IN-DEPTH SURVEY REPORT:

CONTROL TECHNOLOGY FOR CRYSTALLINE SILICA EXPOSURES IN CONSTRUCTION: EXPOSURES AND PRELIMINARY CONTROL EVALUATION

at

Various Sites For Bricklayers Local #9
Pittsburgh, Pennsylvania

REPORT WRITTEN BY
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REPORT DATE
February, 2000

REPORT NO
ECTB 247-12

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Public Health Service
Centers for Disease Control and Prevention
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STUDY SITES	Harris Masonry 420 Greentree Road Pittsburgh, Pennsylvania 15220 Bitz Foundation Building Southeast of intersection of 9th Street and Duquesne Boulevard Pittsburgh, Pennsylvania
BUSINESS OFFICE OF CONTRACTOR	Mr Kenneth Boeltz R G Friday Restoration 148 Perrysville Avenue Pittsburgh, Pennsylvania 15229
SIC CODE	1799
STUDY DATES	June 14-16, 1999
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ABSTRACT

Respirable silica exposures were measured while workers were using grinders to remove old mortar during a building renovation   Respirable silica exposures ranged from 1 0 to 3 0 mg/m^3 grinding mortar, well in excess of the NIOSH Recommended Exposure Limit of 50 µg/m^3 A preliminary evaluation of available engineering controls revealed that control measures ineffectively control the dust generation by the grinding operation   Control measures evaluated included two ventilated shrouds for grinding and the application of water to the grinding wheel Testing on one ventilated shroud was terminated because dusty air, which was likely to contain an excessive amount of respirable crystalline silica, was emitted from the back of the grinder   A 30-minute exposure measurement resulted in a measured exposure of 9 mg/m^3 of respirable crystalline silica   A commercially available grinder was tested which also emitted much dust   A wet grinding device resulted in a respirable dust concentration of 0 3 mg/m^3 for a one hour sampling period   Apparently, wet grinding can suppress dust emissions   However, the use of water with an electric grinder raises concerns about electrical shock hazards for the operator

INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH), a federal agency located in the Centers for Disease Control and Prevention, under the Department of Health and Human Services, was established by the Occupational Safety and Health Act of 1970 This legislation mandated NIOSH to conduct research and education programs separate from the standard setting and enforcement functions conducted by the Occupational Safety and Health Administration (OSHA) in the Department of Labor An important area of NIOSH research deals with methods for controlling occupational exposure to potential biological, chemical, and physical hazards

The Engineering Control Technology Branch (ECTB) of the Division of Physical Sciences and Engineering (DPSE) has been given the lead within NIOSH to study the engineering aspects relevant to the control of hazards in the workplace Since 1976, the ECTB has assessed control technology found within selected industries or used for common industrial processes ECTB has also designed new control systems where current industry control technology was insufficient The objective of these studies has been to document and evaluate effective control techniques (e g , isolation or the use of local ventilation) that minimize risk of potential health hazards, and to create an awareness of the usefulness and availability of effective hazard control measures

The survey at this site was conducted as part of a larger effort to evaluate the technical feasibility of controlling worker exposure to respirable crystalline silica In addition, NIOSH's ECTB has been interested in evaluating new technologies which reduce worker exposure to hazardous air contaminants such as respirable crystalline silica This study occurred because Brick and Allied Crafts Local #9 and NIOSH's ECTB have a common interest in evaluating control measures for the dust generated grinding mortar between bricks prior to tuck pointing At the time this study was being planned and executed, an OSHA inspector in the Chicago area had reported respirable crystalline silica exposures that were typically 10 to 50 times the Permissible Exposure Limit enforced by the Occupational Safety and Health Administration [1] Some preliminary data on the performance of three control ventilated grinders used for tuck pointing was collected In addition, exposure monitoring was done for an uncontrolled tuck pointing job at active job site

Premature death from silicosis still occurs. In 1998, the deaths of two sandblasters from silicosis were reported [2] In one case, a worker was diagnosed with progressive massive fibrosis after 3 years of experience as an abrasive blaster He died of respiratory failure 11 years after his initial exposure This worker was only 36 years old In another case, a worker died of respiratory failure from silicosis at age 30 He worked as sandblaster from 1986 to 1990 and died in 1996 At the autopsy, the lungs of both workers had an extremely high silica content From 1968 to 1992, about 10 workers between the ages of 15 and 44 died of silicosis each year [2] These deaths were attributed to inappropriate respirator usage and recent, intense exposure to crystalline silica that were 10 to 100 the OSHA permissible exposure limit which is approximately 0 1 mg/m^3 of respirable crystalline silica [3,4]

Exposure Evaluation Criteria

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff use exposure limits as evaluation criteria for assessment of a number of chemical and physical agents These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week, for a working lifetime without experiencing adverse health effects. Table 1 summarizes exposure limits for air contaminants which sampled at this site It is important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels A small percentage may experience adverse health effects because of individual susceptibility, a preexisting medical condition, and/or a hypersensitivity (allergy)

The primary sources of environmental evaluation criteria in the United States used for the workplace are 1) NIOSH Recommended Exposure Limits (RELs), 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs), and 3) the U S Department of Labor (OSHA) Permissible Exposure Limits (PELs) In addition to addressing health effects and significant risk when developing PELs, OSHA is also required to consider the feasibility of controlling exposures in various industries where the agents are used, the NIOSH RELs, by contrast, are based primarily on concerns relating to the prevention of occupational disease ACGIH Threshold Limit Values (TLVs) refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects ACGIH states that the TLVs are guidelines It should be noted that ACGIH is a private, professional society, and that industry is legally required to meet only those levels specified by OSHA PELs

