IN-DEPTH STUDY REPORT:

CONTROL TECHNOLOGY FOR CRYSTALLINE SILICA EXPOSURES IN CONSTRUCTION: EXPOSURES AND PRELIMINARY CONTROL EVALUATION AT A RESTORATION PRESERVATION MASONRY CONSTRUCTION SITE

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SIC CODE:	1799, Special Trade Contractors NEC
STUDY DATES	April 10-11, 2000
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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 0.1 to 4.5 mg/m^3 for workers who were grinding mortar. A ventilated shroud was used in an ineffective attempt to capture the dust generated by the grinders. The pressure drop through the shroud, hoses, PVC pipe, and settling chamber were thought to be too large in relationship to the fan's capability to develop static pressure at the needed flow rate. Furthermore, the air was discharged back into the workplace without passing through an appropriate filter to remove the respirable dust. The lack of a filter could result in the dispersal of respirable dust throughout the workplace.

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 and Physical Hazards Branch (EPHB) of the Division of Applied Research and Technology Branch, formerly the Engineering Control Technology Branch (ECTB) of the Division of Physical Sciences and Engineering, has been given the lead within NIOSH to study the engineering aspects relevant to the control of hazards in the workplace Since 1976, 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 Presently, NIOSH's Engineering Physical Hazards Branch is investigating control measures for respirable, crystalline silica exposures which occur while a worker uses a grinder to remove mortar between the bricks on a building wall This task of removing mortar generates an excessive exposure to respirable crystalline silica 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] Because of these excessive exposures, NIOSH has published a Hazard ID on this topic [2]

BACKGROUND

Premature death from silicosis still occurs In 1998, the deaths of two sandblasters from silicosis were reported [3] In one case, a worker was diagnosed with progressive massive fibrosis after 3 years of experience as an abrasive blaster At the age of only 36 years, this worker died of upper respiratory failure 11 years after his initial exposure In another case, a worker died of respiratory failure from silicosis at age 30 He worked as a 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 [3] These deaths were attributed to inappropriate respirator usage and recent, intense exposure to crystalline silica that were 10 to 100 times the OSHA permissible exposure limit which is approximately 0.1 mg/m^3 of respirable crystalline silica [4,5]

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 were 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 that are 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). The OSHA PELs are 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) 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[6] mg/m^3	OSHA PEL[7] mg/m^3	ACGIH TLV[8] mg/m^3
respirable crystalline silica	0.05	varies with amount of quartz in dust. See equation 1	0.05
particulates, not otherwise classified - respirable		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

This study took place at a building renovation The side of this multi-story building was being tuck pointed Prior to the replacement of mortar, the workers used grinders to remove mortar to a depth of 0 5 - 0 7 inches between the bricks This creates an obvious dust exposure At this study site, the workers wore half face-piece respirators to control their dust exposures The workers stood on either scaffolding (Figure 1) or a suspended platform (Figure 2) in order to complete the grinding

VENTILATION SYSTEM

The grinders used to remove the mortar were outfitted with ventilated shrouds as shown in Figure 3 The ventilation take-offs on the shroud were fitted with flexible hose The one end of the flexible hose slipped over the 1 inch diameter ventilation take-off shown in Figure 4 A fan (Makita model 410) draws air though the grinder shroud, pvc pipe, and a settling chamber that was 2'x2'X3' long and the fan discharges air through a plastic box which was about 2'x2'x2' cube The top of this discharge box had 165 rectangular holes which were 0 5'X0 5' The air handling unit and the pvc pipe are pictured in Figure 5

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 respirable dust and crystalline silica were measured Air samples for respirable dust were collected as described by NIOSH method 600 [9] 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 The air flow was estimated by using a velometer (Velocicalc , TSI St Paul, MN) to measure the air velocities into the grinder and various components of the air handling system

In order to develop some recommendations for improving the dust capture, the ability of the fan to move air in the presence of friction caused by elbows, expansions and contractions, and air cleaners that are needed to remove dust was experimentally evaluated using the apparatus shown in Figure 6 This device was used to develop a plot of fan static pressure as a function of flow rate The fan was started The amount of pressure loss was varied by adjusting the blast gate setting The minimum flow condition was created by sealing the upstream duct with tape The

