IN-DEPTH STUDY REPORT:
CONTROL TECHNOLOGY FOR CRYSTALLINE SILICA EXPOSURES IN CONSTRUCTION:THE EFFECT OF EXHAUST FLOW RATE UPON THE RESPIRABLE DUST EMISSIONS FOR TUCK POINTING OPERATIONS AND A PRELIMINARY EVALUATION OF A VENTILATED TOOL FOR BRICK CUTTING

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DISCLAIMER

ABSTRACT

As brick buildings age, mortar deteriorates and needs to be replaced. Before replacing the mortar, the existing mortar is removed to a depth of 0.5 to .75 inches. Typically, a 4-inch diameter grinder, operated at 10,000-12,000 rpm, is used to remove mortar. Mortar removal causes exposures to respirable crystalline silica concentrations as high as 10 mg/m^3. A tool resembling a router can also be used to remove mortar. For four different shrouds, the effect of exhaust flow rate upon respirable dust emissions was experimentally evaluated. To conduct this testing, a small brick wall was built and enclosed in a hall-shaped, ventilated test chamber. The grinder was mounted on a mechanical trolley which moved the grinder horizontally down the wall at a constant velocity of approximately 1 m/min and the mortar was removed at a fixed cut depth of 0.5 or 0.75 inches. A vacuum cleaner equipped with high efficiency filters (99.9% at 0.3 μm) exhausted air from the shrouds to a location outside the enclosure. The vacuum cleaner's exhaust air flow was varied by controlling the voltage applied to the vacuum cleaner. An air flow rate of 2794 cubic feet per minute was drawn through the test chamber and past mixing baffles and into an exhaust duct. A time-of-flight aerosol spectrometer was used to measure the respirable dust concentration in the duct. Dust emissions per volume of mortar removed were plotted as a function of the exhaust flow rate. For uncontrolled grinding, respirable dust emissions were about 20 mg/cm^3 of mortar removed. As flow rates increased, respirable dust emissions were reduced to under 0.2 mg of respirable dust per cm^3 of mortar removed. For the 4-inch diameter grinding wheel and the router, 80 and 35 cubic feet per minute (cfm), respectively, were the minimum exhaust volumes which reduced respirable dust emissions to under 0.2 mg/cm^3 of mortar removed. Further flow rate increases did not provide useful emission reduction.

In addition, the facility used to evaluating dust control measures for tuck pointing was used to conduct a preliminary study of a dust control for the dry cutting of bricks. Generally, brick cutting is done wet. However, some contracts specify that bricks are to be cut dry. Dry cutting is specified due to concerns related to brick staining and reduced adhesive strength between the brick and the mortar. An Equipment Development Company (EDCO) masonry saw was used for the wet cutting of bricks and it was equipped with two exhaust take-offs. One exhaust take-off was located below the brick in an exhaust channel. The second exhaust take-off removed air from the blade guard located above the brick and spindle for blade. Vacuum cleaners were used to provide exhaust volume to both exhaust ports. The EDCO masonry saw was set in the enclosure and bricks were cut with and without ventilation. With no ventilation, the in-duct respirable dust concentration was 13 mg/m^3. When 93 cfm was exhausted from the exhaust channel below the brick and 113 cfm was exhausted from the blade guard, the in-duct respirable dust concentration was 0.05 mg/m^3. Because the lower exhaust channel had a cross-sectional area of about 1 inch square, the static pressure loss was greater than 30 inches of water. This exhaust channel needs to be redesigned to operate at a transport velocity of 4500 feet per minute (fpm) and enlarged to reduce the pressure loss.

The results presented here for the 4" grinder and 10" inch brick saw indicate that a minimum

exhaust flow rate of at least 20 cfm/inch of blade or grinding wheel diameter is needed to control the dust emissions. This is in agreement with the ACGIH recommendation that 25 cfm/inch of blade or grinder diameter are needed. This ACGIH recommendation should be used as the specification for choosing exhaust flow rates. The ACGIH recommendation involves a prudent amount of over design which compensates for equipment deterioration with age and unknown factors that influence the capture of dust.

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 has been given the lead within NIOSH to study the engineering aspects relevant to the control of hazards in the workplace. Since 1976, EPHB and its predecessors have assessed control technology found within selected industries or used for common industrial processes. The EPHB 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. The silica exposure of construction workers is receiving some public attention.[1] In addition, EPHB has been interested in evaluating new technologies that reduce worker exposure to hazardous air contaminants such as respirable crystalline silica. EPHB is investigating control measures for respirable, crystalline silica exposures that occur while a worker uses a grinder to remove mortar between the bricks on a building wall. During tuck pointing, the old mortar between the bricks is removed by grinding. Mortar contains crystalline silica. Frequently, this task is performed without engineering control measures. This can result in exposures to respirable crystalline silica that are excessive. Shields reported on respirable crystalline silica exposures during tuck pointing. Of 37 exposure measurements, 38% of the samples exceeded 1 mg/m^3 and 19% of the exposures exceeded 5 mg/m^3 of respirable crystalline silica.[2] These exposures are 20 to 100 times the NIOSH recommended exposure limit of 50 $\mu g/m^3$.[3] Such high exposures are associated with adverse health outcomes.

Excessive silica exposures in a sandblasting environment have caused premature deaths from silicosis. In 1998, the deaths of two sandblasters from silicosis were reported.[4] In one case, a worker was diagnosed with progressive massive fibrosis after three years of experience as an abrasive blaster. He died of respiratory failure at age 36, 11 years after his initial exposure. 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, approximately 10 workers between the ages of 15 and 44 died of silicosis each year.[4] These latter 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.[5,6]

Existing control technology for controlling worker dust exposures during the grinding operations, conducted as part of tuck pointing, appears to be marginally effective. To control the dust generated by mortar grinding, a shroud is used to enclose the grinding. A centrifugal impeller is mounted on the grinder's axle. The impeller was designed to move 40-50 cfm of air to an air cleaning bag. The tools appeared to leak dust so that our view of the worker was obscured. However, some dust appeared to be collected in the filter collection bags. Based upon data collected by OSHA and a NIOSH contractor, the geometric mean and geometric standard deviation for the respirable crystalline silica exposures were 0.7 mg/m^3 and 2.7 respectively.[7] These exposures are not very different from the exposures reported by Shields.[2] For uncontrolled grinding operations, Shield's data has a geometric mean of 1.2 mg/m^3 and a geometric standard deviation 6.1.

Because effective engineering control measures for dust generated by grinders are not available, NIOSH EPHB in partnership with the Brick and Allied Craftworkers are jointly evaluating methods for controlling worker exposure to respirable crystalline silica. Control of the dust generated by the grinding operation is, for the purposes of this protocol, a two-step process

1. A ventilated shroud must capture the dust generated by grinding mortar; and
2. An air cleaner removes the respirable dust from the air.

This study will focus on the capture of the grinding dust by the ventilated shroud. However, air cleaner performance probably affects exposures at work sites. Air cleaner performance can be addressed after the developing ventilated shrouds or enclosures which captures mortar dust.

In addition to studying tuckpointing, some preliminary data was taken on a masonry saw manufactured by the Equipment Development Company (EDCO), Frederick Maryland. The saw, an EDCO GMS 10, was equipped with an electric motor. This masonry saw was designed for cutting bricks and masonry blocks with water or with an exhaust vacuum to control the dust emissions. To control respirable crystalline silica exposures, brick and block cutting is usually done wet. However, some architects specify dry cutting. In response to an informal request from the Laborer's Union, some preliminary data was collected on this masonry saw.

Physical and Theoretical Considerations.