Table 1. Relevant Exposure Limits (mg/m^3) as 8- Hour Time Weighted Averages

Air Contaminant	NIOSH REL[5] mg/m^3	OSHA PEL[6] mg/m^3	ACGIH TLV[7] mg/m^3
Respirable Cystalline Silica	0 05	Varies with amount of quartz in dust See equation 1	0 05
Particulates, not otherwise classified - respirable		15	10
Particulates, not otherwise classified - inhalable		5	3

The current OSHA Permissible Exposure Limit (PEL) in mg/m^3 for respirable dust containing quartz is calculated from the following formula

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

Site Description

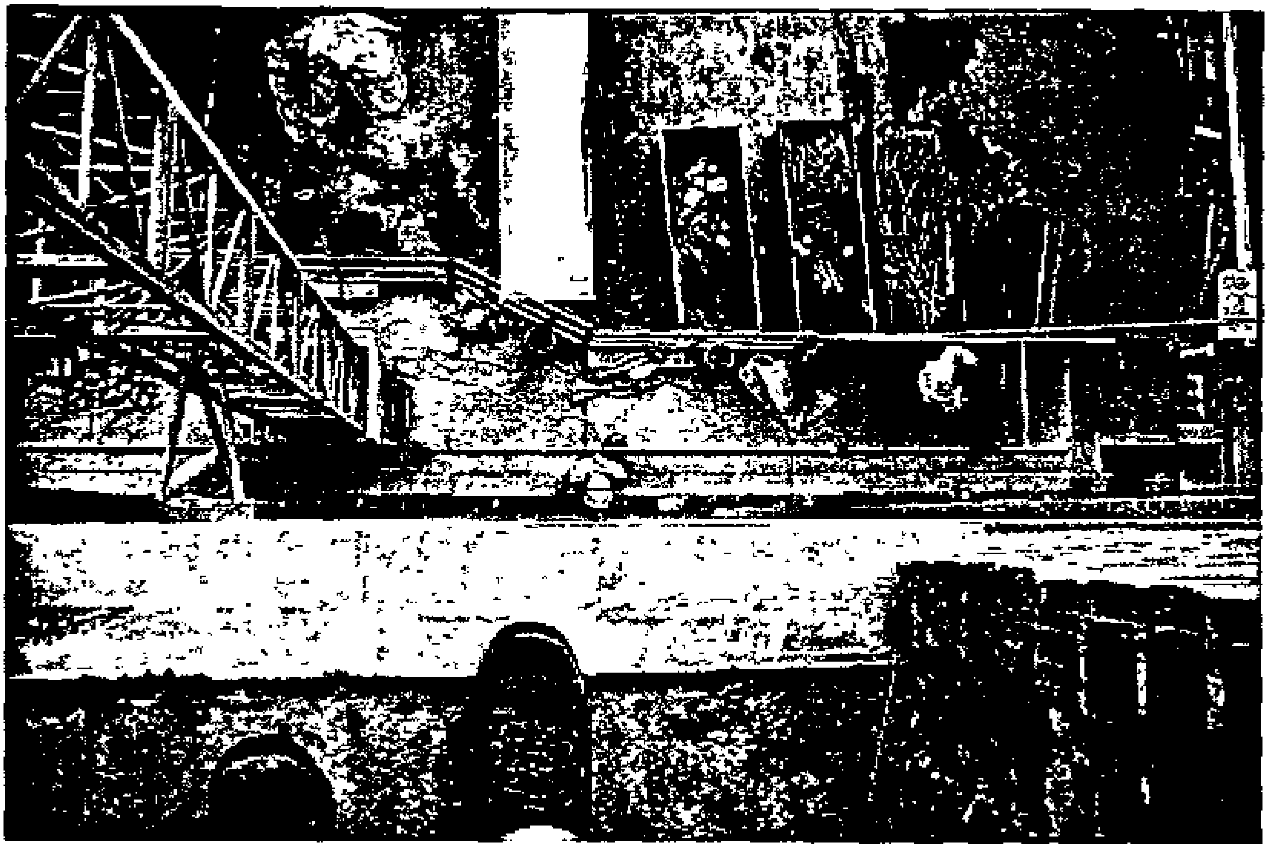

Figure 1 Top view of the platform on which the tuck pointing occurred

This study took place at two locations At the Bitz foundation building in downtown Pittsburgh near the intersection of 9th Street and Duquesne Boulevard The side of this multi-story building was being tuck pointed Two or three workers stood on the platform shown in Figure 1 These workers used grinders to remove about 0 5 inches of mortar from between the bricks creating much obvious dust exposure Before replacing the removed mortar, a power washer was used to remove the dust At this study site, the workers wore respirators to control their dust exposures

The second site was the Harris Masonry warehouse This was an old building which was being renovated and used for training masonry workers Three tuck pointing grinders were evaluated at this site

Figure 2 Dusty workers after grinding mortar The worker on the left wore his own full-face piece respirator The worker on the right wore a half-face piece disposable respirator with an exhalation valve A close up of this worker's face indicated some leakage suggesting that his fit was inadequate

