An Evaluation of Silica Exposure Controls for Tuckpointing: Ermator S26 Vacuum with Two ICS Dust Director Shrouds and Two Bosch Grinders Conducted June 19-20, 2013

CPWR – The Center for Construction Research and Training

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Executive Summary

This report describes the results of an evaluation of a tuckpointing dust control system for use by two workers simultaneously. The system consisted of **two Bosch grinders; two Dust Director shrouds attached by duct to a single Ermator S26 vacuum.** Randomized trials with and without use of the dust control system were conducted in a controlled setting. Removing mortar with the Bosch grinders without the dust control system resulted in a mean task time-weighted average (TWA) respirable silica exposure 690 times the National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limit (REL). Use of the same grinders with the dust control system reduced exposures by approximately 98 percent. However, exposures measured during the use of the dust control system still exceeded NIOSH REL. It should also be noted that the NIOSH REL is based on exposures averaged over a ten-hour workday and our results represent TWAs of the task-based samples.

ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
CPWR	CPWR – The Center for Construction Research and Training
Ce	coefficient of entry
HEPA	high-efficiency particulate air
IUBAC	International Union of Bricklayers and Allied Craftworkers
LEV	local exhaust ventilation
PACT	Partnership for Advancing Control Technologies
NIOSH	National Institute for Occupational Safety and Health
OEL	occupational exposure limit
OSHA	Occupational Safety and Health Administration
PAPR	powered air-purifying respirator
PEL	Permissible Exposure Limit
PVC	polyvinyl chloride
REL	Recommended Exposure Limit
RPM	revolutions per minute
TWA	time-weighted average
SP	static pressure

I. Introduction and Background

In 2010 CPWR – The Center for Construction Research and Training began a four-year project to identify and evaluate tuckpointing local exhaust ventilation (LEV) systems and disseminate information on their availability and effectiveness. A Partnership for Advancing Control Technologies (PACT) comprised of masonry contractors, representatives from unions, government, equipment manufacturers, and researchers was formed as part of this project. PACT members participated in identifying important characteristics for control technologies and this information was used to identify LEV systems for tuckpointing using that criteria. Contractor and labor members of the PACT selected specific tuckpointing LEV systems to be considered for evaluation. Each system consisted of a tuckpointing grinder, shroud, and vacuum. This report describes the third of four systems which were among the most highly rated by industry representatives (labor and contractors) and were evaluated between 2012 and 2014. Each system was evaluated, with and without LEV (**Figures 1 and 2, respectively**), in a controlled setting to determine effectiveness in silica exposure reduction. The report describes the methods used to test the system consisting of the **Ermator S26 vacuum with two ICS Dust Director shrouds and two Bosch grinders** and the results of the evaluation.

Figure 1. Bosch grinder with Dust Director shroud and Ermator S26 vacuum

Excessive exposure to respirable silica can result in silicosis or other silica-related diseases including pulmonary tuberculosis, lung cancer, silicoproteinosis (Lyons et al, 2007) and autoimmune disorders such as rheumatoid arthritis, sarcoidosis and scleroderma (Miller et al, 2012). Respirable particulate is generally defined as particles less than 10 micrometers (μm) in aerodynamic diameter (ACGIH, 2013). Silicosis can lead to symptoms including shortness of breath, fatigue, chest pains, susceptibility to infection and possibly death. There is no cure for silicosis, however it is totally preventable. Construction workers exposed to dust, including silica, are also known to have higher rates of chronic obstructive pulmonary disease (COPD).