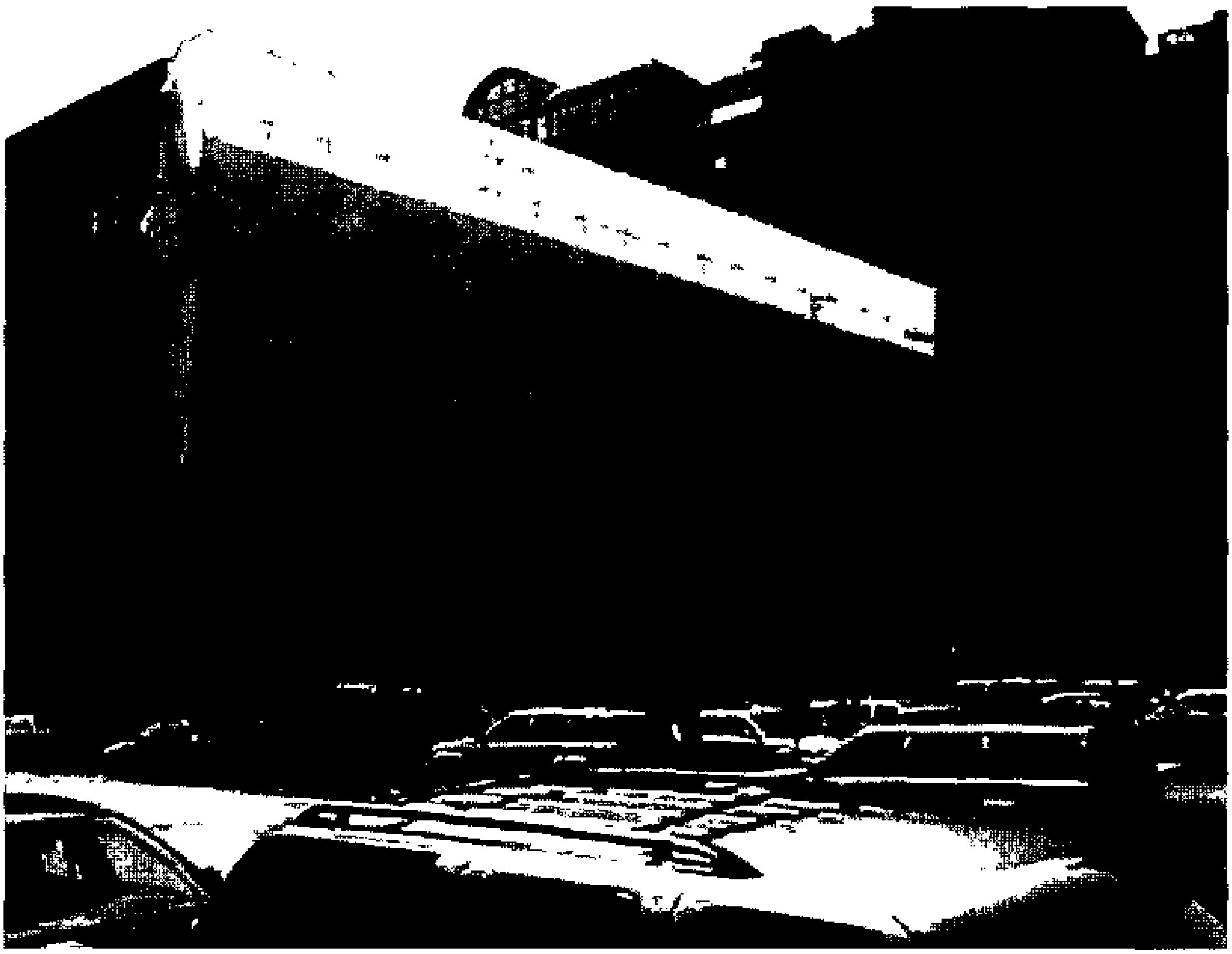

Figure 1 Scaffolding covered with non-porous sheeting used to contain dust generated by the grinding associated with tuck-pointing