PROCEDURES

The study was conducted to evaluate the exposures to crystalline silica and to identify exposures associated with the operation of the tuck pointing grinders The workers' exposures to dust and crystalline silica were measured At the Bitz Foundation Building, full-shift exposure monitoring was conducted on tuck pointing operations which did not have provisions for dust control At the Harris Masonry warehouse, short-term exposure monitoring and video exposure monitoring were conducted to obtain preliminary information on the three grinders which had provisions for dust control

At the study sites, the worker's exposure to total dust, respirable dust, total crystalline silica and respirable crystalline silica was measured Air samples for total and respirable dust were collected as described by NIOSH methods 0500 and 600 [8,9] This involved mounting two sampling trains on each worker Total dust samples were collected by mounting a 37-mm closed face cassette on the worker's shirt collar and using a calibrated battery-operated pump to draw a known volume of air through the cassettes Respirable dust samples were collected by mounting a 10-mm cyclone on the worker The outlet of the cyclone is attached to the inlet of a 37-mm filter holder A calibrated sampling pump draws 1 7 lpm of air through the cyclone During the grinding operations at the Bitz foundation building, the samples were collected over a full shift At the Harris Masonry warehouse, short term air samples were collected

During short term tuck pointing at the Harris Masonry warehouse, short-term respirable dust samples were collected at a flow rate of 4 2 lpm Instead of using the 10-mm nylon cyclone specified in NIOSH Method 0600, a stainless steel cyclone (BGI-4 High Flow Respirable Dust Cyclone, BGI Incorporated, Watham, Massachusetts) was used to conduct respirable dust sampling at 4 2 lpm

At the end of the sampling period, the sampling time was recorded and the plugs were placed back into the cassettes The samples were analyzed for total weight gain per NIOSH methods 500 and 600 Then, the samples were analyzed for crystalline silica by x-ray diffraction using NIOSH method 7500 [10] The following modifications were used in the sample analysis

1 Filters were dissolved in tetrahydrofuran rather than being ashed in a furnace
2 Standards and samples were run concurrently and an external calibration curve was prepared from integrated intensities

When an excessive amount of material was collected on the filter, the samples were treated as bulk samples A 2-milligram portion was removed from the material collected on each sample and the mass of crystalline silica in the 2-milligram portion was measured The percent of crystalline silica in this 2-mg bulk was reported For these samples, the mass of crystalline silica was the product of the gravimetric analysis conducted under methods 0500 and 0600 and the fraction of crystalline silica in the bulk sample obtained from the filter cassette

Video Exposure Monitoring

Video exposure monitoring was done as part of a short-term evaluation of grinders which incorporated some form of dust control Video exposure monitoring is typically done to evaluate how work activities affect exposure [11] An aerosol photometer (HAM, PPM Inc Knoxville, Tennessee) was mounted on the worker's chest. Air is drawn through the sensing chamber of this instrument by a battery-operated pump at 2 lpm The dust in the sensing chamber scatters light emitted from a light-emitting diode The scattered light is detected by a photo multiplier tube The analog output of the aerosol photometer is proportional to the amount of light detected by the photo multiplier tube Because the amount of light scattered by the aerosol varies with the particle's size and optical properties, the analog output of the aerosol photometer is a measure of relative concentration. The HAM's were used with a 1 second time constant and their analog output was recorded every second by a data logger (Metrologger dl 3200, Metrosonics, Rochester, New York) While the output of the HAM was recorded on the data logger, the worker's activities were concurrently recorded on videotape The videotapes and the analogy output were reviewed to evaluate the extent to which work practices affected exposure

Ventilation Measurements

The grinders studied at the Harris Masonry warehouse all involved some form of ventilation The air flow was estimated by using a velometer (Velocicalc , TSI St Paul, Minnesotan) to measure the air flow

RESULTS
At the Bitz Foundation Building - Uncontrolled Grinding

Tables 1 and 2 list the dust exposures measured on workers who are doing the grinding task associated with tuck pointing The respirable crystalline silica exposure measurements reported in Table 1 are very excessive in terms of the NIOSH-recommended exposure limit (REL) of 0 05 mg/m^3 The OSHA permissible exposure limit is approximated at twice the NIOSH REL The total and respirable exposures reported in Tables 2 and 3 exceed the OSHA permissible exposure limits for limits for total dust and respirable dust of 15 and 5 mg/m^3, respectively These results clearly indicate a need to develop control measures for the dust generated by grinding mortar

Table 2 Respirable Dust and Cystalline Silica Exposures.

Date	Start	Stop	Total Time (minutes)	Respirable Dust Concentration (mg/m^3)	Respirable Crystalline Silica Concentration (mg/m^3)
6/15/99	7 00	15 20	500	5 4	1 29
6/15/99	7 00	15 20	500	8 51	1 88
6/16/99	7 00	15 30	510	16 6	2 65
6/16/99	7 00	15 30	510	12 9	2 19
6/16/99	7 00	15 30	510	13 3	2 8

Table 3 Exposures to Total Dust

Date	Start	Stop	Total Time (minutes)	Total Dust Concentration (mg/m³)
6/15/99	7 00	15 20	500	24 4
6/15/99	7 00	15 20	500	91 1
6/16/99	7 00	15 30	510	315 0
6/16/99	7 00	15 30	510	35 2
6/16/99	7 00	15 30	510	442 0