There are many sources of silica in construction that result in exposures of varying intensity among workers. Masonry restoration workers are among the most highly silica-exposed trades in construction. The process of grinding out deteriorated mortar joints between masonry units and replacing or repointing with fresh mortar (often referred to as tuckpointing) is a fundamental part of masonry restoration work. The removal of mortar with powered angle grinders generates enormous levels of dust. Between 2004 and 2006, the National Institute for Occupational Safety and Health (NIOSH) and CPWR evaluated silica exposures while grinding mortar in a controlled setting, at a local training center, where tasks, sample times and task variables were defined by the study design. These studies demonstrated that grinding mortar without controls can result in elevated respirable silica exposures. Meeker et al., (2009) reported exposures between 5 and 25.8 milligrams per cubic meter (mg/m^3) in a controlled setting. The NIOSH Recommended Exposure Limit (REL) for respirable silica based on a 10-hour time weighted average (TWA) exposure is 0.05 mg/m^3. This study also showed that LEV systems for tuckpointing grinders can reduce exposures to respirable silica by greater than 90 percent.

Figure 2. Bosch grinder without tuckpointing LEV system

II. Objectives

The objective of this evaluation was to assess the effectiveness of a LEV system for controlling exposure to silica during the grinding of mortar. The control technology was tested under controlled conditions, similar to those experienced by tuckpointers on actual job sites, using journeymen bricklayers experienced in tuckpointing and repeat, randomized trials with and without LEV. All other variables were held constant throughout so that the only variable was whether or not the tested control was used.

III. Description of Equipment Tested

Two **Bosch grinders, models 1775E and AG40-85**, (Robert Bosch Tool Corporation, Prospect, IL) were fitted with new 1/4-inch wide, 4½-inch diameter segmented diamond abrasive blades made by DeWalt (model #DW4740). The 1775E grinder weighs six and a half pounds, draws 8.5 amps, and has a variable speed up to a maximum of 11,000 revolutions per minute (RPMs). The AG40-85 grinder weighs four and a half pounds, draws 8.5 amps, does not have a variable speed, and is capable of up to 11,500 RPMs.

The **Ermator S26 vacuum** (Pullman-Ermator, Tampa, FL) (**Figures 1 and 4**) was tested in combination with **two Dust Director shrouds** (Industrial Contractors' Supplies, Inc., Huntingdon, PA) (**Figure 3**) attached to two **Bosch grinders**.

Figure 3. Bosch Grinder and Dust Director Shroud with manometer

The vacuum weighs 103 pounds and is specified to provide 258 cubic feet of air flow per minute (cfm) and a "static lift" or "vacuum suction pressure" of 100 inches of water. The vacuum includes a cyclonic pre-separator, which removes larger particles, a pre-filter (rated >99.5 percent efficient) and two high-efficiency particulate air (HEPA) filters (which by definition is designed to capture 99.97 percent of the particles with an aerodynamic diameter of 0.3 micrometers).

CPWR sponsored research and contractor experience have found use of HEPA filters for tuckpointing may have an adverse effect on dust capture. However, Ermator strongly recommended use of the HEPA filters so we left them in place. While the cyclone and the fine pre- filter removes most of the dust, especially the large particles, before they reach the HEPA filter, the HEPA filter is still subject to heavy loading which may cause a pressure drop and subsequent decrease in vacuum air flow. The relatively small increase in the efficiency of the filtration system while using the HEPA filter is expected to be quickly offset by a more significant decrease in capture efficiency as the air flow and ability to capture particles decreases. The filter loading, pressure drop, and decrease in air flow may be mitigated through regular filter cleaning.

Figure 4. Ermator S26 vacuum with Longopac system

Dust captured by the Ermator S26 collects in bags or a 70-foot continuous Longopac tube. Both are relatively inexpensive, made of heavy-gauge plastic and located below and outside of the cyclone (**Figures 4 and 5**). When the bag reaches the desired level of dust accumulation or weight then it is removed and sealed at the top with a plastic cable tie. When the plastic tube fills with dust, two ties are secured below the cyclone but above the dust load and the tube is cut between them leaving one tie in place at what will be the bottom of the next dust collection section. Use of the continuous tube allows the tuckpointer to tie off a section loaded with dust and cut it off without having to remove or replace any bags attached to the vacuum and can be removed relatively quickly and easily without exposing the operator to its contents.

