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On-tool controls to reduce exposure to respirable dusts in the construction industry

A review

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A review

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Many processes in the construction industry create large quantities of dust; often materials used in construction contain silica. If the dust emissions from these processes are not controlled they can cause exposures that exceed UK workplace exposure limits and consequently lead to occupational diseases such as cancer, silicosis, chronic obstructive pulmonary disease and asthma. A common way to control these hazards is to apply local exhaust ventilation (LEV). However, construction sites tend be temporary workplaces, which makes the application of traditional LEV difficult. One solution is to affix LEV to the tool being used or to use another mobile form of on-tool control such as water suppression.

The objective of this project was to conduct a review of the literature on the subject of the effectiveness of on-tool controls and to summarise this information for HSE. The main findings were that:

- On-tool LEV is capable of reducing exposures by 90% or more.
- Important factors in achieving this reduction is hood design and choice of vacuum extraction source.
- Even with exposure reductions of 90 %, on-tool controls never completely eliminated exposure. This may mean that the use of supplementary respiratory protective equipment (RPE) is required, especially where materials contained silica.

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HSE Books

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KEY MESSAGES

- Many construction activities such as grinding, finishing, polishing, mortar removal, sanding and cutting produce large quantities of dust including materials containing silica and gypsum in the inhalable and respirable size fractions and if uncontrolled can cause exposure exceeding UK occupational exposure limits.

- A large body of work has been carried out in the last 10 – 15 years on controls. These studies have demonstrated that significant reductions in exposure to workers in excess of 90 % are achievable for the following activities; tuck-point grinding, surface grinding and polishing, floor sanding, drywall sanding and block, slab and tile cutting using both on-tool LEV and water suppression methods.

- Where the two on-tool methods were directly compared there was often no significant difference in control effectiveness.

- The choice of vacuum source is critical, maintaining the vacuum flow rate is vital. To do this, the studies reviewed indicated that vacuum cleaners with cyclone type pre filters are desirable or a vacuum fitted with an automatic back flush system.

- Although the European standard states that class H vacuums should be used for carcinogenic materials several studies have shown that maintaining an adequate volume flow rate is easier with a class M vacuum cleaner. Maintaining an adequate volume flow rate is vital to achieving good capture and control of process generated dusts. It should be recommended that for silica containing dusts a **minimum** of a class M vacuum cleaner should be used.

- For applications such as tuck-point or surface grinding a minimum volume flow rate of 50 m^3h^{-1} (30 cfm) is required to maintain good control but volume flow rates of 80 – 130 m^3h^{-1} (50 – 80 cfm) are recommended, the European standard states that vacuum cleaners should be fitted with a low flow alarm when extract velocity in the largest diameter duct falls below 20 ms^{-1}, this equates to approximately 140 m^3h^{-1}.

- On-tool controls should be considered as a complete system, where vacuum cleaner/extract units that have been matched to specific tools should be used for best results.

- Water suppression methods were often considered to be unfavourable in some applications for both safety and quality control reasons.

- Some studies found that the application of on-tool LEV did not significantly reduce exposure and in one case actually increased it before modifications were made, hood design/position/use was found to be critical in achieving effective removal of dusts. Some studies found that only partial reductions in exposure were achievable.

- Even with exposure reductions in excess of 90 %, with many construction materials containing respirable crystalline silica the use of supplementary respiratory protective equipment (RPE) may be necessary to meet exposure limits.

- Many workers using these on-tool controls complained that the addition of extraction hoses or water tanks made the tool heavier and more difficult to use and sometimes compromised their productivity.

EXECUTIVE SUMMARY

Objectives

Many processes in the construction industry create large quantities of dust; often materials used in construction contain silica. If the dust emissions from these processes are not controlled they can cause exposures that exceed UK occupational exposure limits and consequently lead to occupational diseases such as cancer, silicosis, chronic obstructive pulmonary disease and asthma. A common way to control these hazards is to apply local exhaust ventilation (LEV) however, construction sites tend be temporary workplaces, which makes the application of traditional LEV difficult. One solution is to affix LEV to the tool being used or to use another mobile form of on-tool control such as water suppression.