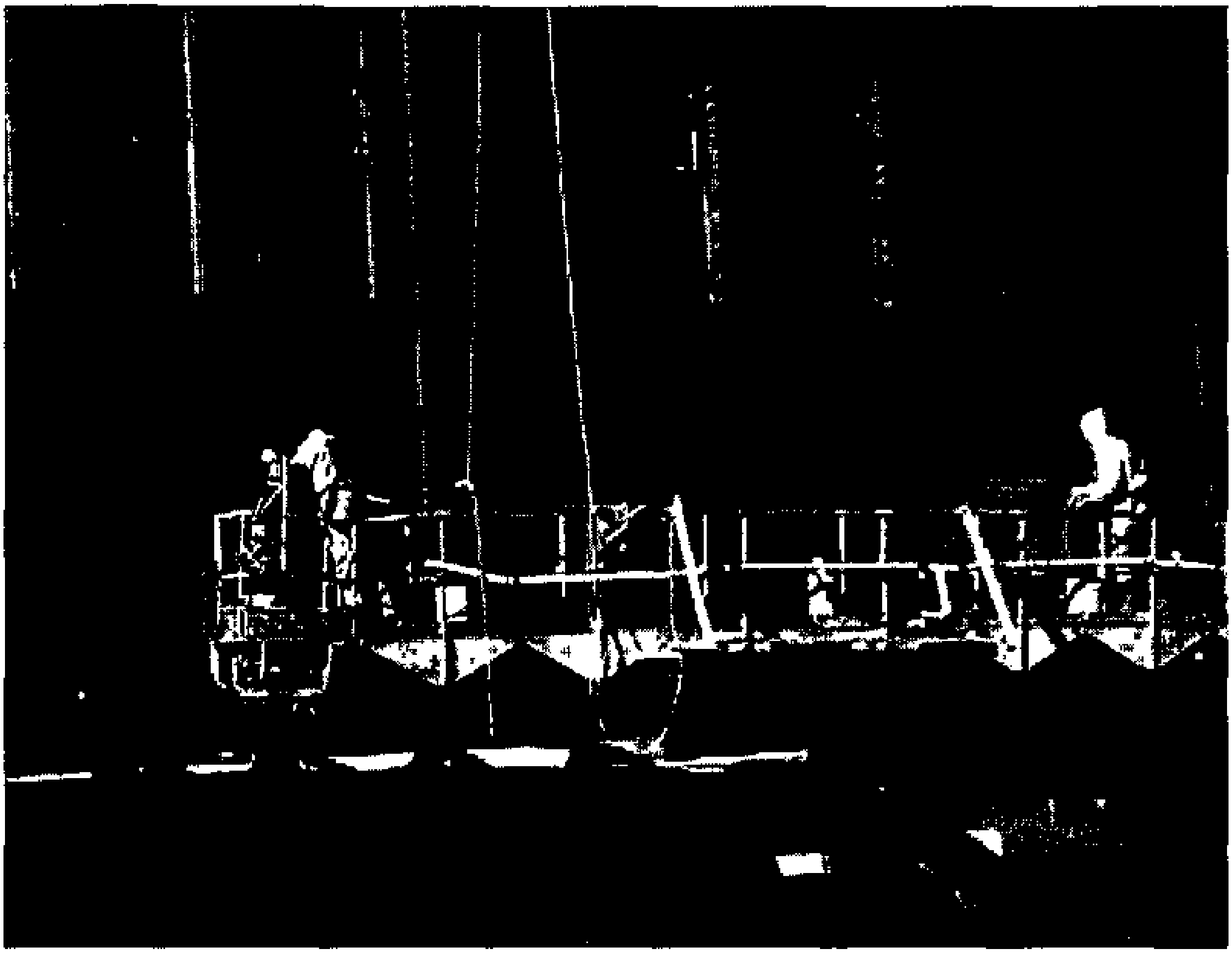

Figure 2 Suspended platform used for tuck pointing The white pipe is used to provide exhaust ventilation for the grinders