Figure 5. Procedure for using the Longopac tube

Continuous plastic tube is pulled downward and divid-ed in single bags of any size.

Tie the plastic tube twice.

Cut between the ties and dispose the filled bag.

The Ermator S26 is equipped with an indicator to alert the user when the filters need to be cleaned or changed (**Figure 6**). The Ermator S26 features a "Jet Pulse" filter cleaning system to remove accumulated dust from the pre-filter without having to remove it from the vacuum. The system requires the operator to disconnect the hose from the vacuum and plug the air intake with a provided cap. This causes the vacuum to become pressurized. Subsequent to that, with the vacuum running, a lever on the top of the vacuum is depressed five times to release built up pressure in strong pulses that dislodge dust from the filter.

Figure 6. Filter cleaning indicator on Ermator S26 vacuum

Each Dust Director shroud had a 2-inch diameter take-off that was connected to a corrugated, 2-inch diameter, 12-foot long flexible vacuum duct. The two 12-foot ducts were connected to a 2.5-inch diameter, 4-foot long duct with a Y fitting. The latter, larger diameter and shorter duct was connected to the S26 vacuum (**Figure 1**).

IV. Study Methods

This evaluation was conducted at the International Union of Bricklayers and Allied Craftworkers (IUBAC) Local 1 Philadelphia/Delaware Training Center in Philadelphia, PA on June 19 and 20, 2013. Two journeyman bricklayers, experienced in tuckpointing, used the grinders and LEV system being tested to remove mortar from joints generally wide enough to require two passes. The type S mortar had been allowed to cure for at least four weeks. The bricklayers either possessed or were provided with personal protective equipment including sturdy work boots, gloves, hearing protection and a powered air-purifying respirator (PAPR). The PAPRs used were a 3M GVP system with a bump cap (3M, St Paul, MN) and a Pureflo PF60 ESM with type 1, class G head protection (meeting ANSI Z89.1-2003 (Interactive Safety Products, Inc., Huntersville, NC). Both units had a hood or loose-fitting face piece with a face shield (meeting ANSI Z87.1+) and a HEPA filter.

The study was designed to include five paired rounds of sampling during mortar removal. Each round included a trial with two workers using Bosch grinders with Dust Director shrouds connected to a single Ermator S26 vacuum and a trial with the same workers using the Bosch grinders with the factory-supplied guards but without a vacuum. The order of the trials (with and without LEV) within each round was randomly selected to minimize bias that might be introduced due to variation associated with environmental factors, equipment operators, blade wear, changes in vacuum performance over time, and any other factors unrelated to LEV use. The workers always worked on the same wall and the distance between them ranged from approximately three and a half feet to 29 feet but was not controlled by the researchers. Tools were operated for approximately 20 minutes per trial with controls and for approximately 10 minutes when controls were not used. These times were selected based on the results of previous sampling efforts and estimates of the minimum sample time necessary to accurately measure down to 0.05 mg/m^3 – the NIOSH REL for respirable silica – during use of the LEV system. The bricklayers were required to take a 5-minute break in the middle of the 20-minute trials to reduce variability in dust generation rates between trials with and without LEV use that may be attributed to fatigue.

Personal air samples were collected in each operator's breathing zone during each trial to measure respirable silica concentrations during grinding with and without LEV. The samples were collected using a GilAir-5 pump (Sensidyne, Inc., Clearwater, FL) to draw 4.2 liters of air per minute through a GK2.69 Respirable Cyclone (BGI Inc., Waltham, MA) with a pre-weighed, 37 mm diameter, 5-micron pore size polyvinyl chloride (PVC) filter positioned on the operators' lapels.