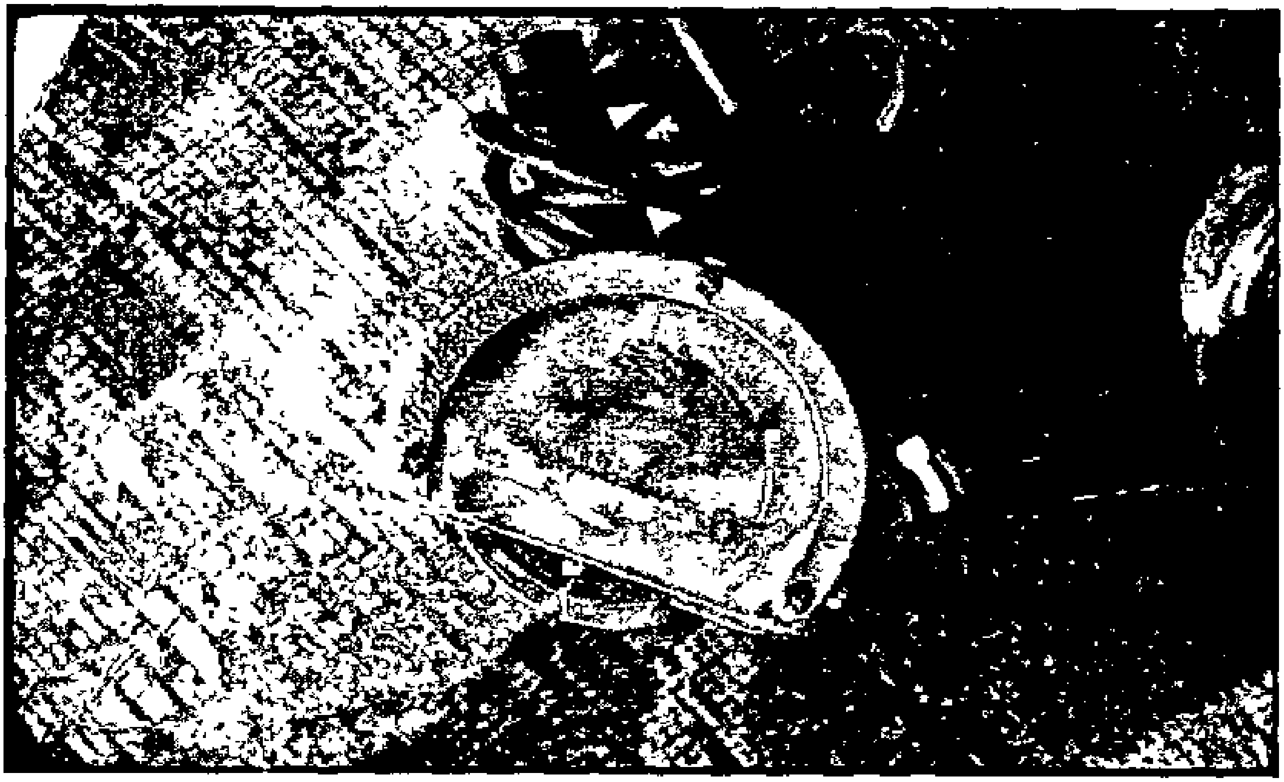

Figure 3 Matabo grinder with shroud The exhuast takeoff is at about a 45 degree angle with the flat surface

RESULTS
Harris Masonry Warehouse

Ventilated Metabo Grinder

A Metabo Grinder (Vollwellenei Germany) with ventilation was studied A vacuum cleaner exhausted 54 cfm of air from the ventilated shroud The air flow was measured by placing the grinder in an enclosed container which had a 1"x 9" slot The exhaust volume is based upon the air velocities measured in this slot The grinder had a maximum rotational speed of 8500 rpm The blade diameter was 4 inches and the blade thickness was 1/4' The enclosure allowed a cut depth of 0 75 inches

Short term exposure monitoring was conducted while the grinder was being used to remove mortar on the Harris Masonry Warehouse During the grinding operation, much dust was observed to be flowing out of the gap between the brick wall and the grinder enclosure The dust appeared to flow from the back of the grinder Sampling was terminated after 30 minutes because the control measure appeared to be ineffective The sampling results presented in Table 4 confirm the visual observation that the control measure did not adequately control the workers dust exposure

Table 4. Ventilated Metabo Grinder

Date	Sampling Location	Type of Sample	Start Time	Stop Time	Sampling Time	Sampling Rate (lpm)	Respirable Dust (mg/m^3)	Quartz Concentration (mg/m^3)
6/15/99	near air cleaner	respirable	9 58	17 18	30	1 7	6 47	1 71
6/15/99	near air cleaner	total	9 04	13 05	30	2 00	1 67	0 33
6/15/99	personal - doing tuck pointing	respirable	9 23	13 17	30	1 70	103	9 01
6/15/99	personal - doing tuck pointing	total	9 16	13 17	30	2 00	647	245

Sawteck Grinder

The Sawteck grinder (see Figure 4) was a modified Hilti DC500 that operated at 11,000 rpm with a 5 inch diameter blade The axle which turned the blade also turned the blower The blower exhausted air from the enclosure and discharged the air through a 2 3/16" diameter flexible hose into a Sawteck filter bag (US patent 5,074,044) Based upon a centerline velocity of 1500 fpm in the flexible duct (See Figure 5), the exhaust volume was estimated to be 40 cfm A worker used this tool to conduct some tuck pointing on a wall on the building Video exposure monitoring was conducted to obtain some insight whether this device provides some dust control Exposure is plotted as a function of time in Figure 6 Continuous grinding appears to cause exposure peaks The operator thought these peaks occurred when he pulled the tool back to see the cut In Figure 7, the fraction of exposure less than a concentration (cumulative distribution function) is plotted for three grinder positions