Much of the information held by HSE on on-tool controls requires updating and there has been much research carried out in the field in recent years. The objective of this project was to conduct a review of the literature on the subject of the effectiveness of on-tool controls and to summarise this information for HSE.

Main Findings

On-tool LEV is capable of reducing exposures created by processes such as; tuck-point grinding to remove mortar, surface grinding, finishing and polishing, block, slab, brick and tile cutting, floor and drywall sanding. In most cases exposure reductions of greater than 90 % were achieved, sometimes after modifications to the LEV hood. Water suppression was found to be an effective on-tool control for reducing exposure to respirable dusts. Where the two on-tool control methods were compared no significant differences were found.

The volume flow rate of air for good on-tool control required is typically 50 m^3h^{-1} as a minimum but ideally 80 – 130 m^3h^{-1} is recommended. The choice of vacuum source is vital; typically industrial vacuum cleaners are used, which tend to recirculate air back into the workplace. It is important that they have a final filter with a filtration efficiency of at least 99 % to prevent reintroducing captured respirable dusts back into the workplace air. To this end vacuum cleaners with cyclone type pre-filters are desirable or a vacuum fitted with an automatic back flush system to maintain adequate volume flow rates. Where dusts containing crystalline silica are produced a minimum of a Class M vacuum cleaner with final filter efficiency greater than 99.9 % should be used. When using water suppression, the importance of the volume flow rate of water was not widely agreed upon. Although where it was considered a flow rate 0.5 $lmin^{-1}$ was considered to be a minimum.

Even with exposure reductions of 90 % and greater, on-tool controls never completely eliminated exposure and could not always reduce it to below occupational exposure limits, especially where materials contained silica. This may mean that the use of supplementary respiratory protective equipment (RPE) is required. It should be noted however that most of the studies reviewed measured task-based exposure and not whole shift exposure and that 8-hour time weighted average (TWA) exposures may be lower, especially where workers perform different tasks throughout the day.

The use of on-tool controls was not without issue. Many workers commented that the addition of extraction hoses or the need to carry or move water tanks made the tools ergonomically difficult to use and adversely affected their productivity. Some field studies noted that as operators became more familiar with new tools the effectiveness of the controls improved. This shows that where new tools and controls are to be applied training will be an important part of achieving good control.

An internet search was conducted to determine the types and availability of on-tool extraction devices. A wide range of power tools fitted with extraction and dust control devices were available for purchase or hire either direct from manufacturers or from retailers and hire companies. Most companies offering extracted tools also offered vacuum cleaners/extraction units; most were of unspecified dust class. Vacuum cleaner manufacturers tended to be those who specify the dust class. L and M class vacuum cleaners were widely available, H class vacuum cleaners were only available from a limited number of suppliers.

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1. INTRODUCTION

Many processes in the construction industry in general and stone masonry in particular are highly energetic and create large quantities of inhalable and respirable dust. Uncontrolled emissions of these dusts present significant risks to workers' health. These dusts may contain respirable crystalline silica (RCS), which is a group 1 human carcinogen[1] and exposure to them can lead to the development of silicosis, lung cancer and chronic obstructive pulmonary disease (COPD). In addition respirable wood dusts can also be respiratory sensitizers, which can cause occupational asthma. There is a requirement under the Control of Substances Hazardous to Health (COSHH) regulations to eliminate or prevent such exposures. Where this is not possible, such emissions must be adequately controlled to reduce exposure to below the occupational exposure limit. One of the most effective controls is the application of local exhaust ventilation (LEV) to control emissions at source.

