IN-DEPTH SURVEY REPORT OF A WATER SPRAY DEVICE FOR SUPPRESSING RESPIRABLE AND CRYSTALLINE SILICA DUST FROM JACKHAMMERS

at

E E Cruz Company
South Plainfield, NJ

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ABSTRACT

The objective of this study was to quantify the exposure reduction that could be achieved through the use of a water spray attachment while breaking concrete with jackhammers The effectiveness of the water spray examined in this study was evaluated by measuring the reduction in the respirable dust and quartz exposures in the breathing zones of two construction workers 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 In addition, personal breathing zone samples for respirable dust and respirable crystalline silica were collected and analyzed using established NIOSH methods Water applied using a solid cone nozzle at a flow rate of 300 mL of water per minute resulted in a 69 to 71% reduction in respirable dust exposure and a 77% reduction in quartz exposure A water flow rate of 250 mL/minute resulted in a 42 to 43% reduction in respirable dust exposure and a 39% reduction in silica exposure Use of the control with a clogged nozzle resulted in exposure increases The best exposure reduction demonstrated in these trials would permit a worker to use the jackhammer under these conditions for up to 4 hours and 45 minutes in an eight-hour shift with no other exposures to quartz without exceeding the REL or up to 6 hours and 40 minutes in an eight-hour shift with no other quartz exposures without exceeding the calculated OSHA PEL

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, 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 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

The goal of this project was to quantify the exposure reduction that could be achieved through the use of a water spray attachment while breaking concrete with jackhammers In this case, the water spray attachment consisted of a spray nozzle, of the type used with oil-burning furnaces, and associated hoses and fittings Water was supplied by a pressurized tank mounted on the air-compressor trailer

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, a crystalline structure is one in which the atoms are arranged in a repeating three-dimensional pattern [1] The three major forms of crystalline silica are quartz, cristobalite, and tridymite [1] Quartz is the most common form of crystalline silica [1] 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 μm [2]

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

$$\text{Respirable PEL} = \frac{10}{(\%\ \text{Silica}) + 2} \qquad (1)$$

If, for example, 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, 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 effectiveness of the water spray dust control examined in this study was evaluated by measuring the reduction in the respirable dust exposure 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 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 battery-operated sampling pump connected via Tygon tubing to 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, and a cyclone (GK 2.69 Respirable/Thoracic Cyclone, BGI Inc., Waltham, MA)[5]. Bulk samples of settled dust were also collected in accordance with NIOSH Method 7500[5].

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 (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[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 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 [5] 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

Description of controls

This study evaluated the effectiveness of a water spray control The water spray attachment was fabricated by one of the contractors who participated in this study (Tilcon New York, Inc at their Mt Hope facility in Wharton, NJ) The water nozzle used was a solid cone nozzle of the type used for oil burners (Type B, 12 00 GPH, 80°, Delavan Inc Fuel Metering Products, Bamberg, SC) The nozzle was mounted in a channel welded on to a 90-pound jackhammer (Ingersoll Rand, Woodcliff Lake, NJ) and held in place by a set screw (Figure 1) The nozzle was connected via 16 pounds per square inch (psi) ⅜-inch-diameter flexible hydraulic line to a quarter-turn shut-off valve mounted near the handle of the jackhammer A length of ⅜-inch-diameter air hose led from the valve to a 30-gallon tank (Speedaire model 5F564A, Dayton Electric Mfg, Inc , Chicago, IL) mounted on the air compressor trailer (model 185, Ingersoll Rand, Woodcliff Lake, NJ) (Figure 2) The tank was pressurized to 30 psi The pressure in the tank was controlled by a regulator Two jackhammers were fitted with this control The jackhammers were used with standard moil point chisels for all trials

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)] (2)

In order to measure this reduction, trials were conducted with the control in use (wet) and without using the control (dry) Each trial lasted approximately 1 hour Real-time and filter samples were collected during each trial Sampling pumps and aerosol monitors were turned off during breaks or process disruptions during a trial Sampling resumed until data were collected for approximately 1 hour, when a trial was halted Two construction workers each operated a jackhammer during four trials, two wet and two dry each, for a total of eight trials In order to minimize the effects of lingering dust upon the exposure measurements, the wet trials were conducted before the dry trials The trials were conducted concurrently (Table 1 illustrates the order in which the trials were performed)