The flow rates of the sampling pumps were calibrated at the beginning of each day using a DryCal DC-Lite Primary Flow Meter (Bios International Corporation, Butler, NJ). Flow rates were measured again near the middle of the day to ensure that post-sampling flow rates were within 5% of pre-sampling flow rates. Average flow rates were used to calculate sample air volumes. Samples were analyzed by R.J. Lee Group, Inc., (Pittsburgh, PA) using NIOSH Method 0600, to determine exposure to total mass of respirable dust. The same samples were also analyzed using X-Ray diffraction following NIOSH method 7500 to determine quartz, cristobalite and tridymite concentration in the respirable mass. Reported masses for these analytes were used with the sample air volumes to calculate airborne concentrations of total respirable dust, quartz, cristobalite and tridymite.

We used a reduction of greater than 50 percent in respirable silica exposure concentrations or a reduction to less than the NIOSH REL of 0.05 mg/m^3 as our criteria for determining whether or not a control was considered effective. This is consistent with criteria used by in previous studies conducted by NIOSH (Echt et al., 2007) and CPWR (Meeker et al., 2009). The Occupational Safety and Health Administration (OSHA) and the American Conference of Governmental Industrial Hygienists (ACGIH) publish additional occupational exposure limits (OELs) for silica, which are listed in **Table 1** with the NIOSH RELs. OELs for silica are based on the respirable fraction of the aerosol, which consists of particles less than 10 μm in aerodynamic diameter.

Table 1. Occupational Exposure Limits for Respirable Crystalline Silica

Organization or Agency	Form of Crystalline Silica	Occupational Exposure Limits (mg/m^3)
NIOSH[A]	Quartz	REL = 0.05 mg/m^3
	Cristobalite	REL = 0.05 mg/m^3
	Tridymite	REL = 0.05 mg/m^3
OSHA - Construction[B]	Quartz	PEL = 250 / (5 + % quartz)
	Cristobalite	PEL = 250 / (5 + % cristobalite)
	Tridymite	PEL = 250/ (5 + % tridymite)
ACGIH	Crystalline Silica	TLV = 0.025 mg/m^3

[A] NIOSH Publication No. 2005-151 describes use of a 10 hour time weighted averaging time over a 40-hr workweek for RELs.
[B] The PEL for silica in OSHA's Safety and Health Regulations for Construction, 29 C.F.R. 1926.55(a), is an 8-hour time-weighted average (TWA) expressed in millions of particles per cubic foot (mppcf). However, the units mppcf can be converted to milligrams per cubic meter by dividing mppcf by 10 (OSHA, 2009). The formula used by OSHA to determine the PEL for silica is dependent on the percentage of silica in each collected sample. The concentration of respirable dust measured is compared to the sample specific PEL to determine if the PEL has been exceeded. In September 2013, OSHA proposed lowering the PEL to 0.05 mg/m^3 of respirable silica as an 8-hour TWA.

The flow of air in ventilation systems is governed by fundamental principles that describe the behavior of gases. Pressure measurements taken within a ventilation system along with knowledge of hood (or shroud) entry losses can be used to calculate air flow. Hood entry losses are dependent on the shape and configuration of a particular hood or shroud and described by the term "coefficient of entry (Ce)". Ce is the ratio of *actual* air flow through a hood and the *theoretical air flow absent any* hood entry losses. Given hood Ce and the area of the duct where static pressure (SP) measurements are taken, actual air flow can be calculated. The Ce for the Dust Director shroud was previously determined by CPWR to be 0.813 (Meeker et al., 2009). Static pressure, with the vacuum on and the grinder off, was measured periodically to monitor the changes in air-flow over time.

mmMeasurements were taken following use and after filter cleaning. The static pressure was measured at a port attached to a 2-inch diameter steel pipe positioned more than 3 duct diameters downstream from the shroud's air intake using a UEi EM200 Electronic Manometer (Universal Enterprises, Inc., Beaverton, OR).

The vacuum bag was changed after each trial weighed to the nearest pound. The bag weights and corresponding grinding durations were used to calculate the average weight of dust collected per unit time.