Traditionally, in industries such as stonemasonry dust control is often achieved through the use of capturing or receiving hoods, but these need to be frequently repositioned in order to function effectively. In the construction industry where the location of work changes frequently often no such controls are used. During a study of dust exposures to 1335 construction workers in the Netherlands Nij *et al* (2003) found that only 9 % used external LEV, 14 % used on-tool LEV and 66 % of respondents relied upon respiratory protective equipment (RPE) to control dust exposure[2].

On-tool controls are integrated or mounted onto the tool and therefore move with the source of the dust generation. As such it can provide a high standard of control and offers a possible alternative method of traditional LEV control. On-tool extraction has been considered before but much of the information held by HSE on the use and efficacy of these controls is old and dates back to the late 1980s. Since then, there has been significant progress in the design and use of on-tool controls.

This project was commissioned to conduct a review of the current literature on the subject of on-tool controls, including extraction and water suppression and to summarise this information for HSE.

2. IMPLICATIONS

The findings of this literature review will better inform HSE policymakers and inspectors of the abilities of on-tool controls to reduce respirable dust exposures to construction workers and allow them to further consider the inclusion of on-tool controls in guidance and recommendations to the construction sector.

The review of approximately 30 studies on the effectiveness of both on-tool LEV and on-tool water suppression methods applied to construction related processes, such as tuck-point grinding, surface grinding, polishing, brick, block and tile cutting, floor and dry-wall sanding is capable of producing significant reductions in exposures to dusts in some studies. Where materials containing silica were used it may be necessary to use supplementary RPE, as exposure was not always reduced to below the workplace exposure limit (W.E.L) of 0.1 mgm^{-3} [3].

The studies have shown that the two main factors to consider when selecting an on-tool LEV control are hood design and air volume flow rate. The use of tools with well-designed integrated LEV hoods are preferable to retrofitted or after market systems. The choice of vacuum source is instrumental in achieving and maintaining a sufficient volume flow rate. To do this, the studies reviewed indicated that vacuum cleaners fitted with cyclone type pre filters or automatic back flush systems are desirable. Class L vacuums are for dusts with an occupational exposure limit grater than 1 mgm^{-3}, Class M for dusts with an occupational exposure limit of no less than 0.1 mgm^{-3} and Class H vacuums are for dusts with all exposure limits including carcinogenic and pathogenic materials. Whilst Class H vacuum cleaners have higher filtration efficiency than Class M it can be more difficult to maintain a sufficient volume flow rate to provide good capture and control of process generated dusts. For this reason, a Class M vacuum cleaner as a minimum should be used in on-tool control systems for use in construction related tasks.

The information gathered in this literature review is not specific to the construction sector and the lessons learned could be applied to any sector where these tasks are performed.

3. METHODOLOGY

A set of key words was defined to perform the literature search. These included terms for airborne contaminants such as dust, mist and fume, relevant sectors such as construction, building and stone masonry, tasks that were likely to produce airborne contaminants such as drilling, grinding and sanding and interventions of interest such as ventilation and extraction. These terms were formatted into a viable search strategy by the HSE search team in consultation with the author; the search strategy used is given below.

mist or mists or dust or dusts or silica or gypsum or wood or lead or masonry or concrete or brick or stone or metal*

AND

construction or build* or tool or tools or vacuum or ventilat* or scabbler* or grinder* or saw or saws or sander or sanders or chisel* or drill* or router or routers or scaler or scalers or hammer* or weld* or grinding or scabbling or sanding or cutting or chiselling or routing or exhaust* or "low volume high velocity" or lev or lvhv or scarifying or chipping or polishing or burning or plastering or gouging or screeding or seaming or pointing or sweeping or scaling or splitting or breaking or jointing or raggling or harling or stippling or chasing or sawing or mixing

AND

"technology control*" or "engineering control*" or ((control* or captur*) **near5** (expos* or emission* or emit* or efficien* or effect* or extract* or evaluat*))

(* = truncation)

This strategy was used to search a number of databases including Web of Science, Oshrom, OshUpdate, ANTE and Iconda. In addition the author performed several internet searches and searches of specific journals such as Annals of Occupational Hygiene, Journal of Applied Occupational and Environmental Hygiene and the Journal of Occupational and Environmental Hygiene. These searches produced approximately 200 articles, papers, policy, guidance and review documents. The abstracts for these documents were sifted and the full texts of the relevant articles were obtained. During the review several other referenced papers that hadn't been identified in the original search were added, in total 36 documents were selected and reviewed.