Each trial consisted of using a jackhammer to break up a block of concrete or a concrete traffic barrier (laid on its side) in the materials storage yard of the construction company Two large blocks of concrete and 4 concrete traffic barriers were arranged in rows running from northwest to southeast in an area approximately 25 by 30 feet Two construction workers participated in the study Both workers wore hard hats, safety glasses, ear plugs (Form Fit, MSA, Pittsburgh, PA), work gloves, work boots, and N95 respirators (Affinity Pro, MSA, Pittsburgh, PA)

Wind and weather measurements

Wind direction and velocity were measured using an ultrasonic wind sensor (WindObserver II, Gill Instruments Ltd , Lymington, England) mounted on a low wooden stand and placed on top of a stack of stored construction material Temperature and relative humidity were recorded twice during the course of the day using a multi-parameter ventilation meter (VELOCICALC® Plus model 8386, TSI Inc , St Paul, MN)

Water flow measurements

Water flow through the spray nozzle was measured using a stopwatch and a measuring cup 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

Statistical methods

All data were first tested for lognormality, and were found to be lognormal Descriptive statistics and percent reduction in exposure were calculated from the results Plots were made from the real-time data to illustrate the effectiveness of the dust control

RESULTS AND DISCUSSION

During the initial wet trial, the spray nozzle on the jackhammer used by Worker 1 became clogged when it struck the concrete One of the authors accidentally replaced the nozzle with a Type B, 12 0, 60° nozzle (Delavan Inc Fuel Metering Products, Bamberg, SC) Worker 1 used the jackhammer equipped with this nozzle for the remainder of the day The compressed air exhaust on the jackhammers may have influenced the performance of the control After the first hour, the exhaust outlets were rotated so they exhausted more to the front than down, but the range of adjustment was limited to about halfway between straight down and horizontal in either direction

Respirable crystalline silica and respirable dust exposures

The results of personal breathing zone samples collected using the filters and cyclones are presented in Table 1 Values in parentheses indicate results between the limit of detection and the limit of quantitation Results in this range are semi-quantitative estimates Respirable dust results for the wet trials ranged from 0 26 to 0 83 mg/m^3 for both workers Respirable dust results for dry trials ranged from 0 38 to 2 8 mg/m^3 Quartz results for wet trials ranged from 0 04 to 0 29 mg/m^3, for dry trials the quartz results ranged from 0 05 to 0 32 mg/m^3 Dry exposures were higher for Worker 2 than they were for Worker 1

Table 3 illustrates the reductions achieved through the use of the water spray attachment documented by the filter and cyclone sampling For Worker 1, the use of the spray increased his exposure to respirable dust and crystalline silica overall The use of the water spray reduced respirable dust exposure and quartz exposure by 42 and 39%, respectively, when the results of Trial 1, when the water spray nozzle was clogged, are excluded For Worker 2, use of the water spray reduced respirable dust exposure by 71% and reduced quartz exposure by 77%

The results of direct-reading sampling for respirable dust and exposure reduction are provided in Table 4 Average respirable dust exposures during dry trials ranged from 0 67 to 2 6 mg/m^3, for wet trials, they ranged from 0 42 to 1 6 mg/m^3 These results also indicate that Worker 2 experienced higher exposures during dry work than Worker 1 Again, the use of the water spray was shown to increase dust exposure to Worker 1 overall, but when Trial 1 is excluded, the use of the water spray resulted in an exposure reduction of 43% For Worker 2, the water spray reduced respirable dust exposure by 69% Figures 3 and 4 illustrate the reductions achieved through the use of controls Figure 3 compares the results of trials 2 and 3 for Worker 1 Figure 4 compares trails 1 and 3 for Worker 2