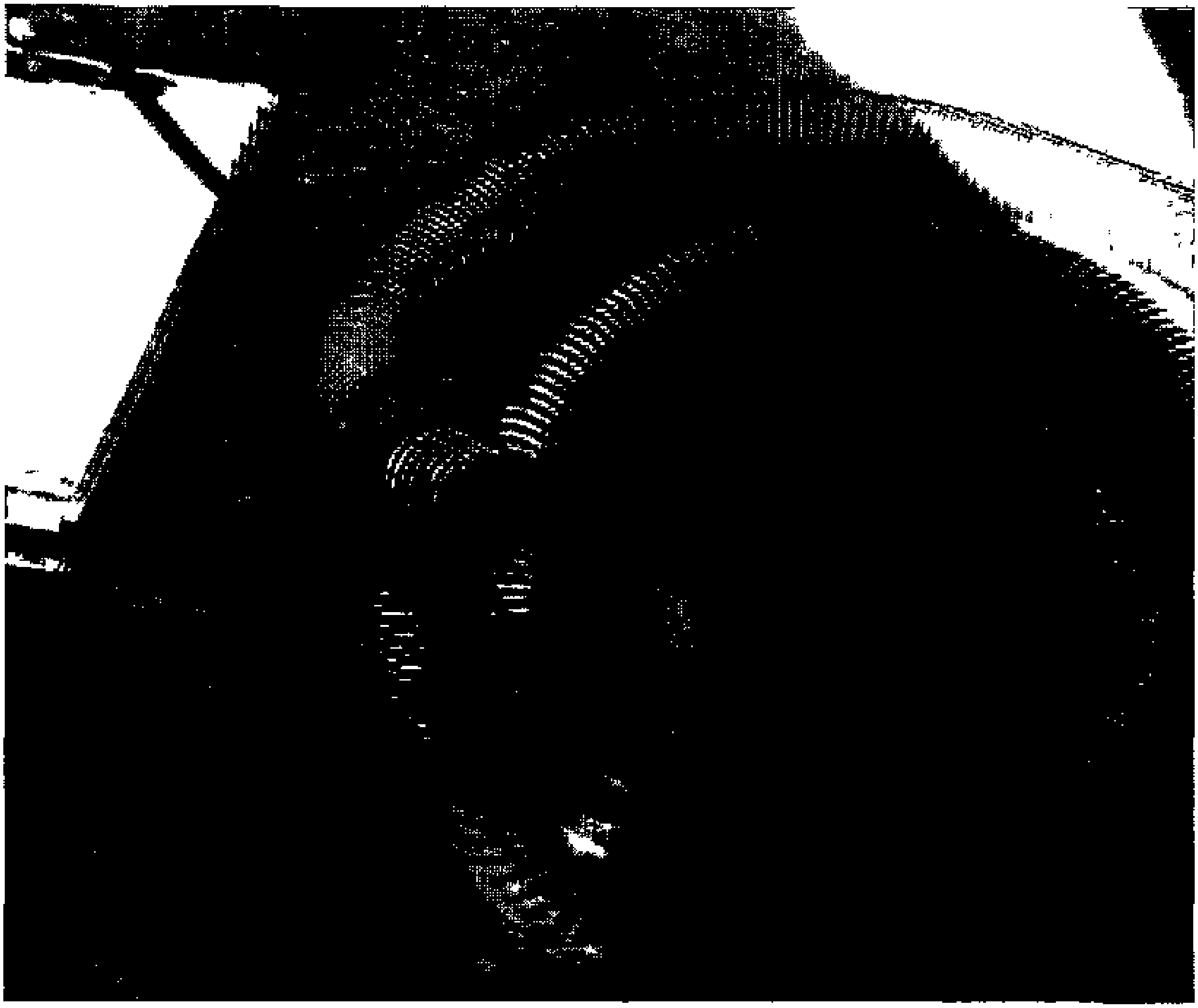

Figure 3 Grinder with 4 inch diameter grinding wheel, shroud, and 1 inch inside diameter flexible hose