1 Grinder moving away from the body
2 Grinder moving toward body
3 Grinder being outside of cut

None of these positions appeared to affect the distribution of concentrations measured with the HAM All of these exposures remained below 1 mg/m^3 for about 70 percent of the time When the grinder remains flush against the wall, little dust escapes Quite possibly, dust and leakage exposure occurs because the worker is not able to maintain the tool flush against the wall

In using this tool, the operator was unable to remove mortar without damaging the bricks The bricks had numerous gashes which would be unacceptable for some customers The operator offered these comments on the use of this machine

1 Gouged bricks because of poor visibility, need to see joint in order to cut properly
2 Need to keep the tool flat and flush against the wall to avoid dust emissions
3 Moving the tool backwards (right to left) seemed to cause dust emissions
4 The bag for air cleaning appeared to leak dust Dusty air appeared to be flowing through the bag's media This did not appear to be a leak due to a poor seal

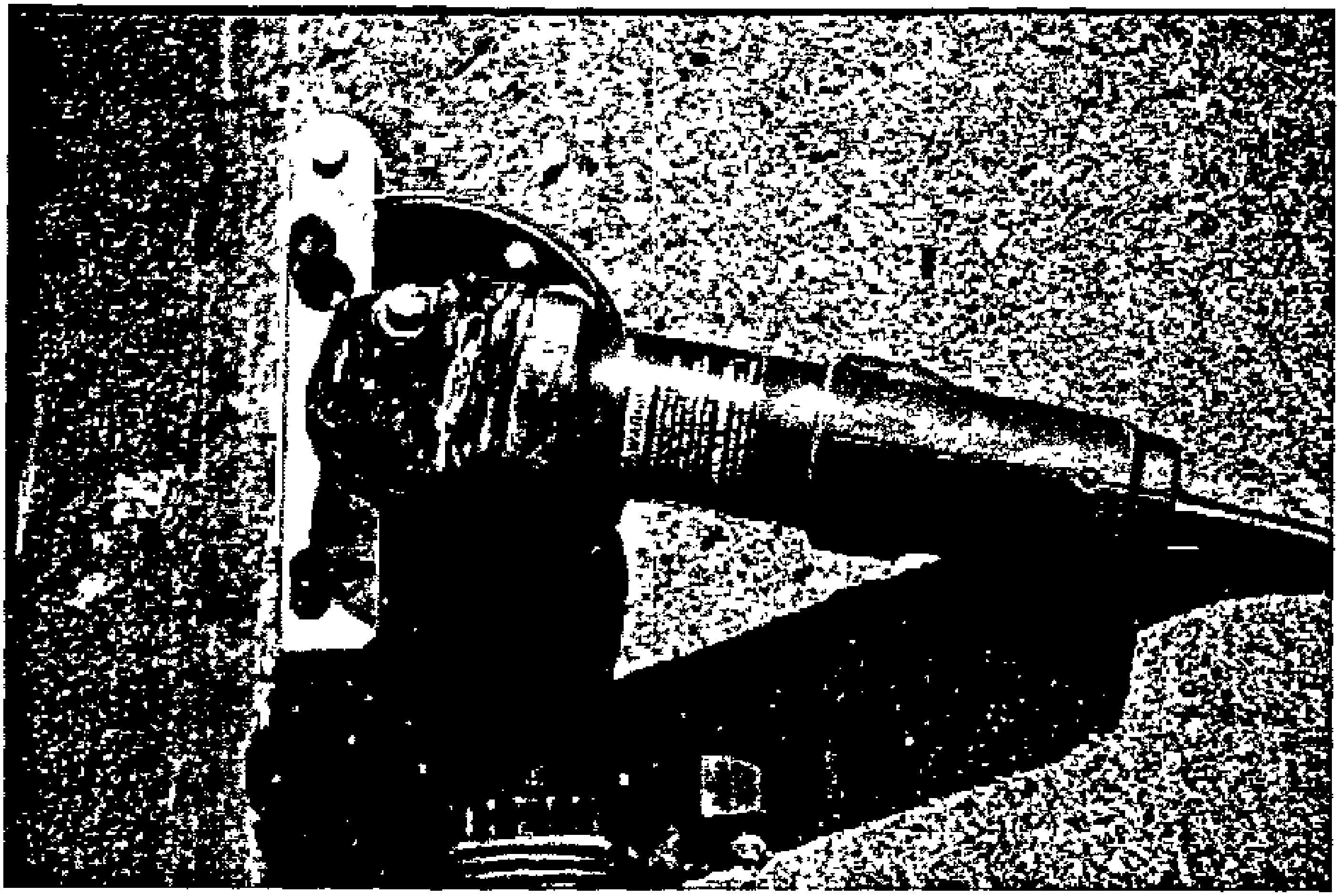

Figure 4 The Sawteck grinder Note the exhaust take off near the back of the shroud

Figure 5 The Sawtec filter bag The performance of the air cleaning bag was suspect A Grimm PDM (model 106, Ainring Germany) indicated that an alveolar dust concentration of 22 mg/m^3 was measured adjacent to the bag The dusty air appeared to flow though the bag's filter media