Water flow results

The water spray attachment used by Worker 1 with the 12 0, 60° nozzle delivered approximately 250 mL of water per minute at the jackhammer This flow rate reduced quartz and dust exposures by 39 and 43% when compared to no control The water spray attachment used by Worker 2 delivered approximately 300 mL/min at the jackhammer, resulting in a 77% reduction in quartz exposure and dust exposure reductions of 71 to 77% Water supplied at these flow rates did not add a substantial amount of water to the work surface Figure 5 shows a wet trial, illustrating the wetting of the surface, as well as the positions of the workers and the layout of the site

Bulk crystalline silica sampling results

Analysis of the bulk samples collected from three of the highway barriers indicated that they contained 4 0, 28, and 30% quartz (by weight) This variability may depend on whether the sample contained more aggregate

Wind and weather results

The average wind speed was 1 4 mph, with a maximum of 6 3 mph The prevailing wind was from the southwest (average bearing 254 degrees) The workers' positions in relation to the wind direction changed throughout the day, so no attempt was made to correlate wind speed with exposure However, based on observations of the airborne dust, the wind did not appear to hinder the effectiveness of the controls The temperature ranged from 85 to 92 °F The relative humidity ranged from 56 to 60%

Conclusions and recommendations

This study demonstrated that a water spray control that used a readily available nozzle at a low flow rate was capable of achieving up to a 71% reduction in respirable dust exposure and up to a 77% reduction in respirable quartz exposure Compare Figure 5, which shows the use of the control, with Figure 6, a dry trial The inadvertent use of a different nozzle for one of the trials demonstrated the effects of water flow and spray angle on dust suppression for this control A reduction in flow from 300 ml/min to 250 mL/min and a reduction in spray angle from 80° to 60° resulted in a reduction in dust control effectiveness from about 70% at the higher flow rate and wider spray angle to around 40% at the lower flow rate and narrower spray angle The difficulties encountered with the nozzle repeatedly striking the concrete and clogging during the first trial with Worker 1 indicate that worker training in the use of the control is important, that the design should be modified to shield the nozzle, and that the worker should pay attention to whether or not water is flowing from the nozzle

Even with the reduction in quartz exposure seen in the trials for Worker 2, the average quartz exposure of 0 085 mg/m^3 would still exceed the NIOSH REL and ACGIH TLV if this exposure level remained constant over an entire eight-hour shift However, Worker 2 could operate the jackhammer for up to 4 hours and 45 minutes in an eight-hour shift with no other exposures to quartz without exceeding the REL * The average quartz content of 16% in the two samples collected on Worker 2 during the wet trials results in a calculated OSHA PEL of 0 56 mg/m^3 Worker 2 would also exceed the PEL for respirable dust if this exposure level was maintained for an entire shift, given that the average respirable dust concentration for Worker 2's wet trials was 0 67 mg/m^3 At this exposure level, Worker 2 could operate the jackhammer for up to 6 hours and 40 minutes in an eight-hour shift with no other quartz exposures before he exceeded the calculated OSHA PEL of 0 56 mg/m^3 †

* (0 085 mg/m^3 quartz x 285 minutes)/480 minutes = 0 050 mg/m^3 of quartz, 8-hr TWA

† (0 67 mg/m^3 respirable dust x 400 minutes)/480 minutes = 0 56 mg/m^3 of respirable dust, 8-hr TWA

The current configuration consisted of one nozzle aimed at the front of the jackhammer chisel Additional designs should be constructed and tested to determine if a different nozzle arrangement, a higher flow rate, or another nozzle type would result in better control To minimize the influence of the compressed air exhaust from the jackhammer on the effectiveness of this control, the exhaust should be directed away from the point of operation