Tuck pointing involves a grinding wheel used to remove mortar perhaps to a depth of 0.5 to 0.75 inches. The cut mortar dust moves tangentially away from the grinding wheel as this wheel exits the cut. The momentum of the mortar dust induces air flow which disperses dust throughout the work place.[8] The motion of the grinding wheel also induces an airflow which can disperse dust throughout the workplace.[9] The depth of cut and the blade width may affect the mortar dust's mass generation rate, momentum generation rate, angle of dispersal, and amount of mechanically-induced air flow. Thus, depth of cut and blade width are likely to affect the capture of mortar dust by a hood.

The motion of the grinding wheel or cutter imparts mechanical motion to the mortar dust. The motion of moving powder or dust is known to induce air flow.[10] The grinders used for tuck pointing typically have diameters of about 10 cm and rotational speeds of 10,000 rpm. The mortar dust moves in a direction tangential to the cutter disk as the dust exits the uncut mortar. This mortar dust has a velocity equal to the tip speed of the mortar grinding wheel. The relative motion between the dust and the air causes the transfer of some the dust's mechanical energy and momentum to the surrounding air. This causes a drag force, F_d, on the individual dust particles:

$$F_d = \pi r_p^2 C_{dp} \rho_a v_p^2$$

Where,

r_p = dust particle radius (cm);

C_d = drag coefficient, assumed to 0.44;

ρ_a = density of air (g/cm^3); and

v_p = particle air velocity, (cm/sec).

As the particle moves away from the grinding wheel, the particle does work on the air, inducing some air motion. Assuming the particle velocity is not reduced appreciably before it enters the take-off for the shroud, the work, w_p, done by the particle on air is the product of the drag force and the distance traveled, Δr:

$$W_p = F_d \Delta r \, .$$

The total energy transferred from the dust particles to the air is simply the sum of the work done on the air. This relationship can be expressed as follows:

$$0.5 m_a v_a^2 = \frac{R}{w_p} \pi r_p^2 0.44 \rho_a v_p^2 \Delta r$$

where:

m_a = mass of air in motion (grams);

R = dust removal rate (grams/min); and

w_p = mass per individual dust particle grams/particle.

This induced air flow is moving into an exhaust take-off with area, A_T. The volume of induced air flow , Q, is the product A_T and v_a :

$$Q = (.88\pi r_p^2 v_p^2 (\Delta r) A_T^2 R / w_p)^{1/3}$$

This approach to estimating the quantity of induced air flow will result in an overestimation because the particles do not act independently. When this modeling approach is applied to gravity discharge from conveyor belts, the quantity of induced air flow has experimentally been found to be overestimated by a factor of 3.[11]

The rotation of a grinder wheel or cutter wheel in a shroud resembles the rotation of a disk in a housing. For the case where the distance between the housing's wall and the disk is small compared to the radius of the disk, Schlichting summarized the air flow patterns.[12] For a disk rotating freely in air, the disk draws air toward the center of the disk and disperses the air from the outer edges. This air moves in a direction tangential to the rotating disk. The air flow around a grinding wheel involves two sources of mechanically induced air flow[13,14]:

1. The rotation of the grinding wheel induces air motion. This air flow is drawn toward the wheel along the axis of rotation. It moves radially outward across the wheel and is discharged tangentially from the wheel's surface.
2. The grinder swarf is ejected tangentially at the same velocity as the grinding wheel. The grinder swarf is a powder generated from the surface. As mentioned earlier, powder moving through air induces air motion.

The hoods for capturing the dust from grinders have capture efficiencies which can vary with particle size. Reportedly, fine particles are trapped in the fluid boundary layer around the grinding wheel. When grinding tools are used on cast iron an steel, collection efficiency decreases for particles smaller than 1-3 μm. When grinding tools are used upon a concrete surface, collection efficiency does not vary with particle size.[15] The material removal rates are probably much larger for concrete grinding. This suggests that the air flow induced by the grinder swarf can strip the smaller particles from the boundary layer flow around the grinding wheel.

Ventilation Requirements

Grinder exhaust ventilation needs to exceed the air flow induced by the mechanical motion of the inertial particles generated by the grinding process.[8] In addition, the rotary motion of the grinding wheel also induces an air flow. Most recommendations appear to be based upon undocumented experience. The ACGIH manual, *Industrial Ventilation*, contains several specifications for the design of ventilation systems used for grinding operations.[16] In the manual's Figures VS-40-01 to VS40-03, 25-60 cfm per inch of grinding wheel diameter is recommended. For a 5-inch grinding wheel operated at surface speeds between 6,500 and 12,000 fpm, Figure VS10-122 recommends 220 cfm for good enclosures and 390 cfm for poor enclosures. Poor enclosures have more than 25% of the surface of the grinding wheel exposed. Typically, the grinding wheels used have a diameter of 4 to 6 inches and are operated at rotational speed as high 12,000 rpm and at surface speeds of 12,000 to 15,000 fpm. As a practical matter, Croteau observed that ventilation rates of 70 cfm did provide an order of magnitude reduction in exposure over grinding with no ventilation.[17] There was no explanation for these results. The Dustcontrol Company recommends exhaust flow rates of 180 m^3/hr (106 cfm) based upon proprietary data.[18]

Procedures

Experimental work was conducted to measure the respirable dust emission rate as a function shroud exhaust rate for various shrouds and tools. This done by placing a brick wall in a ventilated enclosure (**Figure 1**). The tool with the ventilated shroud was mounted on a track which moved the tool along the horizontal mortar joints between the brick. Also the tool moved toward the air cleaners shown in **Figure 1**, the mortar was removed. The air flow through the various shrouds was varied. Two air cleaners (Sidekick model PSK 1440, Polaris Industrial Ventilation, Harbor Springs, MI) consisting of fans and filters moved a total 2794 cfm of air through the inlet filters for the test chamber, past the brick wall and mixing baffles in the test chamber, and through a duct containing iso-kinetic sampling nozzles and a Delta tube (Midwest Instruments, Stirling MI). After passing through the air cleaner, the air flowed through flexible ducts to the outside of the building. An Aerodynamic Particle Sizer (APS, Model 3310, TSI, St. Paul MN) was used to obtain the respirable dust concentration in the duct. From the exhaust flow rate and the respirable dust concentration, the respirable dust emission rate is the product of the exhaust flow rate and the respirable dust concentration in the duct.

Test Chamber Construction

The test chamber is illustrated schematically in **Figure 1**. Two air cleaners (Sidekick model PSK 1440, Polaris Industrial Ventilation, Harbor Springs MI) consisting of a fan and filters moved air through this test chamber. These air cleaners consisted of fans which could develop 6.5 inches of static pressure. The filters (Pulsemax, P25.20) were pulsed with 100 psi compressed air to remove accumulated dust. This was done after each test series. After discharge from the air cleaners, the air flowed through a flexible duct and out of the building.

The air flowed through a bank of inlet filters. The inlet filters consisted of furnace type pre-prefilters (panel filter, American Air Filter, Louisville KY) and pleated filters (Biocell 1 510-532-014, type sh, American Air Filter Louisville KY). The pre-filters were 24"X24"X2". As shown in **Figure 2**, the filters provided a uniform air flow distribution over a 4'x6' area.

The air flows past a brick wall which is used for testing the grinders. The brick wall was 13 feet long and 8 high. The masonry cement was produced in accordance with ASTM standard 3270. The mortar mix was 3 parts cleaned mason sand to 1 part type N masonry cement. The horizontal joints between the bricks were about 0.5±0.03 inches apart. As shown in **Figure 3**, a track was mounted to the wall. The track used a chain to move the frame down the wall (**Figure 4**). The grinder and shroud to be tested were mounted on the frame. The grinder was positioned to have a controlled depth of cut of 0.75 or 0.5 inches depending upon the tool being used to cut the mortar (**Figure 5**).

