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

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-

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**

The vacuumweighs 103 pounds and is specified to provide 258 cubic feet of air flow peghs

Figure 4. Ermator S26 vacuum with Longopac system

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 6. Filter cleaning indicator on Ermator S26 vacuum

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 Trueflo 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

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 50 $\mu g/m^3$ 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-]		

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 and 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 7 and 8,** respectively.

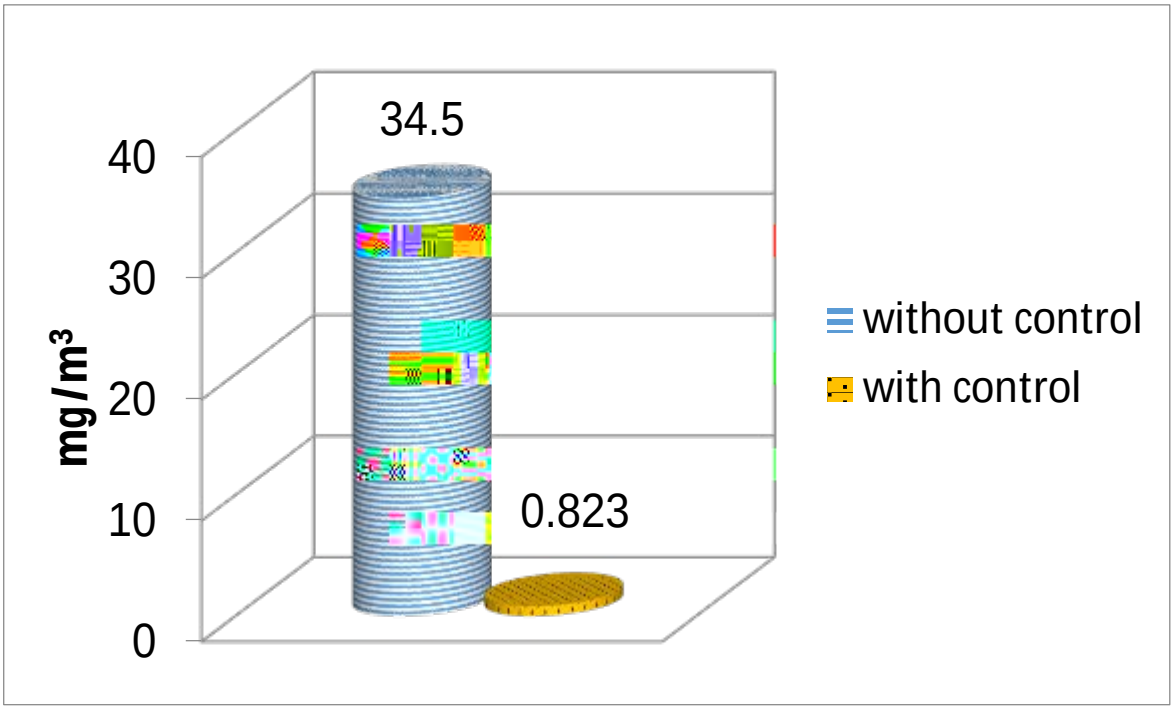
Table 2. Respirable Silica Exposures While Grinding Mortar[A]

	Mean,

The mean respirable silica concentration measured during use of the control system was significantly less than the concentration measured while using the same tool 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 Boschangle 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 shorter 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 (0.423 mg/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 <1.02 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 prefilter 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 prefilter was cleaned following

Figure 8. Respirable dust exposures with and without Ermator S26 Vacuum and Dust

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.

VIII. References

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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