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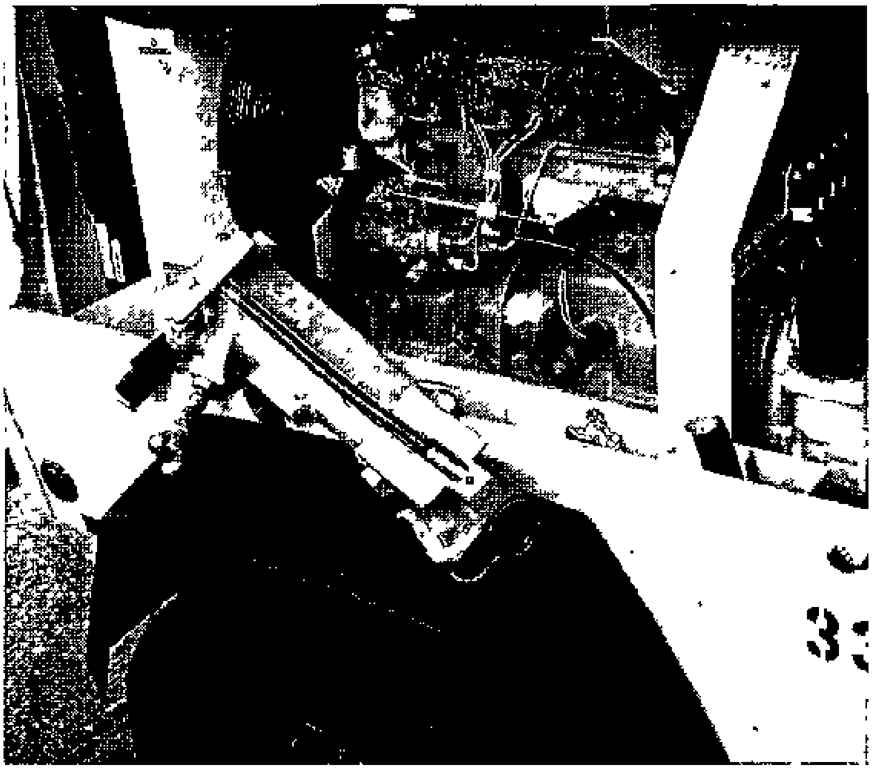