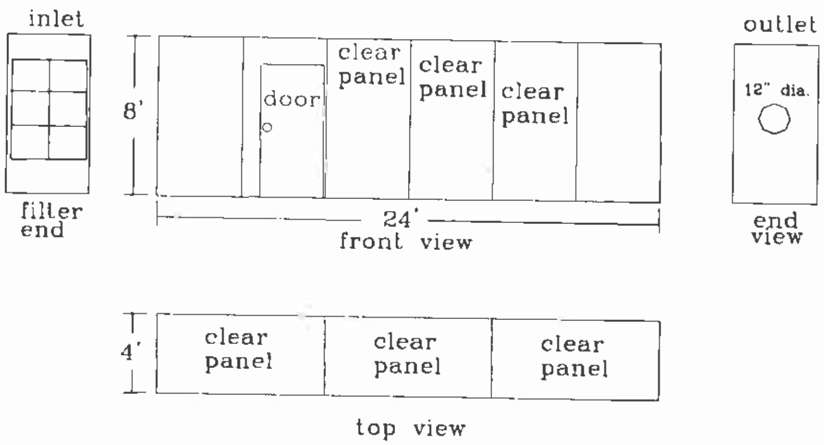
The airflow moves the dusty air generated during cutting past baffles which are intended to mix the dusty air and into a 12 inch diameter duct. (**Figure 6**) The duct contains the sampling probe through which the time-of-flight aerosol spectrometer (APS) samples the air. The nozzle had an inside diameter of 0.123 inches and a wall thickness of 0.003 inches. Over a length of 3 inches, the nozzle diameter expanded to 0.75 inches. This nozzle was mounted into the inlet for 0.75 inch copper elbow that has a turning radius of 0.75 inches. A 9-inch length of vertical copper tubing connected the elbow to the APS dilutor and the APS which were set beneath the duct.

The computed air velocity in the nozzle was 2100 fpm and the air velocity in the duct was 3560 feet per minute. Thus, the air sampling was subisokinetic, isoaxial sampling. Under these conditions, some of the air directly in front of the nozzle flows around the sampling nozzle. As particle diameter and inertia increase, particles do not exactly follow the fluid motion and there is an increase in the number of particles which are inappropriately sampled. As discussed later, the data was adjusted for this source of bias.

Just downstream of the sampling probe, a Delta Tube (part 306AM11AO, Midwest Instruments, Sterling, MI) is positioned in the duct. The Delta Tube is a cylindrical tube with separate pressure sensing chambers on the upstream and downstream sides of the flow. An inclined manometer was used to measure the pressure difference between these two chambers. Just downstream of the Delta tube, the air flowed through a branch connection. One side of the branch connection had a blast gate. The blast gate was adjusted so that the centerline velocity in the duct upstream was approximately 3500 fpm. The pressure differential of the Delta tube was recorded and a 10 point pitot tube traverse of the duct was performed in the horizontal and vertical planes to obtain the actual duct flow rate.[16] This flow rate was 2794 cfm. The Delta tube pressure differential was 1.95 inches of water. Before each experimental run, the blast gate was adjusted so that the Delta Tube pressure differential was 1.95 inches of water.

Two air movers (model psk, 1440, Polaris) were used in parallel to obtain the desired flow rate. The air flow was directed out of the building through two 14-inch flexible ducts.

A) Schematic of of outside of test chamber



B) Schematic of inside of test chamber

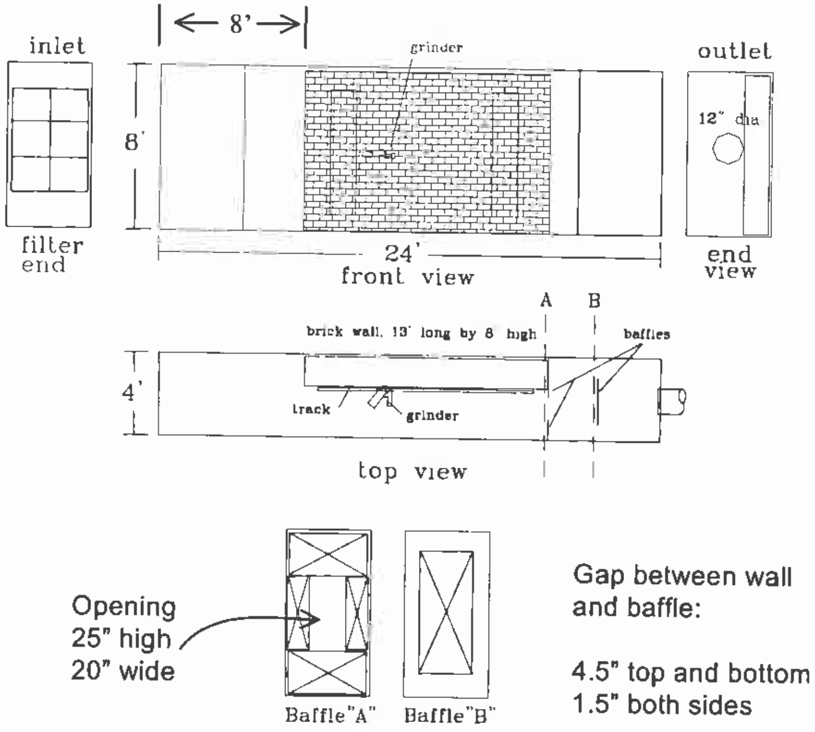


Figure 1 Schematic illustration of the test chamber design details.

Figure 2. Photograph of the inlet filters.

Figure 3. Track and frame for mounting and moving the tool down the wall.

Figure 4. The frame moving down the wall toward the air cleaner.

Figure 5. Grinder mounted on a frame. The grinder moves to the right.

Figure 6 Photograph of instruments and isokinetic sampling location. The blast gate position was adjusted to obtain a 1.95 inches of water across the delta tube.

Figure 6. Photograph of the air cleaners used to move air through the test chamber. The flexible duct is set outside of the building.

Respirable Dust Concentration Measurement

The APS moves 5 lpm of air through the isokinetic sampling nozzle and a diluter (model 3302A, TSI Inc, St. Paul MN). The air in the dilutor flows through one of two paths: through a changeable nozzle or through filters. The nozzles can be changed to obtain 1 to 20 or 1 to 100 dilution. After flowing through the dilutor, the air flows into the APS. The APS is a time-of-flight aerosol spectrometer. In the APS, 4 lpm are filtered and used as sheath air and 1 lpm is used as sample air. The sample air flows through a limiting orifice which accelerates the air flow to 150 m/sec. In the region of acceleration, the air flow passes between laser beams. The transit time between the two laser beams is measured. A calibration curve is used to convert transit time to aerodynamic diameter. Particles are classified into one of 63 bins based upon aerodynamic diameter.

The APS can create phantom particles which are artifacts.[19] To minimize this problem, the dilutor was used to keep the particle concentration measured by the APS below 1000 particles/cm^3. The APS data was adjusted for APS data for phantom particle creation.[20] Phantom particles are uniformly distributed with respect to transit time between the laser beams. Transit time and particle channel width in terms of transit time increase with particle size causing the correction for phantom particles to increase dramatically for particles larger than 10μm. In contrast, the respirability of dust decreases with particle size. As a result, the phantom particle correction has a small effect upon the respirable dust concentration. When the correction factor was applied to the data, the correction was less than 3% in most cases.