The documents fall into four broad categories; the first is policy or guidance documents similar to HSE Information Sheets, these are generic and do not contain any measured exposure data. The second category is articles from peer reviewed scientific literature that do not directly report or contain any measured exposure data such as literature review articles or studies from the social sciences concentrating on perceptions of risk or the implementation of control strategies. The third category is papers or reports that are not published in scientific peer reviewed journals, but are technical reports from organisations such as National Institute of Safety & Health (NIOSH) or the Health and Safety Laboratory (HSL), these contain measurements of exposure and control intervention assessments. The final category is articles from peer reviewed scientific journals that directly report work containing exposure measurements and/or measured effectiveness of control interventions using on-tool controls.

Articles in the first and second categories are generally drafted and written using the data gathered and lessons learned in the work reported in the third and fourth categories. Some of the articles from the third category that were identified in the sift were later discarded as the data from the work was subsequently published in an article that fell into the fourth category. The findings and conclusions in this report are largely drawn from the articles from the third and fourth categories. These are the ones that contain measured exposure caused by performing construction tasks such as grinding, sanding, drilling and blasting and directly measure the effectiveness of on-tool controls by comparing exposures with control on to control off.

4. RESULTS

4.1 CONSTRUCTION ACTIVITIES AND EXPOSURES STUDIED

The articles reviewed considered a variety of construction activities, these were; surface grinding and finishing, tuck-point grinding (mortar removal), rock and surface drilling, sanding (of drywalls, wood and refractory ceramic fibres), wood cutting and shaping, tile cutting, brick and concrete block cutting and abrasive blasting. All of the tasks and activities mentioned above were studied in at least one of the articles reviewed but the most studied were grinding and cutting activities. Similarly, exposure to a variety of materials has been studied but by far the most considered was exposure to silica caused by grinding or cutting concrete. Of the 36 articles reviewed 25 were directly considering exposure to RCS from working with concrete. Other materials considered were wood dust (3), gypsum containing drywall compound (2), refractory ceramic fibres (1), lead and other metals (1). Three articles were sampling for unspecified dust during rock drilling activities although it is likely that silica exposure would be an issue during these activities. Not all articles that considered exposure directly measured exposure to silica, rather to respirable dust, which is sometimes referred to as respirable suspended particulate (RSP) matter.

4.2 TUCK-POINT GRINDING (MORTAR REMOVAL)

4.2.1 On-tool LEV

Tuck-point grinding is performed during the restoration of old brickwork. The old mortar is removed to depth of 1 – 2 cm using a right angle grinder before the brickwork is re-pointed. Grinding is a highly energetic process and creates large quantities of dust, Meeker *et al* (2009) measured personal breathing zone exposures to RCS of 4.99 mgm^{-3} and 10.90 mgm^{-3} during uncontrolled tuck-point grinding using two different right-angle grinders[4]. In a study for NIOSH of RCS exposures in the construction industry in the U.S. Heitbrink *et al* (2000) found exposures of 1 – 3 mgm^{-3} caused by tuck-point grinding[5]. In a study of the effectiveness of on-tool LEV Croteau *et al* (2002) measured RCS exposures of 3.04 mgm^{-3} caused by uncontrolled tuck-point grinding[6]. These values were typical of the measured RCS exposure caused by uncontrolled tuck-point grinding and fall within the range of 10 – 100 times the U.K. 8-hour Time Weighted Average (T.W.A.) Workplace Exposure Limit (W.E.L.) of 0.1 mgm^{-3} as stated in the July 2006 addendum to EH40[3].