Figure 1   Jackhammer with dust control device

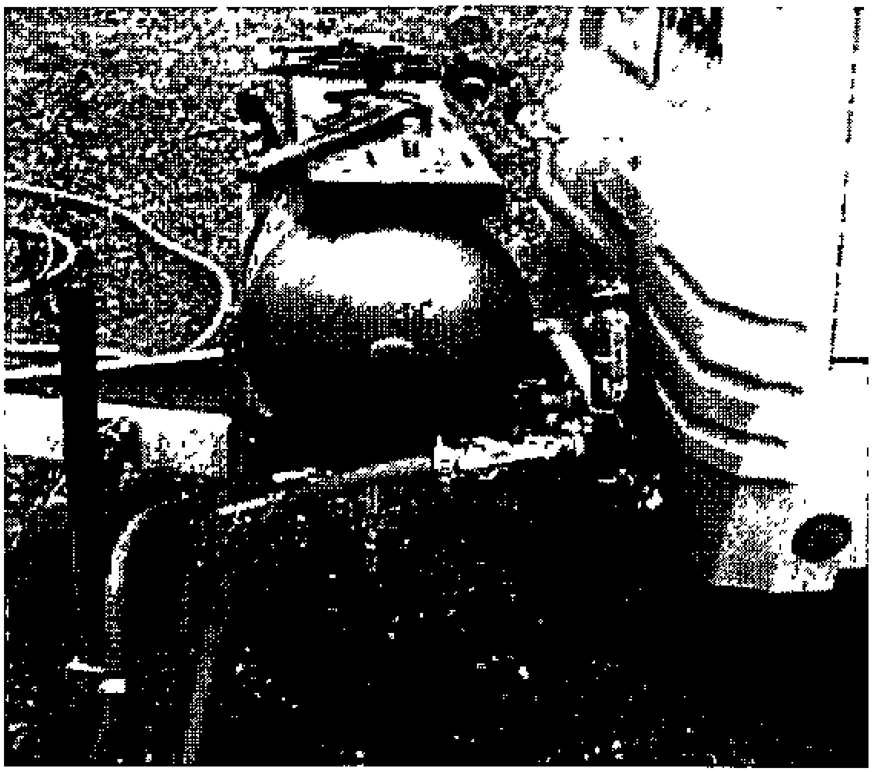

Figure 2 Water tank mounted on compressor trailer

Figure 3 Effectiveness of Control - Worker 1

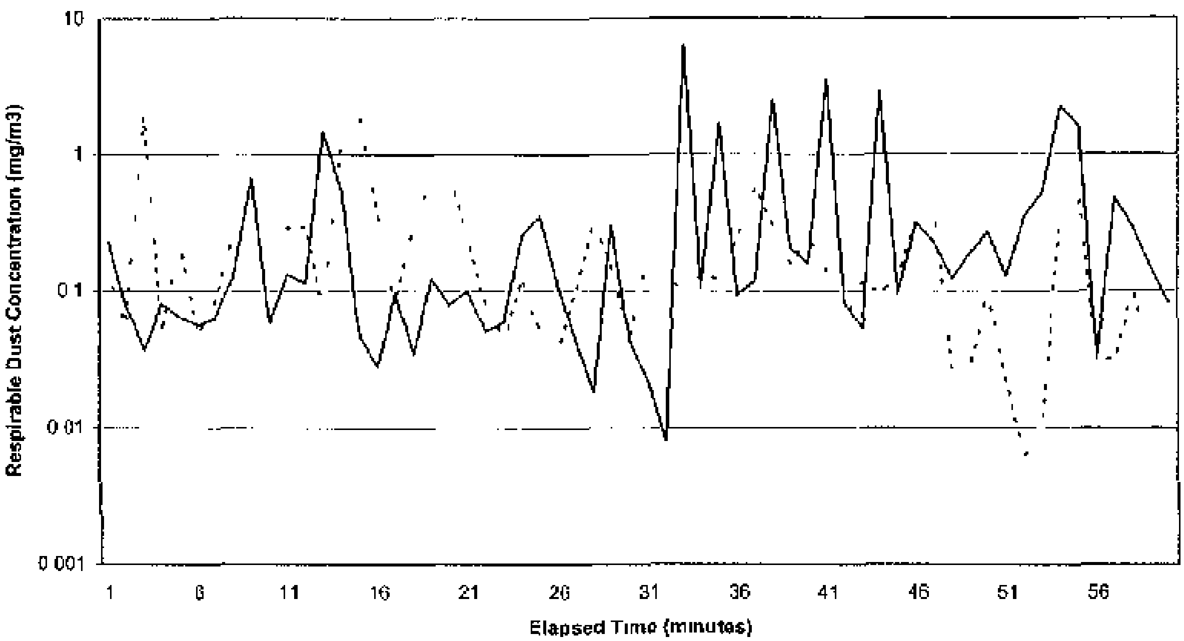

Figure 4 Effectiveness of Control - Worker 2

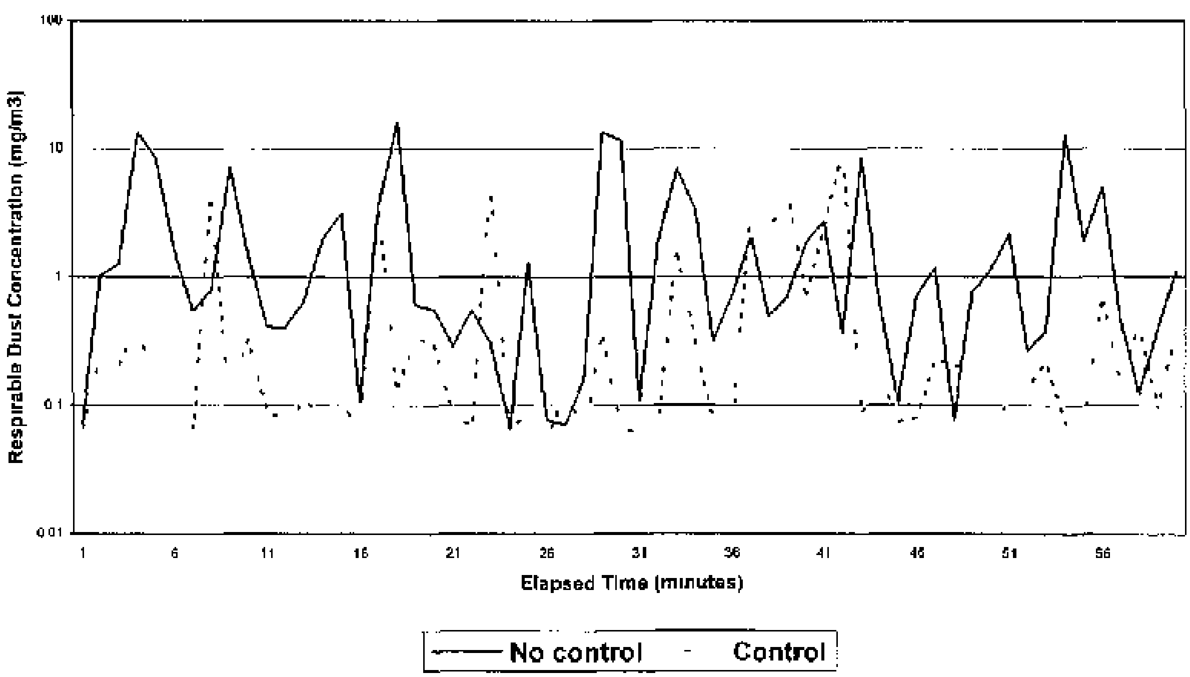

Figure 5 Workers during a wet trial

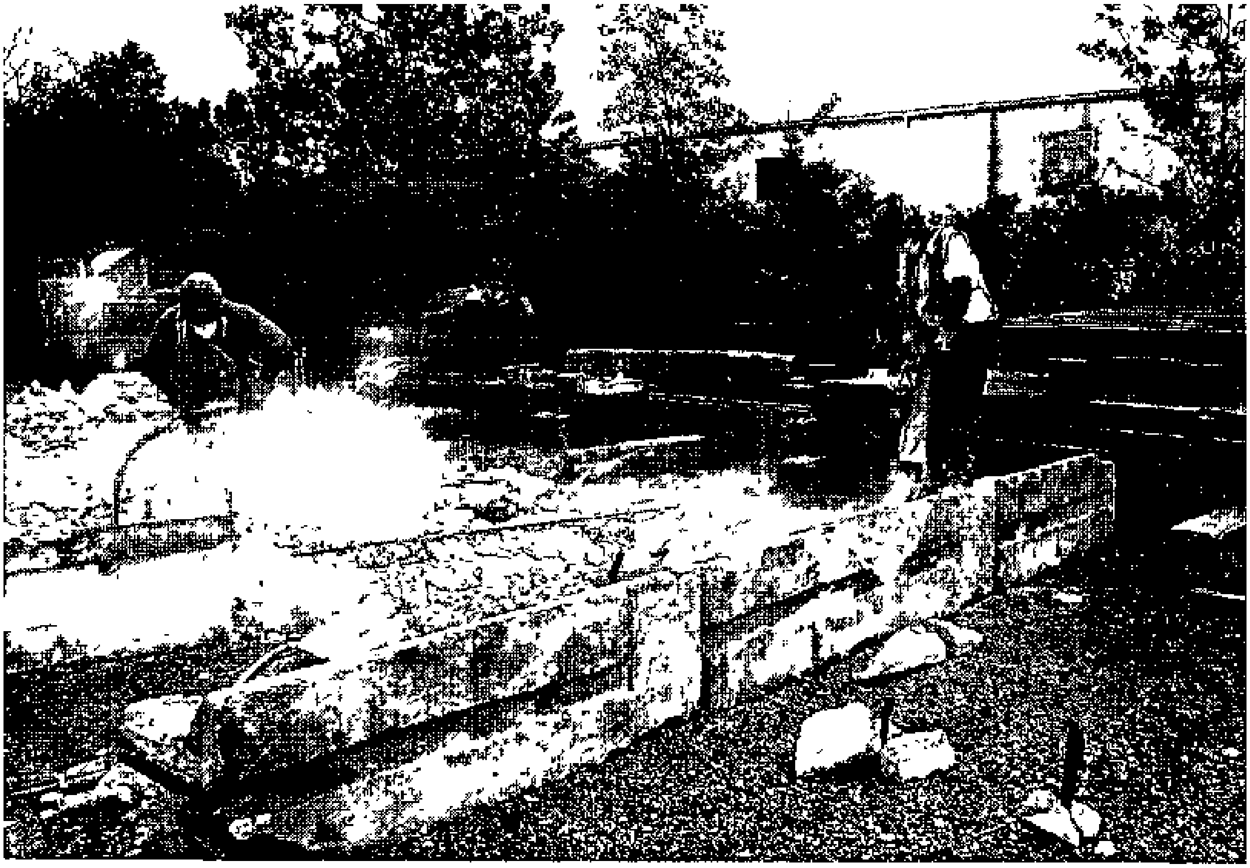

Figure 6 Workers during a dry trial

Table 1 Experimental Design

Worker 1	Worker 2
Wet trial	Wet trial
Wet trial	Wet trial
Dry trial	Dry trial
Dry trial	Dry trail

Table 2 Results of Personal Breathing Zone Samples for Respirable Dust and Quartz Collected on Filters

Trial	Control	Respirable Dust (mg)	Quartz (mg)	Average Flow, (L/min)	Time (min)	Volume (m^3)	Respirable Dust mg/m^3	Quartz mg/m^3
Worker 1								