From the APS's particle count data, the concentration of respirable dust is computed as follows:

$$C_m = \sum_{i=1}^{44} \frac{\pi d_i^3 n_i \rho f_i}{6V \eta_{dil} \eta_{asp}}$$

C_m = mass concentration,
d_i = physical diameter of channel i , $d_i = d_a/(\rho)^{.5}$,
d_a = aerodynamic diameter,
f_i = fraction of dust which is respirable,
i = channel number,
n_i = number of particles counted in channel i adjusted for phantom particle creation,
V = sample volume,
ρ = particle density ,
η_{asp} = aspiration efficiency for subisokinetic sampling efficiency, and.
$\eta_{i,dil}$ = dilutor transmission efficiency (supplied by TSI).

Channel number larger than 44 include particles larger than 10 μm.

Because sampling was conducted under subisokinetic conditions, larger particles will be oversampled. In reviewing the literature on anisokinetic sampling, Brockman noted that the following correlation is reported to predict sampling efficiency to within 10%[21]:

$$\eta_{asp} = 1 + (U_o / U + 1)[1 - (1 + kStk)^{-1}]$$
$$k = 2 + 0.617U / U_o$$
$$Stk = \frac{(\rho d_a^2 U_0)}{18 \mu d}$$

Where:
U_o = free stream velocity in duct (1800 cm/sec),
U = velocity in probe inlet (1080 cm/sec),
μ = viscosity of air (1.8 x 10^{-4} g/(cm-sec),
d = probe diameter (0.31 cm), and
ρ= density of unit density sphere (1 g/cm^3).
The data was adjusted using the preceding correction.

Description of Shrouds Tested

Figures 8-11 provide photographs and line drawings for the ventilated shrouds that were tested. The shroud used for the mortar rake is shown in Figure 8. The mortar rake functions as a router. To use the mortar rake, the worker simply used the end of the mortar rake to drill into the mortar. To remove mortar, the worker simply moves the mortar rake along the horizontal and vertical joints between the bricks. The depth of cut is controlled by adjusting the height of the base plate. The base plate has notches for aligning the mortar rake along the horizontal and vertical joints. To control the dust generated by using this tool, an exhaust ventilation hose is placed over the 5-inch long tube that is shown in Figure 8. This equipment was obtained from American Tool Companies, 301 S. Thirteenth Street, Suite 600, Lincoln, Nebraska 68508. The mortar rake and its shroud were tested with a Metabo model 11025 right angle grinder.

Figures 9 - 11 provide a detailed description of the grinder shrouds studied. All of these shrouds function as receiving hoods. The grinding wheels have a counter-clockwise rotation which moves the dusty-air towards the exhaust take-off. The exhaust-take off is in front of the grinding wheel as it is moved along a horizontal or vertical joint. If the exhaust take-off follows the grinding wheel, the capture efficiency is seriously reduced because the dust is not being directed toward the exhaust take-off. The shrouds for the four inch diameter grinders were tested with a Milwaukee model 6153-20 grinder. Addresses for two commercially available grinder shrouds:

Zantech Inc, 130 Ryerson Ave Suite 218, Wayne, New Jersey 07470; and
Dustcontrol, 6720 Amsterdam Way, Wilmington, DE 28405.

A. MORTAR RAKE, SHROUD ON A RIGHT ANGLE GRINDER

B. MORTAR RAKE MOUNTED ON GRINDER

C. LINE DRAWING SHOWING SHROUD DIMENSIONS

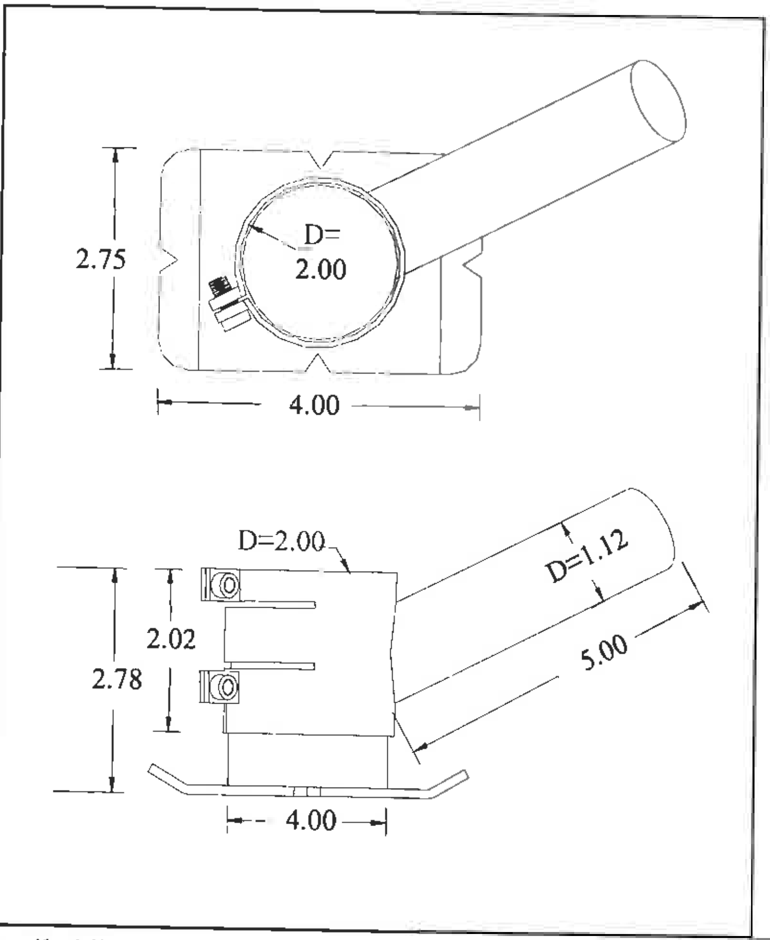


Figure 7. Photograph and detailed line drawing of shroud for the mortar rake. In this figure, all dimensions are in inches and "D=" indicates that the dimension is a diameter.

A. PHOTOGRAPH OF ZANTECH SHROUD, WITH 4 INCH CUTTER BLADE AND A RIGHT ANGLE GRINDER.

B. LINE DRAWINGS WITH DIMENSIONS FOR SHROUD

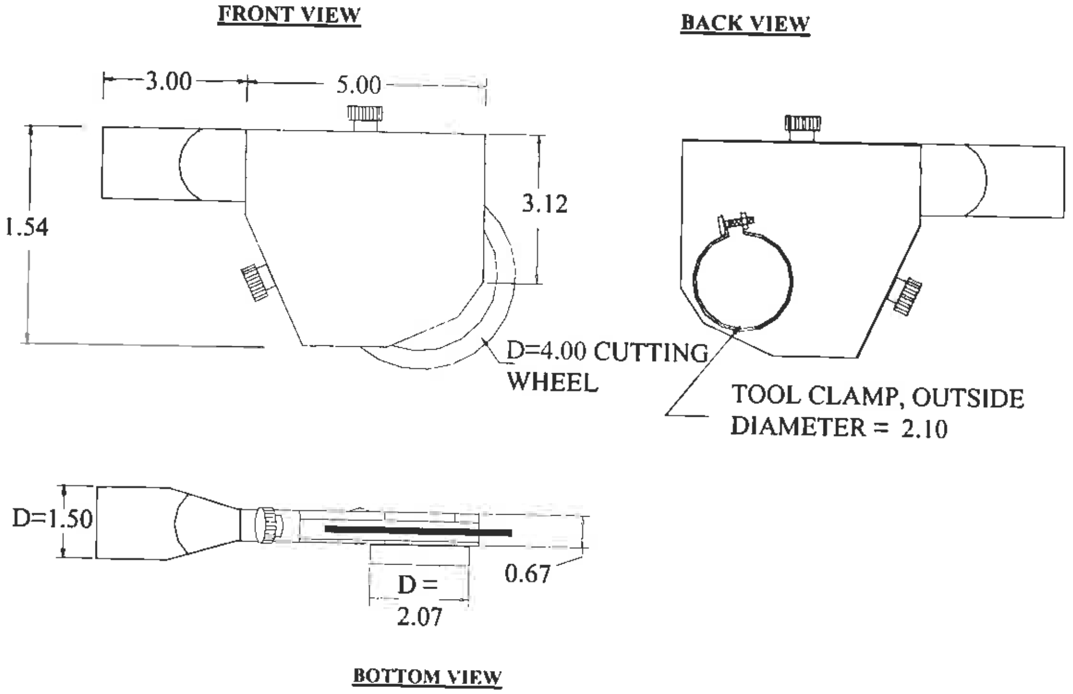


Figure 8. Photograph of Zantech shroud and 4-inch cutter blade mounted on a right angle grinder. In this figure, all dimensions are in inches and "D=" indicates that the dimension is a diameter.