A total of nine articles reporting results from ten studies of on-tool controls for right-angle grinders were reviewed, the control methods assessed had varying degrees of success. The Heitbrink *et al* (2000)[5] evaluated on-tool controls in the field. Uncontrolled personal exposures to RCS were measured to be 1 – 3 mgm^{-3} and total dust exposures of 24 – 442 mgm^{-3}. A Metabo right-angle grinder with an extracted shroud around the grinding wheel was tested; personal exposures to RCS of 9.01 mgm^{-3} and total dust of 103 mgm^{-3} were measured. In this case the control measure increased exposure to dust and in fact testing of the device was halted because the dust exposures were excessive. The authors believed that the poor positioning of the extracted shroud caused the increase in exposure. Nash *et al* (2000)[7] tested a right angle grinder fitted with an extracted shroud, 8-hour TWA exposures to total dust were 22.4 mgm^{-3} and 16.3 mgm^{-3}. Use of the on-tool LEV reduced these exposures to 11.4 mgm^{-3} and 8.6 mgm^{-3} respectively, reductions of 49 % and 47 %. The employees using the ventilated tool found it cumbersome and difficult to use, following modification by the manufacturer the tool was retested. This time 8-hour TWA exposure was reduced by 97 % from 94.6 mgm^{-3} to 3.0 mgm^{-3}. Following their study in 2000 Heitbrink and Bennett tested another on-tool LEV system for a right-angle grinder[8]. They measured personal exposures of workers using the system of 0.94 –

4.0 mgm^{-3}, there were no control off measurements but these exposures are consistent with uncontrolled exposure levels reported elsewhere. The authors believed that the reasons for the control failure included insufficient volume flow rate to the system (measured as approximately 19 m^{3}h^{-1}) and an inadequate filtration system.

Other studies found on-tool LEV systems for right-angle grinders to be more effective, in their study of on-tool LEV for a variety of tasks Croteau *et al* [6] measured an 84 % reduction in exposure to RCS (3.04 mgm^{-3} without control, 0.47 mgm^{-3} with) and an 80 % reduction in total respirable dust (RSP) with a volume flow rate of 128 m^{3}h^{-1}. Shojiro *et al* (2003)[9] assessed control of right-angle grinders using a traditional grinding disc and a mortar rake. The system on the grinding disc reduced exposures to RCS by 98 % (2.84 mgm^{-3} without and 0.059 mgm^{-3} with control). The extracted shroud on the mortar rake reduced exposure by 81 %. Heitbrink *et al* conducted a further study of three ventilated shrouds for right-angle grinders[10] one manufactured by Dust Control (Wilmington, Delaware, USA), one by Zantech (Wayne, New Jersey, USA) and a home made one. The study was conducted in the laboratory using an automated traverse in a ventilated test chamber and sampling for emitted dust, thus not measured personal exposure data but emitted dust per volume of mortar removed. Emission rate with no control was 27 mgcm^{-3} of mortar removed. There was no statistically significant difference in emission rates between the three different shrouds. With a volume flow rate between 51 m^{3}h^{-1} and 136 m^{3}h^{-1} the average emission rate was 0.21 mgcm^{-3} of mortar removed and with volume flow rate greater than 136 m^{3}h^{-1} the average emission rate was 0.06 mgcm^{-3} of mortar removed. Collingwood *et al* (2007)[11] performed a field evaluation of an on-tool LEV system for a right-angle grinder measuring personal exposure to RCS. The geometric mean of 22 samples was 0.06 mgm^{-3} with a range of 0.01 mgm^{-3} to 0.86 mgm^{-3}. There was no measurement of control off exposure but previous work has shown uncontrolled exposures to be up to 10 mgm^{-3}. Finally Meeker *et al* (2009)[4] in their study of on-tool controls measured reduction in exposure to RCS of 91 % for a Bosch grinder (4.99 mgm^{-3} reduced to 0.47 mgm^{-3}) and 97 % for Metabo grinder (10.90 mgm^{-3} reduced to 0.33 mgm^{-3}).