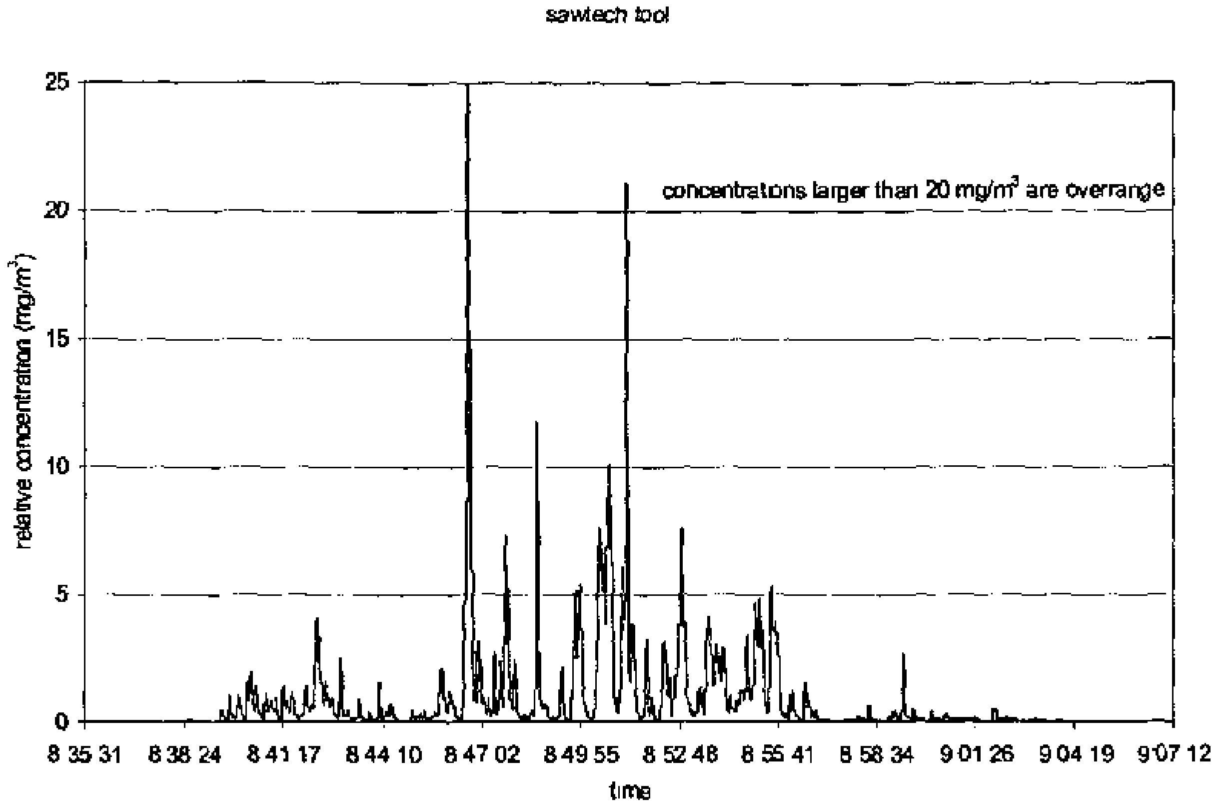

Figure 6 Relative concentrations measured on the worker while the Sawtech tool was used