After each trial, cut lengths were measured on the wall to determine total linear feet of vertical (head) and horizontal (bed) joints cut per unit time.

A Haz-Dust III, Model HD-1003, Real-Time Aerosol Monitor (Environmental Devices Corporation, Plaistow, NH) was used to confirm clearance of dust between trials. The Haz-Dust monitor was positioned on the test wall near the operator at approximately breathing zone height and configured to measure respirable particulate concentration.

V. Results

Personal air monitoring. Five pairs of respirable dust samples were collected for each of the two workers when grinding with and without use of the vacuum producing a total of 20 samples (10 with and 10 without LEV). Personal air monitoring results for respirable silica and a comparison of average exposures relative to the NIOSH REL for silica (0.05 mg/m^3) appears in **Table 2.** Graphical depictions of average respirable silica and dust exposures, with and without the dust control system, appear as **Figures 7and 8,** respectively**.**

Table 2. Respirable Silica Exposures While Grinding Mortar[A]

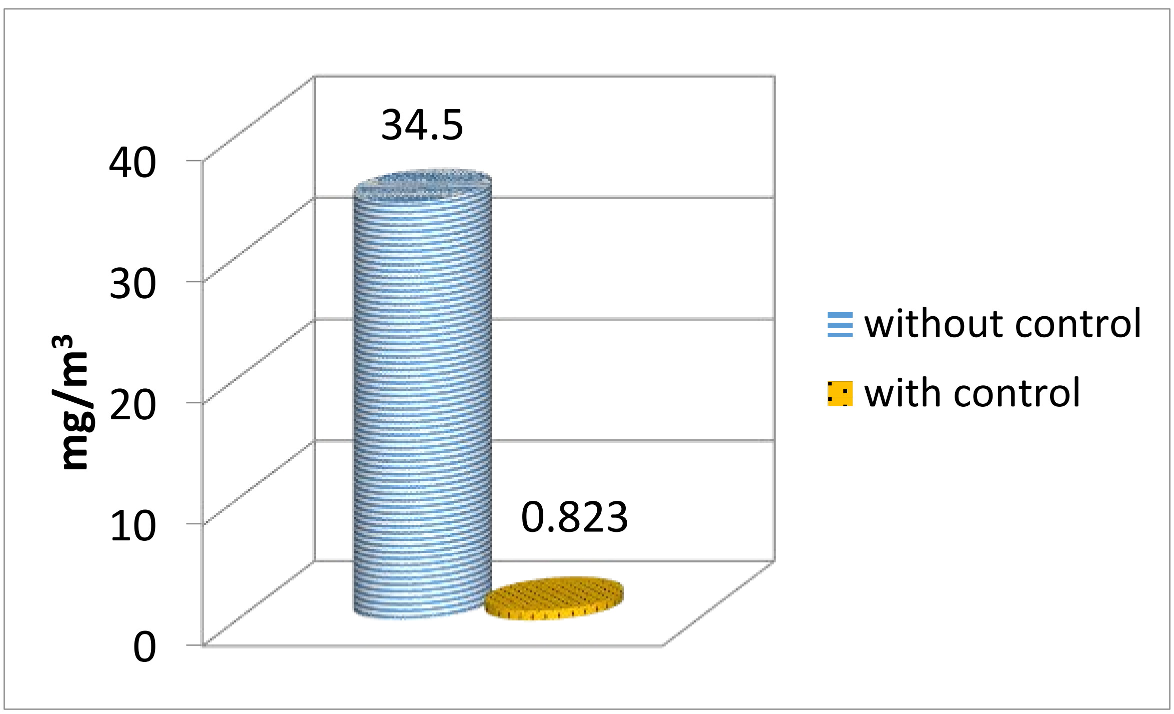
	Mean, mg/m^3 (range)	Std. Dev.	Percent Reduction	Hazard Ratio[B]
Bosch Grinders with Dust Director Shrouds and Ermator S26 Vacuum	0.823 (0.288 – 2.27)	0.601	97.6	16.5
Bosch Grinders with no Control	34.5 (5.54 – 89.0)	28.3	NA	690