The studies reviewed considered the various factors affecting the performance of on-tool LEV for right-angle grinders. All the systems take the form of an extended shroud or guard around the grinding wheel with a take-off for the exhaust, see Figure 1 below.

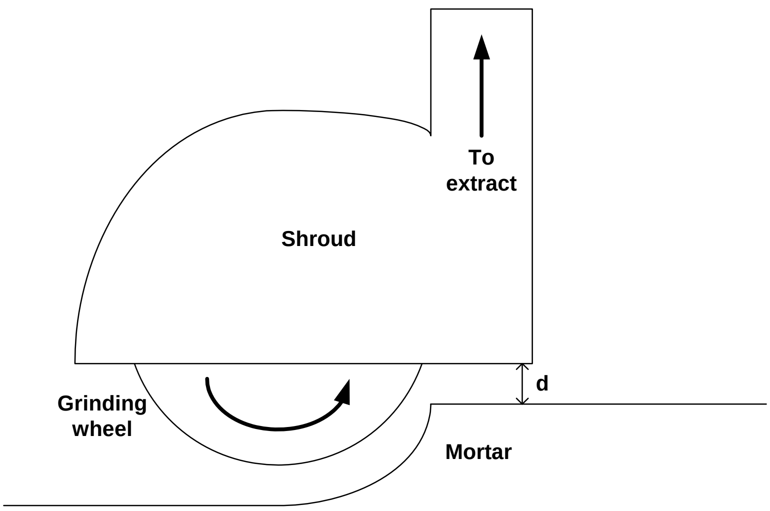

Figure 1 Illustration of a ventilated shroud for a right-angle grinder

The positioning of the extract take-off is important, it should be positioned to best intercept the dust as it is thrown off of the rotating wheel, this was believed to be the problem with the shroud tested by Heitbrink[5]. Collingwood and Heitbrink [10, 11] performed some computational fluid dynamics (CFD) simulations of extracted shrouds. They found that the particle stream emanating from the grinding wheel was the dominant factor inducing airflows and should be the primary focus for design. They found that minimising the distance d between the grinder shroud and the wall (see Figure 1 above) is vital in achieving good control and preventing the dust from escaping the shroud. They also found that the volume flow rate of the system is an important factor and recommend a minimum flow rate of 85 cfm (145 m^3h^{-1}). This is in line with the experimental work carried out in the same study that found the three shrouds to be more effective at volume flow rates in excess of 80 cfm (136 m^3h^{-1}).

An important part of achieving and maintaining the volume flow rate to the shroud is the selection and operation of the vacuum unit. Heitbrink and Santalla-Elias (2009)[12] tested four commercially available vacuum cleaners when used as a vacuum source for on-tool LEV during tuck-pointing. All four vacuum cleaners had a final filter efficiency of at least 99.9 % at 0.3 μm, two of them were 99.97 % at 0.3 μm. Two of the vacuum cleaners had cyclone type pre-filters and the other two used traditional paper bag pre-filters. The vacuum filters fitted with cyclone pre-filters were unaffected by debris build-up and the volume flow rate did not alter significantly during testing. The volume flow rate of the two with bag pre-filters fell from 80 cfm (136 m^3h^{-1}) to as little as 30 cfm (51 m^3h^{-1}). This means that if vacuum cleaners with bag pre-filters are used the pre-filter will have to be unblocked frequently to maintain the volume flow rate to the shroud. It should be noted here that some systems are available with an automatic 'back-flush' filter cleaning system, which would be beneficial for systems with bag type pre-filters. Although no peer reviewed published information was found on evaluation of these systems.