A. PHOTOGRAPH OF SHROUD

B. LINE DRAWING OF SHROUD WITH DIMENSIONS

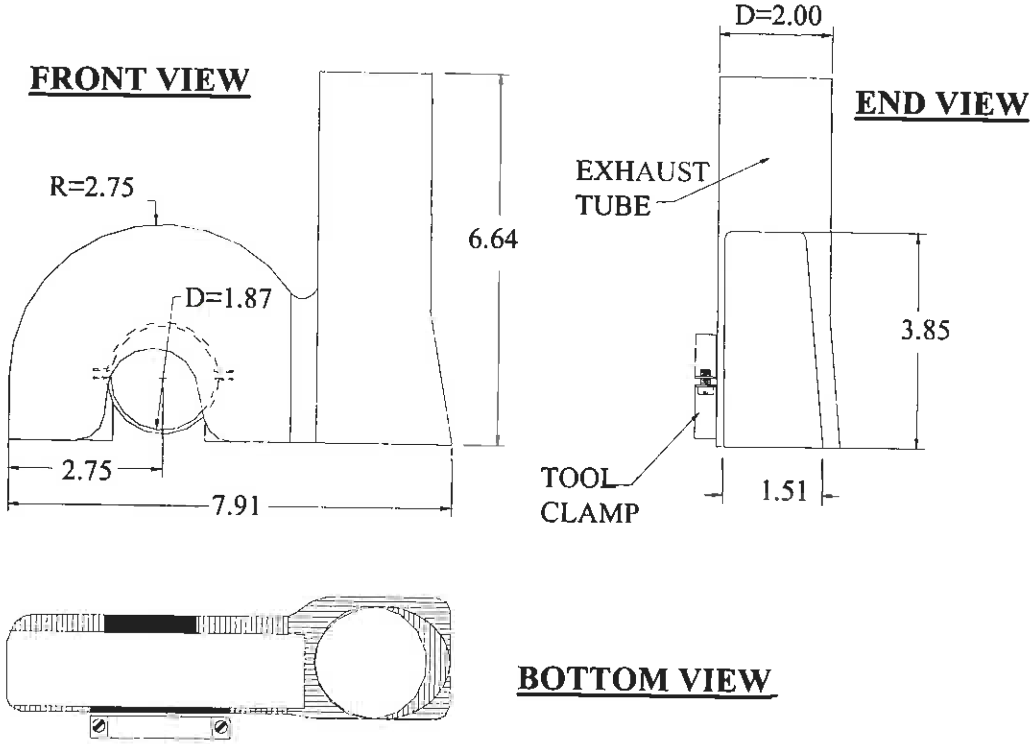
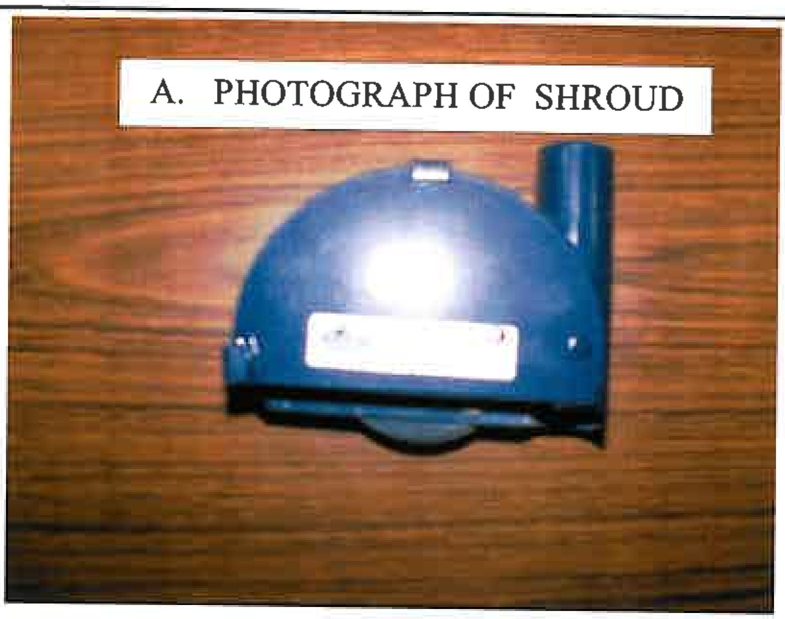


Figure 9. Photograph and line drawing of shop-made shroud. In this figure, all dimensions are in inches and "D=" indicates that the dimension is a diameter. "R=" indicates that the dimension is a radius.



A. PHOTOGRAPH OF SHROUD

B. LINE DRAWING OF SHROUD

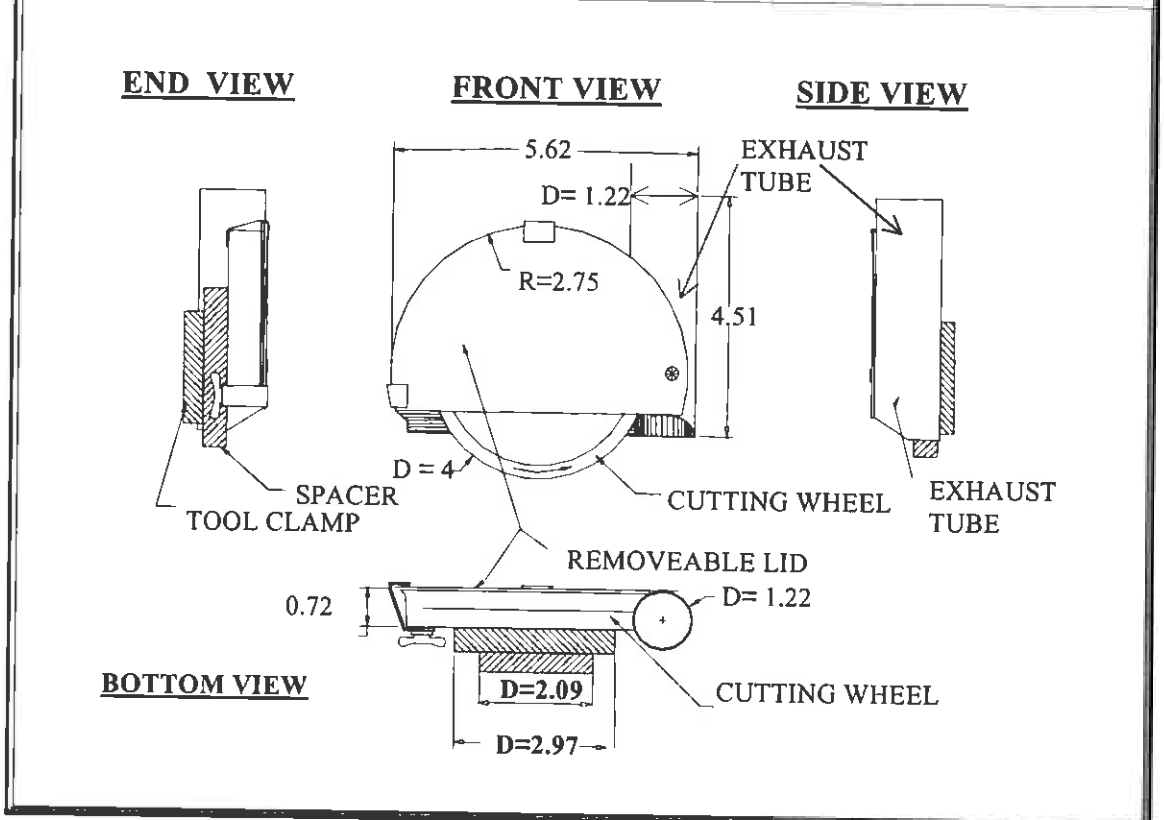


Figure 10. Photograph and detailed line drawing of Dustcontrol shroud. In this figure, all dimensions are in inches and "D=" indicates that the dimension is a diameter. "R=" indicates that the dimension is a radius.

