleaner hose in line with the hose between the shroud and the vacuum cleaner and measuring the suction using a U-tube manometer One end of the manometer tubing was placed on a hole drilled in the side of the metal tube while the shroud was held against a flat surface Centerline air velocity was measured at the same point using a multi-parameter ventilation meter (Velocicalc Plus model 8386, TSI Incorporated, St Paul, MN) Static pressure and centerline air velocity measurements were made with the vacuum cleaner running and with the grinder on and off Air flow was calculated by multiplying 0 9 centerline velocity by the cross sectional area of the hose [6] Pressure and air velocity measurements were made a sufficient number of hose diameters from the tool and the vacuum cleaner to mitigate the effects of turbulence on the measurements

Experimental Design

For the trials where the control was used, four hand-held right-angle grinders were purchased which were identical to two of the types used by the contractors with whom we worked on this project, two Milwaukee model 6153-20 11,000 rpm grinders (Milwaukee Electric Tool Corp , Brookfield, WI) and two Metabo model 11025 10,000 rpm grinders (Metabowerke GmbH, Nurtingen, Germany) Four local exhaust ventilation shrouds were purchased, one of which was identical to the type used by one of the contractors (Vacuguard, Pearl Abrasive Co , Commerce, CA) The other three were selected from those identified through a search of product literature and the Internet (Dustcontrol, Transmatic Inc , Wilmington, NC, and "full dust shroud" and "cut (edging) shroud," Sawtec, Oklahoma City, OK) Those selected appeared to be ruggedly constructed, easily mounted on the tool, and readily available for purchase . The combinations of shrouds and grinders used for the study are listed in Table 1 These grinder/shroud pairs were connected via corrugated flexible hose to an industrial vacuum cleaner (DC 3700 C, Dustcontrol AB, Norsborg, Sweden) The manufacturer reports that this unit has a maximum flow capacity of 320 m^3/hr (188 cfm), and a maximum negative pressure of 21kPa (84 in w g) The grinders were fitted with 4-in diameter diamond cup wheels (PW series, Pearl Abrasive Co , Commerce, CA) For the trials where no control was used, the construction workers used the grinder and grinding wheel normally provided to them by their employer

Table 1 - Grinder/Shroud Pairs

Milwaukee 6153-20 grinder + Dustcontrol shroud	Milwaukee 6153-20 grinder + Sawtec cut (edging) shroud	Metabo 11025 grinder + Pearl Abrasive Co Vacuguard shroud	Metabo 11025 grinder + Sawtec full dust shroud

The aim 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)]

Since there was interest in comparing reductions of shrouds for the same grinding unit, the randomization was carried out so as to first have randomized pairs of the two grinder types, and then randomly order the two shrouds and no control within each of the grinder types An example randomization appears in Table 2, below

Table 2 - An Example Randomization

Grinder Type 1	Run 1=Control 1	Run 2=No-control	Run 3 = Control 2
Grinder Type 2	Run 4=Control 2	Run 5=No-control	Run 6 =Control 1

In the above example, control 1 for grinder 1 was different from control 1 for grinder 2, and analogously for control 2 The actual design differed from that shown above in that in each set of six runs, one no-control run was removed, in order to limit worker exposure to dust (the no-control run that was removed was alternated between the two types of grinders) Each of these sets of five runs constituted a block Multiple blocks were collected at each site Control runs consisted of grinding for approximately five minutes, while most no-control runs were restricted to about two and a half minutes of grinding, beginning with site 2 (The aim was to reduce worker exposure to the dust) The benefit of this design was relatively quick assessment of controls and reduced exposure to the worker, which was only possible because of the availability of real-time instruments

Grinding at site 1 consisted of walls and columns in an open area, site 2 involved grinding on a wall in an underground parking garage, site 3 involved grinding on a wall in a corridor open to the outside at one end Sites 1 and 3 were both new construction at the same performing arts center, while site 2 was a parking garage at an entertainment and shopping complex At site 1 sampling was a much more arduous task than at the other sites because of very low temperatures at that site on that day

Statistical Procedures and Handling of Data

From the sequential measurements in each trial a single summary measure was calculated, the geometric mean of the dust concentrations Example data are given in Figure 1, in which for both of the conditions shown the measurements and the geometric mean are plotted The geometric mean computation required calculation of the average dust concentration on the natural log scale At site 3 there were over 88 dust concentrations equal to zero, all during trials when controls were run In order to take the logarithm of these dust concentrations, 0 01 was added to all zero dust concentrations at that site, before taking the log Addition of this small value made all values positive Since there were almost 5000 measurements at site 3, the inclusion or alteration of the 88 zero values had small effect on the estimated geometric means and the estimated comparisons