On-tool LEV applied to right angle grinders for mortar removal has been tested both in the field and in a laboratory setting. The efficacy of the LEV controls has been found to range from completely ineffective to being able to reduce exposure to respirable dusts by 99 %. The primary factors affecting control performance are design of the hood or enclosure, user training and operation of the tool, the volume flow rate and type of vacuum source used to move air through the system and the location of the work taking place. Exposures outdoors tended to be lower than those indoors, which is likely to be due to the dilution effect.

4.2.2 Water suppression

One study considered a water suppression system for a right-angle grinder. Heitbrink[5] fitted a water suppression device to one of the right-angle grinders tested after the on-tool LEV device had failed and retested it with a wet and dry vacuum cleaner. This reduced exposure to 0.38 mgm^{-3} (uncontrolled exposure 1-3 mgm^{-3}) providing a maximum reduction in exposure of 87 %.

4.3 SURFACE GRINDING (FINISHING)

4.3.1 On-tool LEV

The second most studied construction task was surface grinding or finishing, predominantly of concrete. This ranged from grinding large areas such as floors and walls to finishing beams and pillars. This is again a highly energetic process with the potential to cause high exposures to respirable dust and where the material being ground is concrete or stone potentially respirable silica. Flanagan *et al* (2003)[13] measured exposure to respirable dust of 4.87 mgm^{-3}, Ojima (2007)[14] measured a concentration of metal dust of 7.73 mgm^{-3} approximately 40 cm from a grinder in a test chamber, Croteau[6] measured exposure to RCS of 29.16 mgm^{-3} caused by uncontrolled grinding and Akbar-Khanzadeh (2010)[15] measured exposure to RCS of 6.80 mgm^{-3} and RSP of 47.8 mgm^{-3} caused by uncontrolled surface grinding.

On-tool LEV for surface grinding was found to have varying levels of success, Ojima[14] assessed the effectiveness of a ventilated shroud supplied with a Hitachi grinder in a controlled test chamber. The effectiveness was assessed by measuring respirable dust approximately 40 cm from the grinder with and without control whilst grinding weld beads that had been laid down on a test piece of metal. The shroud reduced the concentration of respirable dust outside of the grinder shroud by 37 %, 7.73 mgm^{-3} without control, 4.87 mgm^{-3} with control. Flanagan[13] studied RCS exposures during a variety of construction activities including concrete cutting, mixing, grinding, tuck-point grinding, sacking and patching and floor sanding. They observed that dust controls were used during only 12 % of tasks studied; personal exposure to RCS was measured during a surface grinding operation. The on-tool LEV reduced exposure by 71 % from 4.87 mgm^{-3} to 1.42 mgm^{-3}. A box fan providing general area ventilation was found to reduce personal exposure to RCS during a similar task by 57 %.

Echt *et al* (2002)[16] performed a field study of on-tool controls on surface grinders being used by construction workers. A variety of grinders were used but they were all fitted with a Vacugaurd ventilated shroud manufactured by Pearl Abrasive Co. and connected to a Dustcontrol H-type vacuum cleaner. Personal samples were collected over a full shift and exposures reported as an 8-hour TWA. Exposure to silica over five days ranged from 0.036 mgm^{-3} to 0.13 mgm^{-3} and respirable dusts 0.55 mgm^{-3} to 1.2 mgm^{-3}. There were no measurements taken with the control off but comparing these exposures to exposures measured from uncontrolled grinding in other studies shows that exposure was being well controlled. The sampling periods over the five days ranged from 265 minutes to 340 minutes so they represent a high level of control over a whole shift. Additionally, workers on the site provided anecdotal evidence that dust emissions were well controlled. The author states that, "The concrete finisher reported that electricians had told him that they didn't need to clean concrete dust from the light fixtures they were installing, and that form crews were able to work nearby, stripping forms, while grinding was conducted. Uncontrolled grinding would not have allowed this to occur."