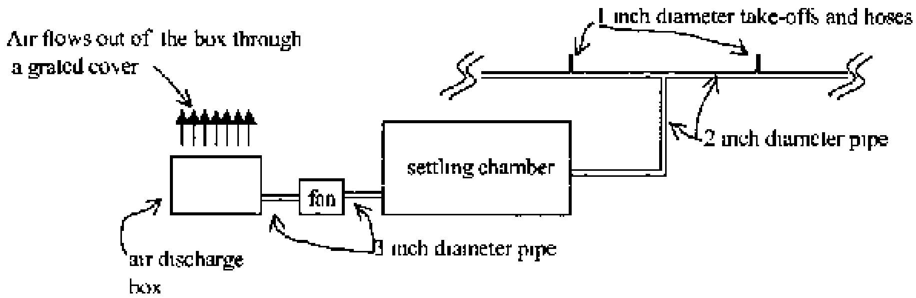

Figure 4 Schematic illustration of air handling system

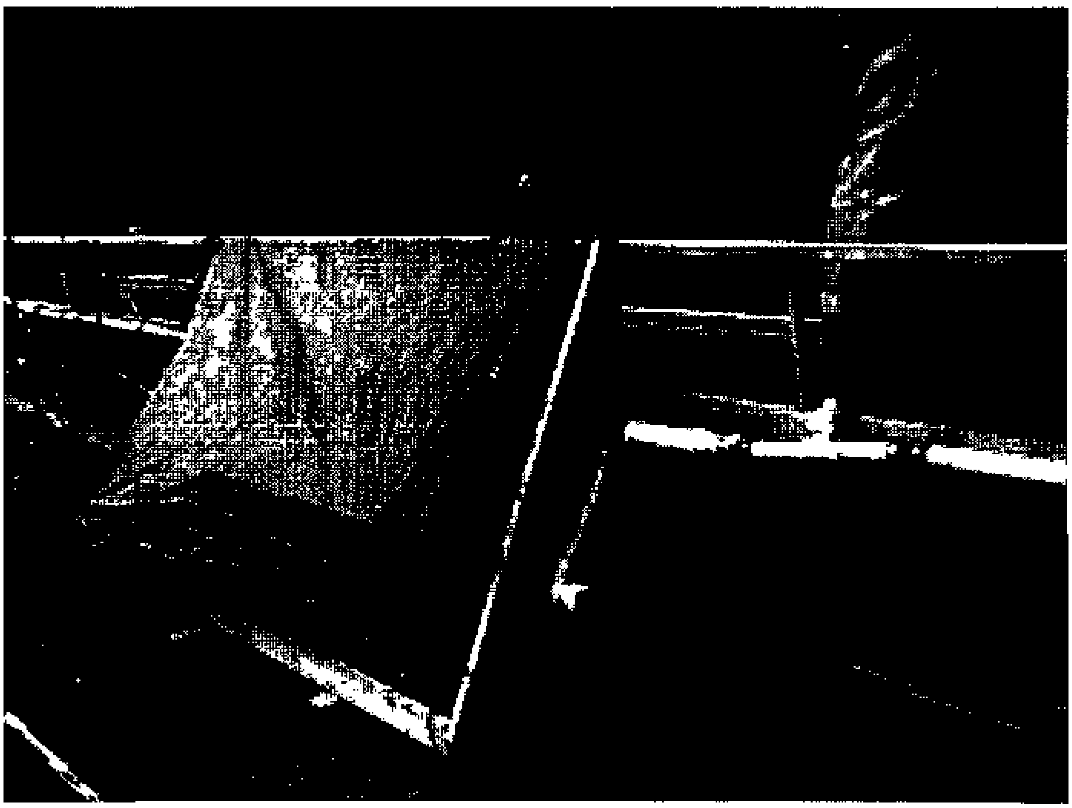

Figure 5 Connection between air moving system and white plastic pipe The white plastic pipe is a 2 inch diameter schedule 40 PVC pipe To use this system with a grinder, the end cabs from the plumbing tee's are removed, a piece of 1 inch diameter PVC pipe is attached using an adapter The hose attached to the grinder slides over the outlet of 1 inch diameter PVC pipe

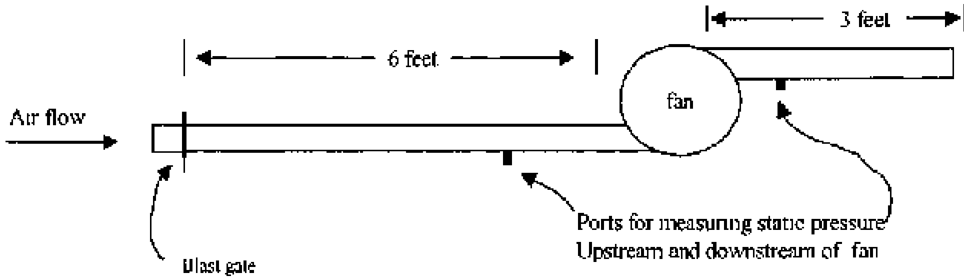

Figure 6 Apparatus for measuring fan static pressure as a function of exhaust volume The duct diameter was 3 inches

maximum flow condition was implemented by removing the blast gate For each bast gate setting, the static pressure (SP) upstream and downstream of the fan was measured at the ports shown in Figure 6 Static pressure is the pressure difference between ambient pressure and the pressure in the duct At the port upstream of the fan, a six point pitot tube traverse was used to measure the air flow moved by the fan Fan static pressure (FSP) is computed as follows [10]

$$FSP = |SP_1| + |SP_2| - VP_1$$

Where

FSP = Fan static pressure,
SP = Static Pressure,
VP = Velocity Pressure, and,
1, 2 = Subscripts referring to upstream and downstream of fan respectively

To characterize flow rate, VP_1, was measured at each traverse location using a pitot tube that registers the difference between total pressure (TP) and static pressure (SP) VP_1 is measured as TP_1-SP_1 where SP1 is negative Velocity (V) at each point is computed as

$$V = 4005 \sqrt{VP_1}$$

Flow rate is computed as a the product of duct cross sectional area and average velocity

RESULTS

Based upon visual observation of the dust generated during the grinding operation, the control measure appeared to be ineffective The respirable dust and respirable crystalline silica concentrations reported in Table 2 are consistent with respirable crystalline silica exposures reported by Shields during uncontrolled tuck pointing [1] The personal samples collected outside of the enclosure on the suspended platform were taken over a partial shift because the mortar removal task was nearly completed Two workers did grind mortar in the enclosure shown in Figure 3 They performed this task for a full shift The respirable crystalline silica exposures measurements reported in Table 2 indicate that workers were exposed to respirable crystalline silica concentrations that are 19 to 92 times the NIOSH REL The workers in the enclosures were somewhat obscured by the dust cloud

Table 2. Respirable Dust and Crystalline Silica Concentrations Measured on April 11, 2000