Data Collection-Tuck pointing.

The grinder was set in a precut grove on the wall. The flow rate to shroud was controlled by varying voltage supplied to the vacuum cleaner. A transformer (Powerstat model 3pn136b, Superior Electric Company, Bristol) was used to vary the voltage applied to the vacuum cleaner. The flow rate was measured by inserting the probe from a velometer (Velocicalc, TSI inc, St. Paul, MN) into the 2" diameter duct. The voltage was adjusted to get the desired air velocity and exhaust flow rate. The hole in the 2" diameter duct was covered with duct tape and the data collection was started.

A series of two APS measurements were made to measure respirable dust concentration in the duct. The sampling period for the APS measurement was 2-4 minutes. The first concentration measurements were intended to be background concentration measurements. At the start of the second measurement, a 62 to 78 inch horizontal joint was cut. The travel time of the grinder was 2-3 minutes. The sampling period was chosen to be at least 30 seconds longer than the time to cut a horizontal joint in the mortar. Upstream of the baffles, the air appeared to be turbulent with plug flow toward the baffles. The motion of grinder and the air's turbulence appeared to generate some mixing as the air flowed toward the baffle. The grinder feed rate was adjusted so that the amperage of the grinder was between 4 and 6 amperes at 120 volts. A digital watt meter (Watt meter WD 768 , Vector VID, Horsham, PA) was used to measure the grinder's electrical current. An adjusted respirable dust concentration was computed as the difference between the second and first respirable dust concentrations. The mass of the respirable dust emissions was estimated as the product of the respirable dust concentration, the sampling time, and the duct flow rate. A normalized emission rate was computed by dividing the mass of respirable dust by the nominal volume of the cut. The volume of the cut is the product of the cut length, the cut depth, and blade width. Some blades could not be inserted 0.75 inches; therefore, in some cases, a cut depth of 0.5 inches was used.

Control Description - Brick cutting

The EDCO masonry saw is pictured in Figures 12-15. For the view shown in Figure12, the 10-inch blade rotates in a clockwise direction and the blade turns at about 3,450 rpm. The saw was tested with different options for exhaust ventilation. As marketed, it has a 1-inch square exhaust channel under the objects being cut. When this device was tested in the chamber without ventilation, most of the dust appeared to flow out the exit port shown in Figure 10. In Figure13, the blade barely extends into this channel. There were no specifications available on the recommended exhaust volume for this tool. In addition to the marketed product, several ventilation variations were tested that involved exhausting air from both the exhaust slot and the blade guard. This configuration is shown in Figure 15.

Figure 11. EDCO GMS10 brick saw with an exhaust take-off. This unit was operated with an electric motor in place of a gas motor. The exhaust slot is 6.625 inches long and 5/16 inches wide. The exhaust channel under the blade is 1 inch square.

Figure 12. Picture of bottom exhaust take-off.

Figure 13 A 2-inch diameter exhaust port for the EDCO brick saw. When brick cutting is done without ventilation, the dust naturally flows out this exhaust take-off.

During test conditions c and d in Table1, the blade guard's exhaust take-off was connected to a Nilfisk vacuum cleaner.

During tests conditions c, d, and e in Table 1,the top of the branch entry was sealed with duct tape.

Figure 14. GMS10 masonry saw modified to have an exhaust take-off on the blade guard.

Data Collection-Brick Cutting.

To evaluate the performance of the EDCO GMS10 masonry saw, this saw was set in the test chamber just down stream of the door shown in Figure 1. Testing was conducted by manually cutting bricks under various conditions. A representative of EDCO performed the brick cutting. The EDCO representative wore a full-face piece, powered air purifying respirator. The vacuum cleaners and ventilation measurements used for the tuckpointing tests were used for these tests conducted on the masonry saw.

Smoke tubes were used to visualize the air flow around the segmented saw blade. The air flow appeared to be dominated by the motion of the saw blade. When the blade was completely in the brick, the motion of the saw blade forces the dusty air into the exhaust slot. This does not happen at the start and end of the cut, the air flow patterns change. When smoke was released at the start of a cut, the smoke appeared to flow into the guard which encloses the top of the masonry saw blade. Perhaps, the air from this guard could be exhausted to control this potential source of dust exposure.

The first set of tests was conducted to evaluate whether dust control was less effective at the beginning and end of cuts. To evaluate whether this occurred, short bricks and long bricks and long bricks were cut with and without the use of ventilation. The short bricks were 3 13/16 inches long and the long bricks were 7 7/8 inches long. The bricks had a height of 2 inches. During each experimental run, one brick was cut lengthwise into 5 slivers. The sampling periods for the APS were 1 minute for the short bricks and 2 minutes for the long bricks. The masonry saw was just down wind of the door. Two short bricks and two long bricks were cut without ventilation. Three long bricks and three short bricks were cut with ventilation.

A second set of tests were conducted to evaluate whether exhausting air from the guard would reduce respirable dust emissions. Prior to this test, a GMS10 was constructed to have an exhaust take-off from the blade guard. (See Figure 15.) The take-off was attached by tubing to the exhaust channel on the GMS10. During this test, the air flow rates from the exhaust channel and the top of the guard were varied. There were 10 experimental runs during which one brick was cut lengthwise into 4 pieces. There were five combinations of exhaust flow rates from the exhaust channel and the1`exhaust take off from the guard that are listed and described in Table 1. During the second set of tests, the masonry saw was exhausted by one or two vacuum cleaners. The Dustcontrol Model 3700 (Norsberg, Sweden) was connected to the exhaust port shown in Figure 14. During test conditions "b", "c", and "d" in Table 1, the exhaust connection to the blade guard was removed and the branch entry connection was sealed with duct tape. This connection is located is located on the top of the exhaust take-off for the vacuum cleaner (See Figure 15) . A Nilfisk vacuum cleaner (model Gm82) provided exhaust ventilation from the blade guard during tests "c" and "d". These tests are listed in the following table:

Table 1. Test flow rates for the EDCO GM10 Masonry Saw with exhaust take-offs for the exhaust channel and blade guard.

Test condition	Air flow from the exhaust channel beneath the table cubic feet per minute (cfm)	Air Flow from the Guard (cfm)	Comments
a	0	0	Exhaust hoses were not attached to the masonry saw.
b	93	0	Dustcontrol vacuum clear attached to exhaust port on back of the masonry saw. The exhaust connection for the blade guard was blocked with duct tape.
c	93	52	Dustcontrol vacuum cleaner exhausts air from exhaust channel. The exhaust take-off for blade guard was blocked with duct tape. A Nilfisk vacuum cleaner exhausted air from the blade guard. The power to the Nilfisk vacuum cleaner was varied to obtain the two flow rates.
d	93	113	
e	54	84	Dustcontrol vacuum cleaner exhausting air from the blade guard and the exhaust channel. The masonry saw was used as designed.