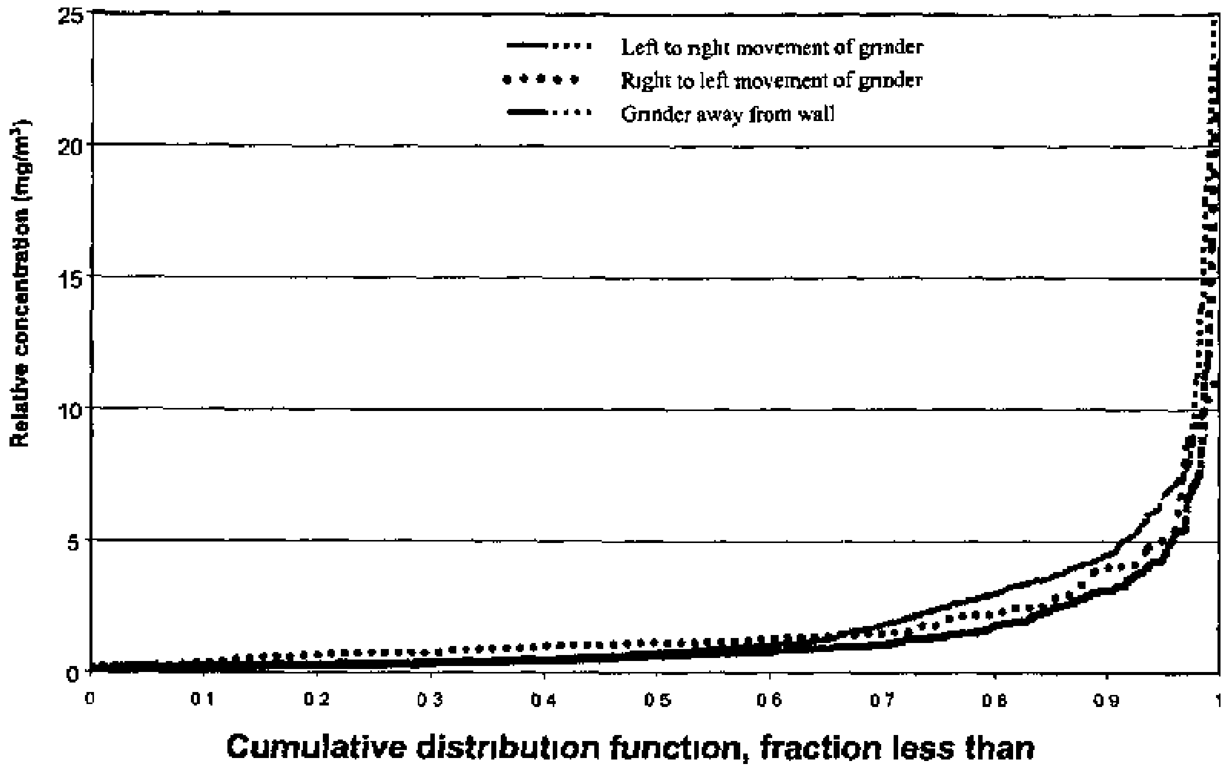

Figure 7 Cumulative distribution of concentrations measured with the HAM About 70 % of the concentrations are below 1 mg/m^3

A Wet Grinder

A local union member modified a Metabo grinder with a ventilated shroud and a small water application nozzle (Figure 8) This grinder had been used 15 years earlier in a restoration of a building on the registry of National Historical Landmarks Water from a garden pump spray (Figure 9) was used to supply water to the grinding wheel via about a 1/16" diameter piece of copper tubbing The flow rate is adjusted by using the pump to increase the pressure in the spray can and a plastic pinch clamp on the hose The water flow filled a 20-once beverage container in 45 seconds The grinder used a 4 inch grinding wheel A shop vacuum cleaner (unknown age, model number, etc) designed for wet and dry use was used to remove the wet, old mortar Based upon a centerline velocity of 5800 fpm and flexible duct diameter of 2 1 inches, the estimated exhaust flow was 140 cfm

Short term dust exposure measurements and video exposure monitoring were conducted to evaluate dust exposures during a brief demonstration of exposure control during this operation During the evaluation, the worker was isolated from dust emissions caused by shop vacuum cleaner The hose was connected to a 10 foot length of 2 inch diameter schedule 40 plastic pipe which, after wrapping with duct tape, fit snugly into the inlet for the shop vacuum cleaner For a one hour sampling period, total dust and respirable dust concentrations were 0 59 and 0 38 mg/m^3 These samples were not analyzed for crystalline silica because the filter loading was too low The results of the video exposure monitoring are presented in Figure 10

Figure 8 The garden sprayer, grinder, and flexible duct connection between the grinder and the plastic pipe

Figure 9 Metabo grinder with exhaust ventilation and provisions for placing water on the grinding wheel

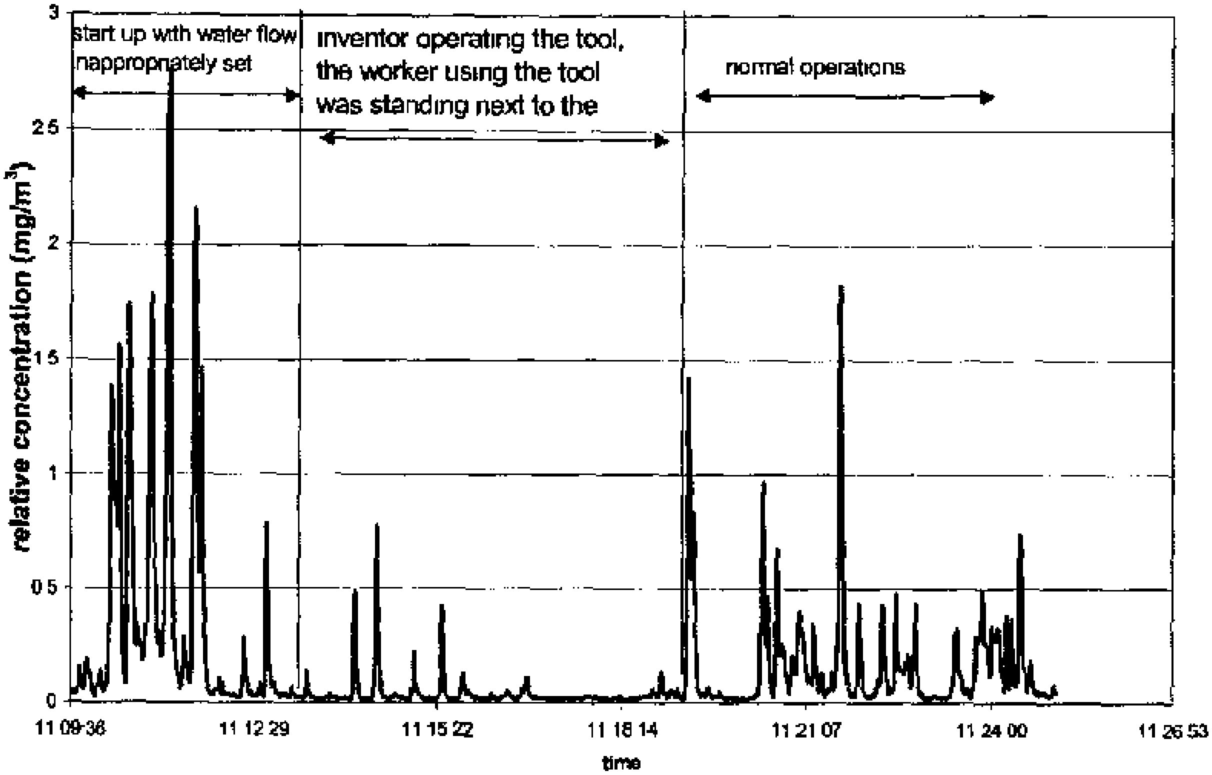

Figure 10 Relative dust concentrations measured on the worker while using the Metabo tuck pointing grinder with water application