Location	Start Time	Stop Time	Respirable Dust (mg/m^3)	Respirable Crystalline Silica (mg/m^3)	Comment
Personal sample of worker doing grinding in enclosed space	7 00	15 00	22	4 0	
Personal sample of worker doing grinding in enclosed space	11 00 12 30	11 50 15 00	16 8	2 2	Pump fell off early in shift
Worker grinding outside of enclosure	7 00	8 30	39 4	4 6	Discharge from air cleaner directed at worker
Worker grinding outside of enclosure	7 15	8 30	5 75	0 94	
Edge of fan discharge	7 20	8 30	6 64	0 76	Area sample

The air flow rate provided by the fan is probably too low to capture the dust Center line air velocities were measured under conditions listed in Table 3 The air flow volumes were estimated as the product of the center line air velocity and cross sectional area Inspection of the results in Table 3 indicate that there is too much resistance to air flow caused by the ventilation system

1 As the cross sectional area of the shroud is increased the exhaust air flow increases (measurements a and b)

2 When the hose to the 1" diameter take off is removed, the air flowing into the ventilation system increases from 11 to 81 cubic feet per minute (measurement c) The air flowing out of the fans discharge increases from 132 to 206 cubic feet per minute

3 The discrepancy between the air flowing into the air handling system and the air flowing out of the air handling system suggests that there is some leakage, perhaps from leakage into the settling chamber which was constructed of plywood (measurements a, b, c, and c)

Table 3 Exhaust Ventilation Measurements			
Measurement Code	Measurement	Exhaust Inflow (cfm)	Outflow at Fan (cfm)
a	one shroud, with a 1"x0 5" take-off	11	132
b	one shroud, with a 1"x2" take-off	35	132
c	hose to tool removed, this leaves a 1 0 diameter take off	81	206
d	settling chamber open		388
e	two 1 5" take-offs open, hoses and tools not attached	123	256

Figure 7 shows the relationship between fan static pressure and the volume of air flowing through the fan The static pressure losses for this fan need to be kept under 14 inches of water in order to keep the flow rate above 100 cfm

DISCUSSION

As studied at this site, the control measures appeared to be largely inadequate resulting in excessive exposure to crystalline silica Thus, improvements in the dust control system are needed to reduce worker exposure to respirable crystalline silica Two control options can be considered

OPTION 1

The existing equipment could be used in a modified system Such a system would consist of a shroud around the tuck pointing tool, flexible duct, 2 inch diameter, a settling chamber, a fan, and a filter to collect the dust To minimize pressure losses, a 2-inch diameter take-off is needed For a 4 inch right angle grinder is used to remove mortar, a ventilation rate of 120 cubic feet per minute per shroud is recommended for dust control [11] In experimental work which is being conducted elsewhere, the static pressure loss through a shroud with a 2-inch diameter exhaust take-off and 10-feet of 2-inch diameter hose was nearly 8 inches of water at a flow rate of 110 cfm At a flow rate of 120 cfm, this pressure loss is estimated to be 9 5 inches of water Between the fan and the flexible tubing, 2 inch diameter pipe could be used to transport the dust to a settling chamber with a 2 7 inch diameter outlet The pressure loss in these connections would involve one elbow and the expansion and contraction in the settling chamber These pressure losses are estimated to be 3 5 inches of water The total pressure loss upstream of the fan would be 13 inches of water The fan could discharge to a filter bag The pressure loss through the filter bag would need to be less than 1 0 inches of water at a flow rate of 120 cfm In addition, the filter would need to be at least 99 9 percent efficient at 0 3 µm aerodynamic diameter The availability of such a filter is unknown In such a system, one would still need to address the dust exposures caused by disposing of the collected dust