1	wet	0.21	0.07	4.24	60	0.25	0.83	0.29
2	wet	0.066	(0.01)	4.24	60	0.25	0.26	(0.04)
3	dry	0.097	(0.02)	4.24	60	0.25	0.38	(0.08)
4	dry	0.11	(0.01)	4.24	50	0.21	0.52	(0.05)
Worker 2								
1	wet	0.13	0.03	4.27	60	0.26	0.51	0.13
2	wet	0.21	(0.01)	4.27	60	0.26	0.82	(0.04)
3	dry	0.71	0.11	4.27	60	0.26	2.77	0.43
4	dry	0.41	0.07	4.27	53	0.23	1.81	0.32

Values in parentheses indicate results between the limit of detection and the limit of quantitation Results in this range are semi-quantitative estimates

Table 3 Exposure Reductions from Water Spray

Respirable Dust (mg/m^3) Average Wet	Respirable Dust (mg/m3) Average Dry	Respirable Dust Percent Reduction	Quartz (mg/m^3) Average Wet	Quartz (mg/m3) Average Dry	Quartz Percent Reduction
Worker 1					
0.55	0.45	-21	0.17	-0.065	-154
0.26*	0.45	42*	0.04	0.065	39*
Worker 2					
0.67	2.29	71	0.085	38	77

*Excluding the results of trial 1 for Worker 1

Negative number indicates an increase in exposure when control was used

Table 4 Direct Reading Respirable Dust Results

Trials	Control	N Obs	Arithmetic Mean mg/m³	Std Deviation	Min mg/m³	Max mg/m³	Mean mg/m³	% Difference	GM	GSD
Worker 1										
1	wet	2766	1 6	3 4	0 026	34	94*	-26*	0 41	5 1
2	wet	3585	0 42	1 2	0 0050	23	42**	43**	0 15	3 5
3	dry	4800	0 79	2 6	-0 0020	42	74		0 12	5 9
4	dry	3158	0 67	2 2	0 0000	40			0 16	4 6
Worker 2										
1	wet	3722	0 68	1 5	0 054	20	66	69	0 22	3 7
2	wet	4146	0 64	1 9	0 040	40			0 24	3 4
3	dry	3617	2 6	4 9	0 032	67	2 1		0 74	5 5
4	dry	3148	1 6	4 0	0 039	58			0 35	5 1

* Including the results of trial 1 for Worker 1 ** Excluding the results of trial 1 for Worker 1 Negative number indicates an increase in exposure when control was used