[A] n = 10 samples for each tool/control combination (5 for each worker)
[B] Hazard Ratio = average measured exposure / NIOSH REL of 0.05 mg/m^3

The mean respirable silica concentration measured during use of the control system was significantly less than the concentration measured while using the same tools without controls ($p<0.01$). Grinding mortar with the Bosch angle grinders without dust controls resulted in an average exposure to respirable silica that was ***690 times the NIOSH REL***. Grinding with the Bosch angle grinders in combination with the Dust Director shrouds and the Ermator S26 vacuum reduced the average concentration of respirable silica by 97.6 percent. With use of these controls, the concentration of respirable silica was 16.5 times greater than the NIOSH REL of 0.05 mg/m^3. However, the NIOSH REL is based on a time-weighted average (TWA) over a 10-hour workday and we report task TWAs over short periods of continuous grinding.

In addition, mean respirable silica exposures were calculated for each worker. The mean respirable silica exposure for one worker (1.22 mg/m^3) was approximately three times the other worker's exposure (0.423mg/m^3), a statistically significant difference ($p<0.05$).

Figure 7. Average respirable silica exposures with and without the Ermator S26 vacuum and Dust Director shrouds in milligrams per cubic meter of air (mg/m^3)

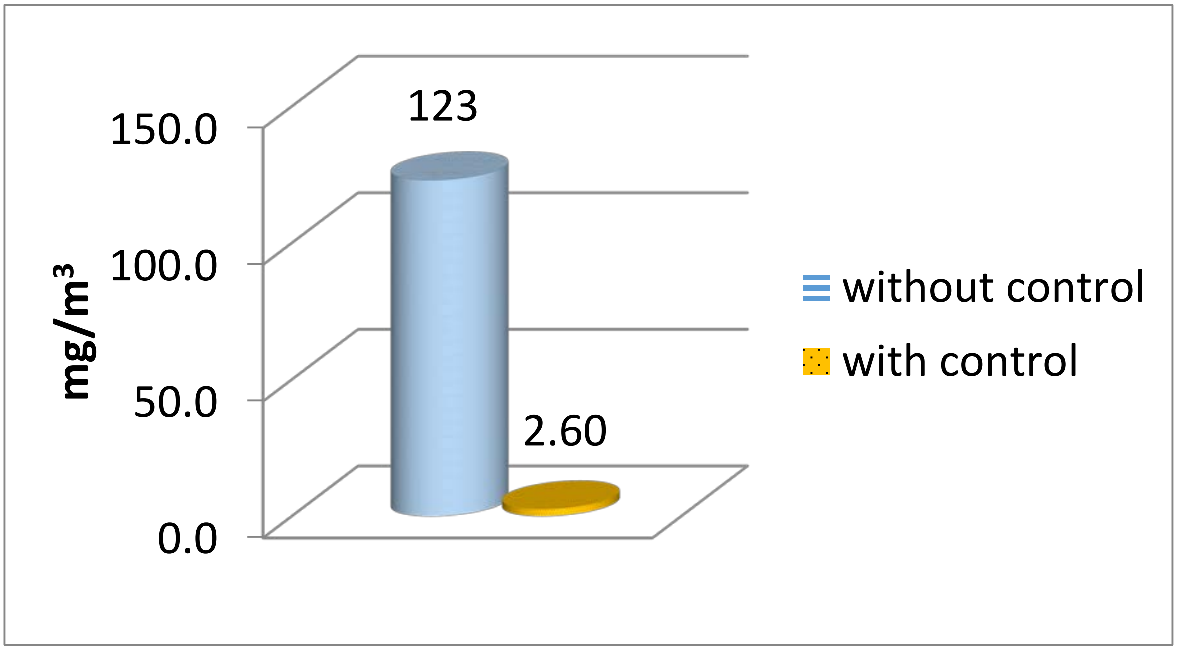


The mean respirable dust levels measured without LEV was 123 mg/m^3. The mean respirable dust levels measured with use of the LEV system was 2.60 mg/m^3. Two samples collected with LEV were below the limit of quantification (LOQ) which ranged from <1.20 to <1.22 mg/m^3. Use of LEV resulted in a 97.9% reduction in mean respirable dust levels. The respirable dust samples collected with use of the LEV system contained an average of 31 percent silica. The respirable dust samples collected during grinding without the LEV system contained an average of 29 percent silica.

Static pressure and air flow. Static pressure was used as a field measure from which to derive air flow as described earlier. Hood static pressure was measured periodically at a tap between the grinder and vacuum duct about 6 inches (3 duct diameters) from the air intake in the shroud (Figure 8). The static pressure, and thus air flow, was generally higher after the vacuum's pre-filter had recently been cleaned as described earlier. The mean, median, and range of calculated flow rates are presented in **Table A1 of the Appendix.