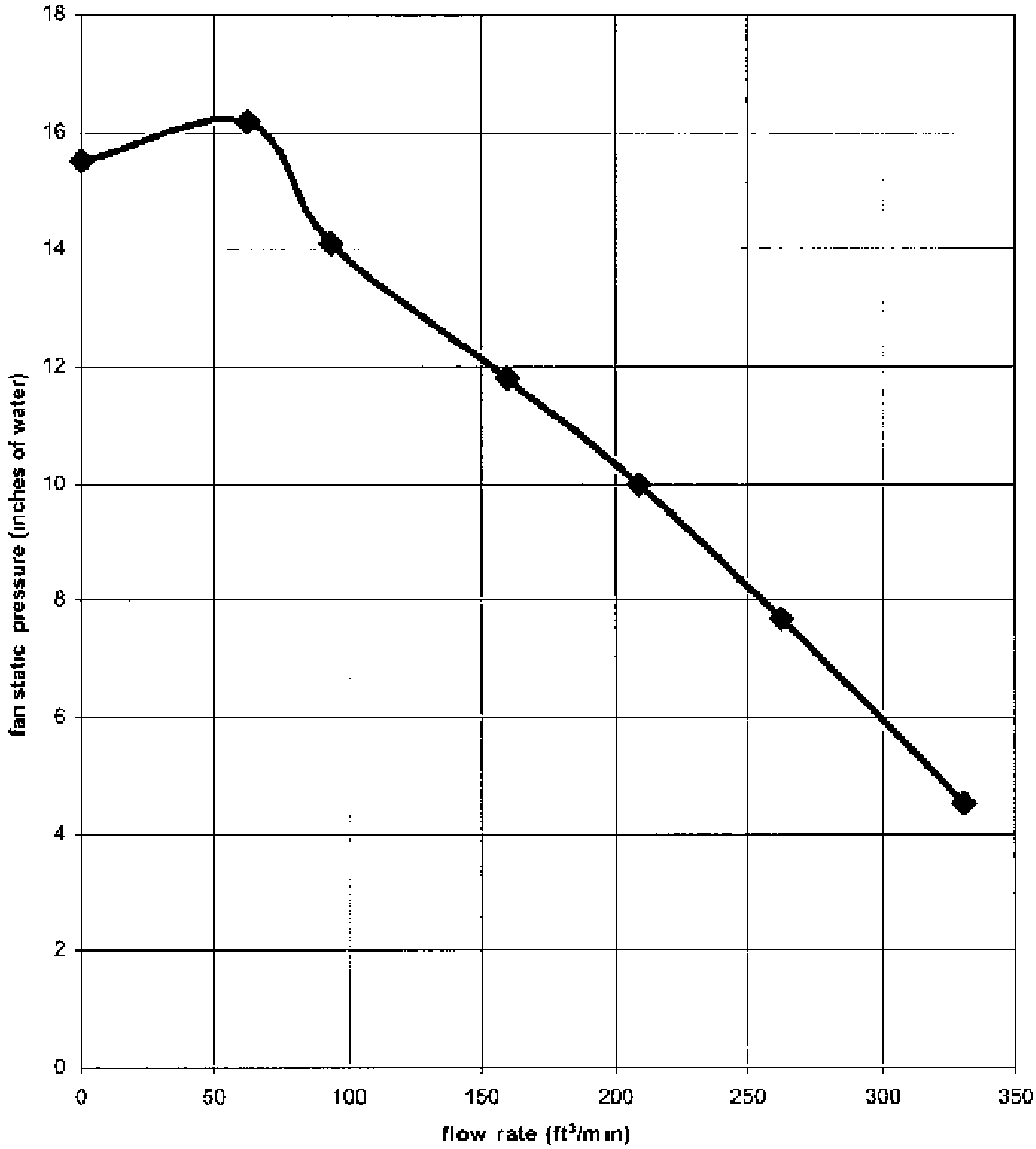

Figure 7 Fan static pressure plotted as a function of flow rate

OPTION 2

Another option is to consider using commercially-available vacuum cleaners to provide air flow through the shrouds and air cleaning Typically, commercially available equipment has filtration efficiency which exceeds 99 percent at 0 3 μm aerodynamic diameter, provisions for filter cleaning by using pressure pulses and the ability to deliver air flows at the appropriate static pressure In purchasing such a system consider using the following specifications

1 A flow rate of 120 cfm per shroud
2 An inertial preselector for the filter This is needed to extend the life of the filter
3 A collection efficiency which exceeds 99 9 percent at 0 3 μm aerodynamic diameter
4 Provisions for pulsing the filter during use to remove the collected dust from the filter
5 Provisions for handling the collected dust without creating worker dust exposure This generally involves the collections of the accumulated dust in a bag so that the worker does not need to handle the dust after collection
6 The vacuum cleaner must develop adequate static pressure The pressure loss is caused by the filter, the roughness of the vacuum hose, the number of bends in the vacuum hose, and the shroud

Until adequate engineering control measures can be implemented, full face piece, air purifying respirators are needed to protect the workers from the exposure to respirable crystalline silica Consult, NIOSH Hazard ID 9 concerning recommendations for respirator usage during uncontrolled tuck pointing [2] A copy of this publication is included in Appendix 1

REFERENCES

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10 McDermott [1976] Handbook of Ventilation for Contaminant Control Ann Arbor, Michigan Ann Arbor Science Publishers