During each trial, a period of time had to elapse before the measurements approached a stable mean An initial increase in measurements was true for most control-off trials For example, the "no control" figure in the Figure 1 data indicates that it took over 20 dust concentration measurements (at one second intervals) to stabilize The statistical model was fitted for several versions of the data However, since results differed little from the unaltered data and it was difficult to determine the optimal number of values to remove, results are presented for the geometric means calculated for all the data collected during the trial

The geometric means were transformed to the natural log scale and used as the response in a statistical model The two sites studied here were thought to be too few to be regarded as a random sample from a larger population Thus, the results apply only to the sites studied here, though there is no reason to think that the results are not representative of those that would be obtained at similar sites In the statistical model individual means were allowed for each site, as well as for the various control-shroud combinations at each site The blocks were treated as a random sample, as was the ordering within each block The data appear to meet the assumptions of approximate normality The model provided estimates of the reduction due to the controls, and also confidence limits for the minimum reduction, based on the Student's t distribution One-sided confidence limits were provided since reduction due to the control was expected Correction was made for multiple comparisons via the Bonferroni method, since many confidence intervals were based on the same data [7] All confidence statements given below hold with at least 95% confidence

RESULTS

Effect of Controls on Respirable Dust Exposures

The data in Table 2 indicate that the levels observed were quite variable among the three sites Site 2 gave the highest dust concentration measurements most no-control dust concentration measurements were greater than about 40 mg/m^3 and control dust concentration measurements were greater than 0 6 mg/m^3 Site 3 differed from site 1 in that the control dust concentration measurements were all lower than about 0.3 mg/m^3 at site 3, and all greater than about 0 8 mg/m^3 at site 1, even though the no-control values overlapped The average site 2 and site 3 estimated control reductions were all between 98 and 99%, and none of the reductions at the two sites for each of the grinder types differed in tests at the 5% level Thus, the differences between site 2 and 3 appear to be due to higher control geometric means at site 2 than at site 3 As was explained in the previous section, the temperatures during the site 1 visit were very low, and this may have affected the results

By the statistical tests, site 1 results indicated lower reductions than those for the two other site visits for all four units, based on tests at the 5% significance level Even with the site 1 results included in the overall averages, reductions were quite high about 97% for the two Metabo units, and about 96% for the Milwaukee units 95% lower confidence limits for each grinder, averaged over all three site visits, exceeded 92% reduction (see Figure 2) Based on percent reduction, we can say that all four grinders were similarly effective, and all reduced the generated dust by at least 90% relative to the no-control, when averaged over all three sites This conclusion holds with 95% confidence

Crystalline Silica Sampling Results

Analyses of the respirable particulate sample collected on a filter using the aerosol photometer at site 1 revealed that the sampled dust contained 6 8% quartz by weight Two samples of this type were collected at site 2, one in the morning and one in the afternoon The morning sample contained 7 3% quartz by weight, while the afternoon sample contained 10 2% quartz by weight At site 3, a single filter sample was collected, and was found to contain 8 6% quartz by weight The mass of quartz found on that filter, 0 03 mg, was between the limit of detection and the limit of quantitation, and should be regarded as a trace value No cristobalite was detected in any of the samples

Vacuum Cleaner Performance Evaluation

The average air flow rate for the Milwaukee grinder and Sawtec shroud was 144 cfm (n=4, range 129-151 cfm) The static pressure for this pairing was 18 inches of water (in w g) The average air flow rate for the Milwaukee grinder and Dustcontrol shroud was 117 cfm (n=4, range 109-121 cfm) The static pressure for this pairing was 32 in w g The average air flow rate for the Metabo grinder/Sawtec shroud pair was 130 cfm (n=3, range 108-130 cfm), while the average air flow rate for the Metabo grinder and Pearl shroud was 105 cfm (n=3, range 95-113 cfm) The static pressures measured for those grinder shroud combinations were 20 in w g and 28 in w g, respectively

Conclusions and Recommendations

This study showed that all four shrouds were equally effective, and that all reduced dust exposure by at least 90% Thus, the choice of shrouds can be made based upon the preferences of the cement finisher and their employer They should work together to select the shroud best suited to the task Anecdotal information conveyed by the cement finishers involved in this study indicate that issues such as light weight, ease of use, ability to see the work surface, and durability were all important factors in determining shroud preference