** Based on the data we collected during the trials, the air flow measured upstream from the Bosch grinder and Dust Director shroud ranged from 50 to 90 cfm with the Ermator S26 vacuum. The air flow was 90 cfm initially and dropped to between 50 and 78 cfm (average of 65 cfm) after as little as 10 minutes of grinding without any filter cleaning. The air flow returned to 78 to 84 cfm (average of 80 cfm) when the pre-filter was cleaned following manufacturer instructions. Collingwood and Heitbrink (2007) found that the minimum exhaust air flow for capture of silica and other particulate under ideal conditions is 21.25 cfm per inch of grinder blade diameter (96 cfm for a 4.5 inch diameter grinding blade). We set 106 cfm as the minimum desired air flow for this study to allow for potential decline in equipment performance and the possibility of inadequate maintenance, both of which may be likely after repeated use under actual work conditions. As found in previous evaluations, the vacuum tested didn't' quite meet these desired air flows and declined over time.

Dust mass collection and grinding rates. The duration of vacuum bag use and mass of dust collected were recorded and are presented in **Table A2 of the Appendix**. The vacuum bags were changed and weighed after each trial utilizing the LEV system for a total of five bags used over the course of the evaluation. The Ermator S26 vacuum captured 44 pounds of dust while two workers were grinding for 100 minutes. The rate of dust collection for two workers ranged from 0.40 to 0.49 pounds per minute with an average 0.44 pounds per minute. Based on these measurements***, approximately 105 pounds of dust would be captured after two workers complete just 4 hours of continuous grinding***.

Figure 8. Respirable dust exposures with and without Ermator S26 Vacuum and Dust Director Shrouds in milligrams per cubic meter of air (mg/m³)



The rate of grinding a combination of vertical and horizontal joints while using the LEV system ranged from 1.6 to 2.8 feet per minute with an average of 2.2 feet per minute. The rate of grinding vertical and horizontal joints without the use of the LEV system and with the stock blade guard ranged from 1.3 to 3.2 feet per minute with an average of 2.6 feet per minute. The differences in mean rate of grinding with and without the LEV system was statistically significant ($p<0.04$). This represents about a 15% reduction in average cut rates.

VI. Discussion

The objective of these trials was to evaluate the effectiveness of a tuckpointing LEV system for controlling respirable silica while grinding out mortar joints. Two Dust Director shrouds with the Ermator S26 vacuum reduced respirable silica concentrations when grinding with two Bosch grinders by approximately 98 percent. Despite being considered effective by our test criteria (greater than 50% reduction), the average task TWA exposure during use of the tuckpointing LEV system was still over sixteen times the 10-hour TWA NIOSH REL of 0.05 mg/m^3 . However, as stated earlier, our samples were collected over short periods of continuous grinding. Depending on how much time is spent grinding over the course of an actual work day and on the extent of exposure while performing other tasks, the full shift TWA exposures may or may not exceed the REL with this system.