11 Dust Control [1987] Handbook for Planning and Dimensioning Spot Extraction Ed Gunnar Soderberg Norsborg, Sweden

Appendix 1

Hazard ID 9

NIOSH HAZARD ID

HID 9

Respirable Crystalline Silica Exposures During Tuck Pointing

Description of HAZARD

Silicosis is a deadly lung disease Construction workers may get sick with silicosis if they breathe in too much respirable crystalline silica, a fine, sandy dust

Silicosis may take 10 or more years to develop when workers are exposed daily to low concentrations of silica dust However, when exposures to silica are very high, symptoms can occur after only a few weeks to 4–5 years

To prevent silicosis, researchers from NIOSH (the (National Institute for Occupational Safety and Health) urge construction workers to protect themselves from dust exposure when doing construction work, especially tuck pointing

In tuck pointing, the worker grinds the mortar out from between the bricks—the first step to fixing up the outside of an older brick building Mortar dust contains crystalline silica During tuck pointing, workers hold power grinders, digging the mortar out to a depth of an inch or less The grinders often have wheel diameters of 4 to 6 inches and rotate at speeds as high as 12,000 rpm The grinding process breaks up the mortar and turns it into airborne dust The rotating wheel creates wind that carries this airborne dust throughout the workplace When workers clean the mortar joints and their clothes, tools, and equipment with compressed air, the strong blast needlessly adds even more dust to the air (see Figures 1 and 2)

During a recent study of tuck pointing at a construction site, NIOSH researchers measured very high concentrations of respirable crystalline silica At this site, the workers' exposures were up to 50 times the REL (recommended exposure limit) At another construction site, investigators from OSHA (Occupational Safety and Health Administration) found high exposures—up to 100 times the REL

Figure 1 Tuck pointing

Recommendations for Prevention

Because these construction studies showed such high concentrations of respirable crystalline silica, NIOSH is running more tests on commercial grinders They want to see how much the built-in ventilation in the grinders cuts down on dust exposures during tuck pointing Also, NIOSH researchers want to find out which engineering controls work best during this work In the meantime, construction workers should follow the recommendations below to reduce their exposures

***Contractors* and *workers* should use good work practices and respiratory protection.**

Good Work Practices

- Use a grinder that has local exhaust ventilation when possible
- Do not use the grinder near another worker Restrict some work areas to cut down exposures to other workers
- Stand so that the dusty air will not blow on you and other workers
- In poorly ventilated areas such as a courtyard or the inside corners of a building, use fans to blow out dusty air
- Do not use compressed air to clean yourself, your clothes, or your equipment Make sure the vacuum cleaners used for dust control and clothes cleaning capture at least 99 percent of the small particles that could be inhaled (0 3 micrometer diameter)

Respiratory Protection (Respirators)

During tuck pointing, employers need to check respirable crystalline silica exposures from time to time to see how well the safeguards are working and if workers need respiratory protection Because ventilated grinders may not control the dust enough, NIOSH recommends the following respiratory protection

- For exposures less than 1,000 times the REL (50 mg/m^3—milligrams per cubic meter), use a supplied-air respirator that has a half-mask Set the respirator on pressure-demand or one of the other positive-pressure settings For example, run a Type CE abrasive-blasting respirator on a positive-pressure setting
- For exposures less than 50 times the REL (2 5 mg/m^3), use (a) an air-purifying, full-face respirator with a high-efficiency particulate air filter or a P100 filter, or (b) a powered, air-purifying respirator with a tight-fitting facepiece and a high-efficiency particulate air filter or a P100 filter
- For exposures less than 10 times the REL (0 5 mg/m^3), use a half-mask, air-purifying respirator that has a P100 filter

***Equipment manufacturers* are encouraged to do the following:**

- Develop ventilated shrouds for grinders that give a clear view and good dust control
- Develop the minimum exhaust volume needed for ventilated shrouds This exhaust volume must be based on experimental and field data

For more information about the health hazards of exposure to crystalline silica, respiratory protection for workers, and the four Type CE abrasive-blasting respirators that NIOSH certifies, order the NIOSH Alert *Preventing Silicosis and Deaths in Construction Workers*, DHHS (NIOSH) Publication No 96–112 To get your free copy, call NIOSH

For More Information

To obtain more free information about this hazard or other occupational safety and health issues,

Call NIOSH at 1–800–35–NIOSH
(1–800–356–4674)
or visit the NIOSH Web site at
www cdc gov/niosh

Acknowledgments

The principal contributors to this document were William A Heitbrink, Ph D , CIH, and Jerome P Flesch, M S , of NIOSH Charlie Shields of OSHA provided much valuable information about tuck pointing exposures Anne Votaw, M A , of NIOSH, translated the text into easier-to-read prose Desktop publishing was provided by Susan Kaelin and Kristina Wasmund

Figure 2 Air blowing

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