References

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Table 2

Estimated Geometric Means and %Reductions due to Controls for Trials from the Three Sites

Site Number	Block	No Control[C]	Metabo Pearl GM(% Red)	Metabo Sowtec full dust shroud GM(% Red)	Milwaukee Dustcontrol GM(% Red)	Milwaukee Sawtec cut (edging) shroud GM(% Red)
1	1	12 31[+]	1 16(91)	0 78(94)		
		9 47[+]			2 17(77)	0 71(92)
1	2	4 57	A	A	1 67(63)	0 86(81)
2	3	70 34	0 74(99)	0 77(99)	1 15(98)	0 36(99)
2	4	39 55	1 67(96)	0 97(98)	1 10(97)	0 94(98)
2	5	48 28	1 52(97)	1 14(98)	1 21(98)	1 42(97)
2	6	84 11	1 58(98)	1 73(98)	1 67(98)	3 01(96)
2	7	4 85[D]	1 18(76)[D]	0 69(86)[D]	0 60(88)[D]	1 32(73)[D]
2	8	46 49	1 12(98)	0 89(98)	1 19(97)	1 05(98)
3	9	1 65	0 061(96)	0 091(94)	0 11(93)	0 13(92)
3	10	2 51	0 048(98)	0 095(96)	0 027(99)	0 037(99)
3	11	9 35	0 064(99)	0 067(99)	0 092(99)	0 016(98)
3	12	24 45	0 11(99 5)	A	0 31(99)	0 24(99)

[A] Data not collected

[+] Two control-off trial were carried out in block 1, one with the Metabo and one with the Milwaukee grinder

[C] A different no control grinder was used at each site For the control settings, the same unit (grinder plus shroud) was used at each site

[D] Value treated as possible outlier and excluded from data analyses The low % reductions are evidence that the no control measurement is an outlier

Figure 1   Example Data

Figures below provide the actual data for two runs, plus the geometric mean for each run
Ln(Geometric mean) was used in statistical analyses
Note that the scale for "no control" differs from scale for the control unit

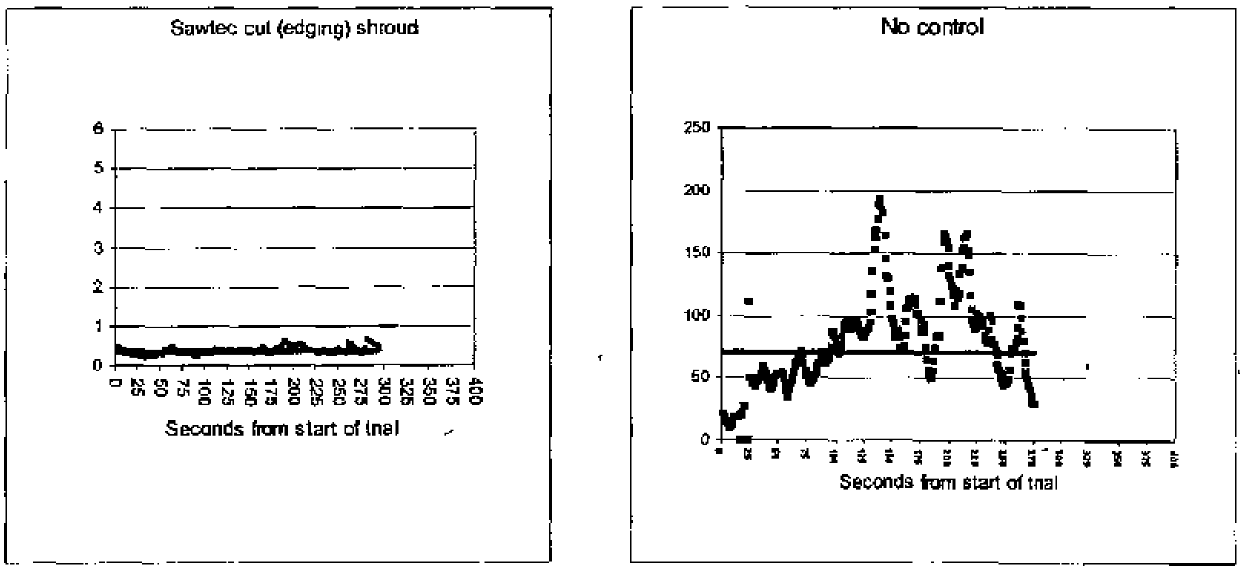

Figure 2   Estimated Reductions, Simultaneous 1-sided 95% Confidence Limits