This evaluation differed from CPWR's 2012 evaluations in that two tuckpointers worked side by side. Since it's common to see tuckpointers working in pairs on suspended scaffolding, exposures measured during this evaluation may be more representative of those encountered on actual job sites. While this LEV system was effective in reducing respirable silica exposure, average exposures were more than twice the concentrations measured in 2012 suggesting that when tuckpointers work side by side airborne silica concentrations are increased substantially.

The effectiveness of this tuckpointing LEV system is likely to vary between workers as demonstrated by the three-fold difference in mean inter-worker exposure during this evaluation. Use of this system by workers with experience and training in proficient use will likely improve dust capture performance. Exposure reduction is greatly influenced by correct use of this system which includes: 1) grinding from right to left[1]; 2) making sure the shroud is held flush against the wall; and 3) making sure that the tool travels at a pace that doesn't exceed the ability of the system to capture dust as it's generated. Deviation from any of these measures produces visible dust clouds, which were observed during trials.

While grinding rates were approximately 15% lower with the LEV system, it's important to note that: 1) the operators had limited experience using dust control systems; and 2) the range of cut rates with and without use of the dust control system overlapped, indicating that the reduction in grinding times, with use of LEV was small. Given that grinding rates with and without use of this LEV system are only available for two operators who had limited experience with the LEV system, these reported cut rates are in no way intended to represent the impact use of this LEV system is likely to have on productivity rates overall.

VII. Conclusions

The LEV system we evaluated, which consisted of two Bosch grinders, two Dust Director shrouds, and an Ermator S26 vacuum reduced TWA respirable silica exposures by 98 percent. Therefore, it met our criteria of reducing exposure by 50%. Use of the tested dust control system may be effective in reducing silica exposure on the job to less than the NIOSH REL if used in combination with administrative controls such as work scheduling to reduce cutting times as needed. Training on correct use of the tested system is also essential. However, employers must conduct personal air monitoring to verify control effectiveness for the materials and work conditions on their jobsites. Personal air monitoring is necessary to verify control effectiveness on actual job sites and under "real-world" conditions and determine if supplemental measures are needed (administrative controls or respiratory protection). Nevertheless, these results clearly demonstrate the availability of viable engineering controls for tuckpointing – a task associated with extremely high silica exposures

[1] Grinding from right to left is required for this combination of shroud and grinder. Other shrouds and grinder combinations may allow working from left to right or both directions.

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IX. Appendices

Table A1. Air Flows Calculated From Static Pressure Measurements

		Air Flow for One Grinder (cfm)*		
Measurement Conditions	**n**	**Mean**	**Median**	**Range**
Before filter cleaning	9	65	63	50-78
After filter cleaning following manufacturer directions	7	80	81	78-84

* Static pressure was measured in inches of water gauge. Air flow for one grinder and shroud was calculated using the formula $Q = Ce\ (A)\ 4005\ (SP)^{1/2}$ where: Q = air flow in cubic feet per minute (cfm), Ce = coefficient of entry, A = area of the duct where static pressure measurements were taken in square feet, and SP = static pressure in inches of water gauge. The hoses from the Y to each grinder were identical and we assume that SP, velocity, and air flow rate in hose where the SP was not measured will also be equal. Therefore, the total air flow provided by the vacuum is estimated to be approximately twice the values reported in Table A1.

Table A2. Rate of Dust Collection for Both Workers

Tool/Control	Total Mass Collected (lb)	Collection Period (min.)	Dust Collection Rate (lb/min.)
Two Bosch grinders/Dust Director shrouds & Ermator S26 vacuum	8	20	0.40
	9	20	0.45
	10	20.5	0.49
	9	20	0.45
	8	20	0.40
		Average	0.44