Results-tuck pointing

Because data collection took place with different sampling times and different amounts of mortar removed, respirable dust emission rates are stated in terms of mass of respirable dust produced per volume of mortar removed. The respirable dust emission rate is plotted as a function of exhaust flow rates for the various combinations of shrouds and tools in **Figure 16-20.** The raw data is summarized in the data appendix. Some summary statistics for the data are presented in Table 2. Visual inspection of the results for the mortar rake (**Figures 16** and **17**) indicate that flow rates in excess of 40 cfm do not result in a noticeable reduction in dust emissions. For data taken below 40 cfm, the mortar dust was not removed from the brick and a line of mortar dust was visible on the brick. This line resembled a chalk line on a school blackboard. Inspection of the concentrations measured during background and during mortar grinding were the same order of magnitude. As observed in Table 2, flow rates above 40 cfm resulted in approximately a factor of 300 reduction in respirable dust emissions.

Visual inspection of respirable dust emissions for the 4 inches grinders (Figures 16 to 20), suggest that an exhaust flow rate of at least 80 cfm is needed to control the dust emissions. **Figure 21** combines the data from all of the grinders. Table 2 presents summary statistics for three different exhaust flow (q) classifications: 0 cfm, $0<q<80$ cfm, and $q \geq 80$ cfm. For the first and third flow rate classification, the emission rates had about the same variability and there is approximately a factor of 300 difference in the emission rates. For $0<q<80$ cfm, the respirable dust emission rates appear to be declining with increasing exhaust flow rate; however, the data appears to have increased variability. (See **Figure 21**.)

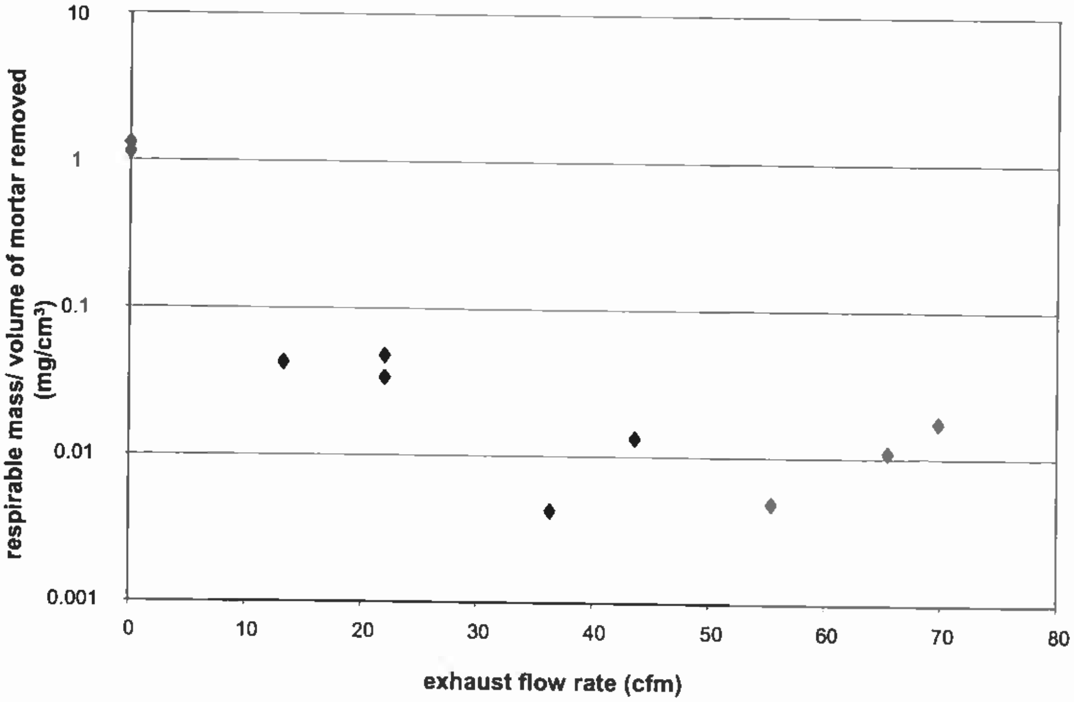


Figure 15. Dust emissions as a function of flow rate when the American Tool Mortar Rake is used. The cutting depth was 0.75 inches.

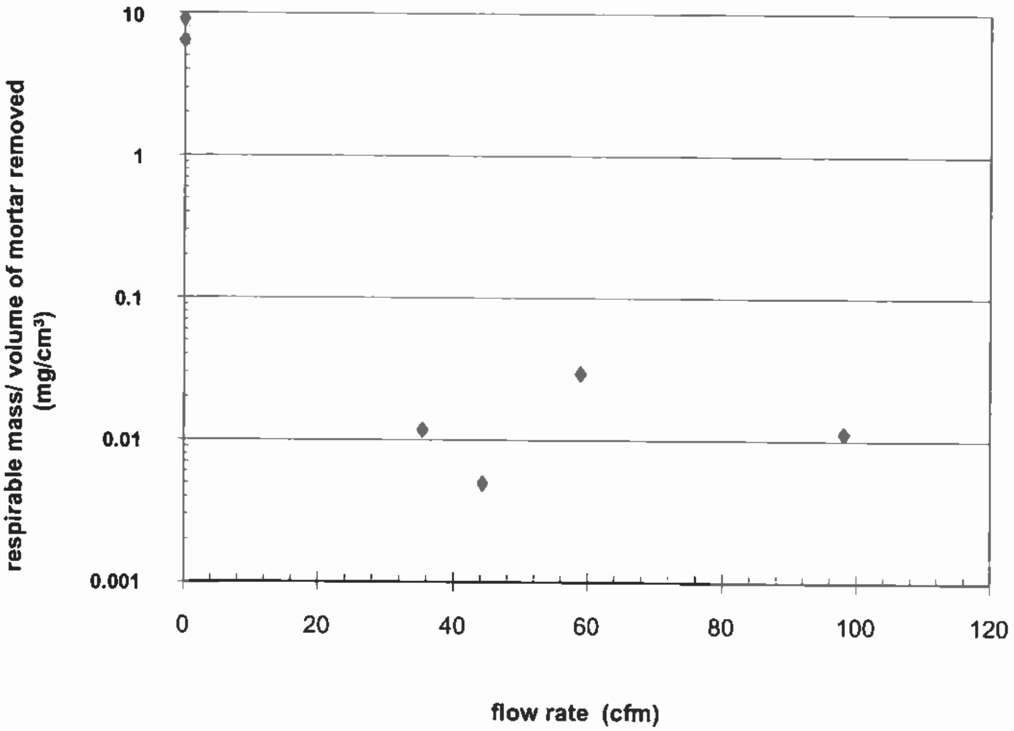


Figure 16. Dust emissions as a function of exhaust flow rate for the mortar rake. The depth of cut was 0.5 inches.