DISCUSSION

Bitz site

At the Bitz site and other tuck pointing operations involving appropriate respiratory protection is an immediate need in terms of protecting workers from excessive exposure to respirable crystalline silica and airborne dust The workers doing the grinding wore either full-facepiece respirators, half-facepiece respirators, or a disposable half-facepiece respirator during our visit Pages 10-13 of the publication "Request for Assistance in Preventing Silicosis and Deaths in Construction Workers" discuss appropriate respirator usage Because one exposure to respirable crystalline silica exceeded 2 5 mg/m^3 (greater than 50X REL), a supplied air respirator operated in a pressure demand mode would be needed to adequately protect the workers The respirators worn by the workers all have assigned protection factors, which are too small in terms of the excessive exposures The use of air hoses on an elevated scaffolding could create a dangerous tripping hazard If the number of workers grinding on the platform were restricted to two (during our site visit, there were 3 grinders), perhaps the exposure to crystalline silica would be reduced sufficiently so that a full-facepiece respirator equipped with a high-efficiency particulate filter (N100) would be provide adequate exposure reduction However, one would need to verify that the exposures and respirator selection are consistent with the recommendation described in the document "Request for Assistance in Preventing Silicosis and Deaths in Construction Workers " In order to ensure that respirators are protective, one needs to run a comprehensive respirator program that complies with 29 CFR 1910 134

Harris Masonry Warehouse

Good occupational safety and health practice dictates that engineering control measures are used to control exposures as much as possible before permanently using respirators to control air contaminant exposures Based upon the data collected at the Harris Masonry site, none of the control measures as tested would adequately control dust exposures during tuck pointing

The Metabo grinder with the ventilated shroud pictured in Figure 3 appeared to provide poor dust control The short- term respirable crystalline silica exposure was 9 mg/m^3. The dust appeared to dispersed from the rear of the grinder The rotational motion of the grinder appears to induce an flow which moves dusty air away from the back of the grinder In fact, the testing of this grinder was halted because the dust exposure was obviously excessive

The Sawteck grinder studied appeared to leak dust as shown in Figure 6 In addition, dusty air appeared to be flowing through the filter media in the filter bag used to collect the dust As used at this site, this tool did not appear to be a completely effective means of controlling the dust generated during tuck pointing There were no directions and training for the proper use of this tool Furthermore, specifications were not available for the minimum air flow rate for this tool Altering work practices, exhausting a greater volume of air, and using more efficient filter media could all potentially be done to reduce emissions and the exposure peaks observed in Figure 6

The wet grinder pictured in Figure 8 appeared to provide lower exposure peaks in Figure 10 than the Sawteck device In addition, respirable dust concentrations were kept under 0 4 mg/m^3 This suggests that wet grinding could be a control option for respirable crystalline silica exposures during tuck pointing However, electrical safety issues will inhibit the use of wet grinding as a control measure The Metabo grinder has holes used for ventilating the motor windings This hole is located on the handle near the shaft for the grinder If water enters this hole, an electrical short circuit could occur and the operator could potentially receive an electrical shock

Based upon the preceding discussion, none of the control measures studied at the Harris Masonry warehouse could be recommended as an engineering control for dust generated by tuck pointing The wet grinding approach and the Sawteck device probably merit further study and development Perhaps, wet grinding could be done with a pneumatic grinder This would eliminate the electrical safety issues. If the exhaust flow rate for the Sawteck grinder were increased and the exhaust filtration were improved, perhaps this grinder could also be used for dust control

Controlled experimentation is needed to develop performance specifications for both wet and dry, ventilated grinders The effect of water application rate and exhaust ventilation rate upon dust emissions needs to be evaluated to determine minimum specifications which will reduce exposures Dry grinders induce air motion which complicates the capture of dust-laden air by any vacuum system Disks rotating in an enclosed housing are known to induce air motion The air in the gap between the disk and the housing rotates at about half the rotational speed as the disk [12] In addition, the grinding disks have notches which are intended to assist in the removal of mortar debris To some extent, these notches may also act to move air

The data with the wet Metabo grinder also suggests that water can be used to control dust generation To develop formal control recommendations, one needs to understand the relationship between water application rate and dust suppression However, electrical safety issues need to be addressed before water is used with electrical grinders

CONCLUSIONS

The respirable crystalline silica exposures at the Bitz construction site were excessive (i e , 1 0 to 3 0 mg/m^3) in terms of the NIOSH Recommended Exposure Limit to respirable crystalline silica and these exposure are a significant hazard to the worker's health These exposures need to be minimized as much as possible by spacing out the grinding operations and using engineering controls which are known to reduce worker exposure to respirable crystalline silica Until suitable engineering control measures can be devised that reduce respirable crystalline silica below the 50 $\mu g/m^3$ recommended by NIOSH, a respirator program which fully complies with the OSHA respirator standard (29CFR1910 134) is essential to the protection of the worker's health

As tested, the control measures evaluated at the Harris Masonry warehouse did not appear to be suitable devices for dust control Perhaps with modification, these devices can be used to reduce worker exposure to respirable crystalline silica

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