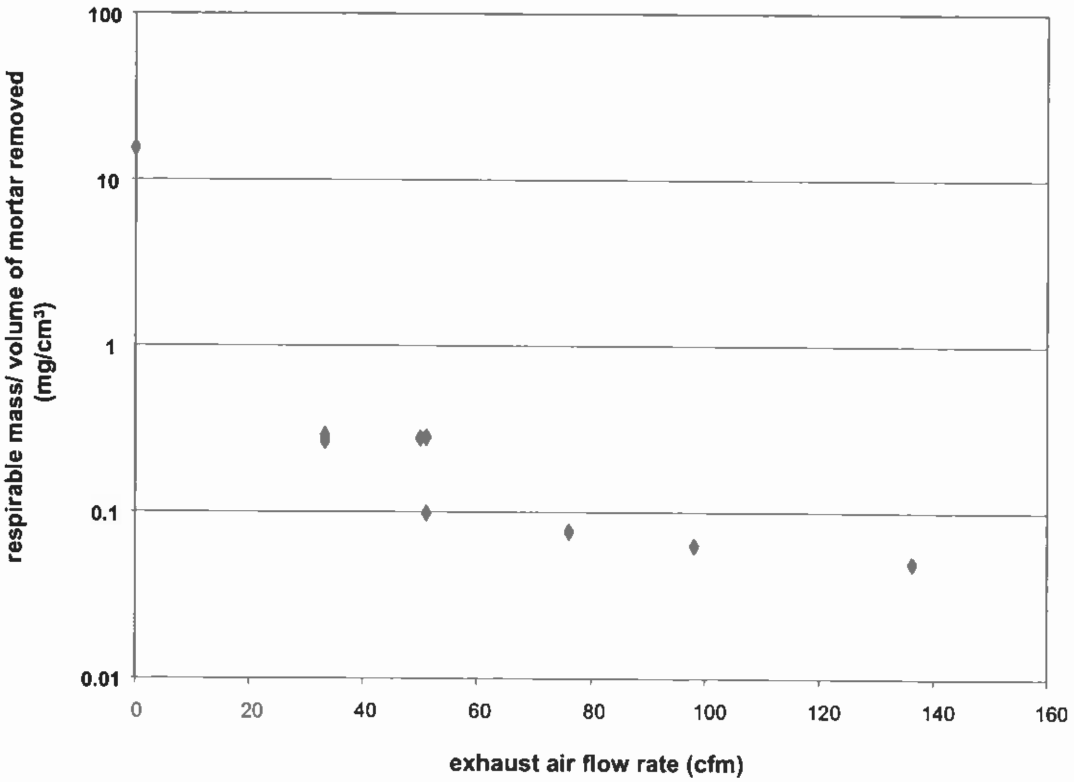


Figure 17. Respirable dust emissions as a function of exhaust flow rate for a 4.5 inch grinder used
with the Zantech shroud.

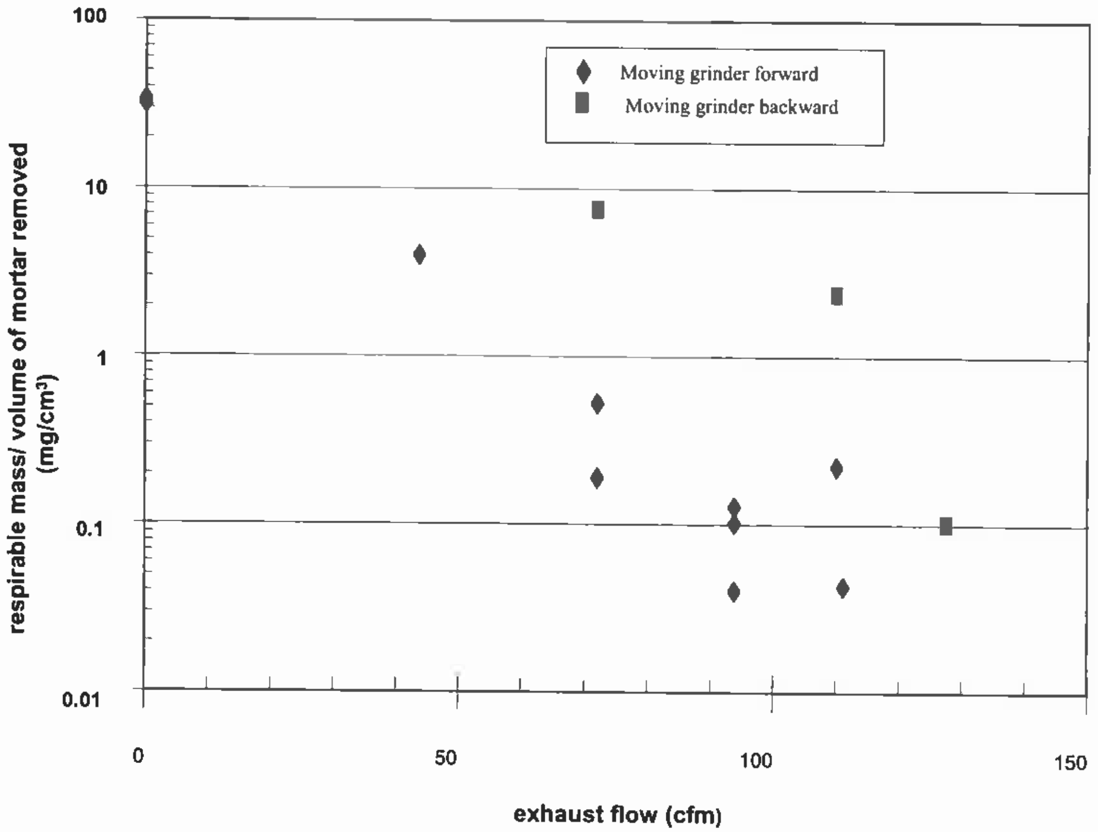


Figure 18. Respirable dust emissions as a function of exhaust flow rate through the Dustcontrol shroud on a 4.5 inch diameter cutter. When the grinder was operated in reverse, there were obvious dust emissions.

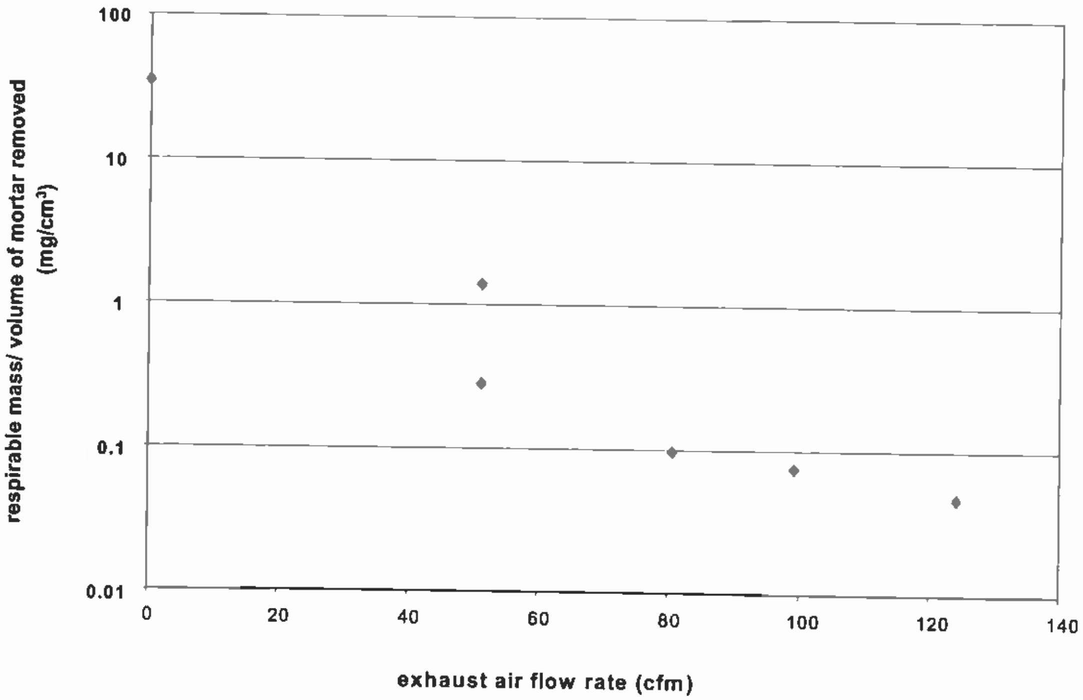


Figure 19. Respirable dust emissions as function of exhaust flow rate for the Shop -made shroud.