Croteau [6] assessed the effectiveness of a ventilated shroud on a surface grinder in a laboratory study. The on-tool control reduced personal exposure to RCS by 94 %, 29.16 mgm^{-3} without control and 1.70 mgm^{-3} with control running at 128 m^3h^{-1}, this was reduced to a 92 % reduction (personal exposure 2.36 mgm^{-3}) when volume flow rate was reduced to 51 m^3h^{-1}. Shepherd *et al*[17] performed a case study investigating the social sciences aspect of applying exposure controls in the construction industry. Whilst there was no measurement of exposures or assessment of controls they do discuss the application of an on-tool control used during grinding of concrete ceilings on a construction site that maintained workers exposure below the Occupational Safety and Health Administration (OSHA) WEL.

Akbar-Khanzadeh *et al* have performed three studies on the effectiveness of on-tool LEV for grinders in the last ten years. In 2002[18] they performed a field study measuring exposures to RCS of 17 concrete finishers. Data for a total of 64 shifts was collected, 15 of the shifts were performed using on-tool LEV. Task mean exposure to RCS for no control was 1.50 mgm^{-3} and for respirable dust 24.3 mgm^{-3}. For shifts with LEV control the mean RCS exposure was 0.38 mgm^{-3} and respirable dust 5.49 mgm^{-3}, which is a 75 % reduction in RCS and 77 % reduction in respirable dust. When these task-based exposures were converted to 8-hour TWA exposures 14 of the 15 with LEV control were below the OSHA Permissible Exposure Limit (PEL). In 2007[19] they performed a laboratory study comparing the effectiveness of on-tool LEV and water suppression to uncontrolled grinding. They found that the on-tool LEV reduced the exposure to RCS from 25.4 mgm^{-3} with no control by 99 % to 0.148 mgm^{-3}, wet grinding reduced the exposure by 98 % to 0.521 mgm^{-1}. Statistical analysis showed that there was no statistically significant difference between the two control measures. Similar reduction were found for exposure to respirable dust, on-tool LEV reduced exposure by 99 % (228 mgm^{-3} with no control, 1.82 mgm^{-3} with control) and wet grinding by 97 % (7.77 mgm^{-3} with control). Again there was no statistically significant difference between the two control methods.

Akbar-Khanzadeh *et al*[15] conducted a study of on-tool controls for surface grinders in controlled conditions. They investigated several parameters; the effect of general ventilation, orientation of surface being ground, size of angle grinder and grinding wheel, and a variety of control combinations. The control combinations were LEV with a HEPA filtered vacuum cleaner, LEV with a standard vacuum cleaner, wet grinding and water volume flow rate and uncontrolled grinding. They found that LEV with the HEPA filtered and standard vacuum cleaners reduced respirable dust exposure by 99 % and 97 % respectively. Wet grinding reduced respirable dust exposure by 93 %, there was no statistically significant difference between LEV and water control. The general ventilation applied was 62 air changes per hour (ach), this is extremely high and would be the equivalent of working inside a ventilated booth, and would be unlikely to be found on a construction site unless working outdoors. The study found that this level of general ventilation reduced exposure to RCS and respirable dust by 66 % and 70 %, however I feel that it would be impractical to achieve this level of ventilation without building a ventilated enclosure to contain the work. The study found that larger grinders produce more dust and that reductions in dust exposure decreased with the larger grinders which used larger diameter wheels , this is expected because the same vacuum cleaners were used and the larger diameter grinding wheels would require a higher volume flow rate. It was found that the orientation of the work piece, the water volume flow rate, and the smaller grinder sizes (100, 115 and 125 mm wheels) did not have a statistically significant effect on control efficiency.

On-tool LEV for use with surface grinders has been tested in the field and in the laboratory in a variety of configurations. It has been found to be able to provide exposure reductions from 37 % to 99 % depending on the application. Factors affecting performance are again maintaining an adequate volume flow rate to the hood and user training and operation. Anecdotally construction workers have found the tools harder to use than tools without on-tool controls, specifically finding them more cumbersome to manoeuvre because of the added weight of the extraction hose. Several workers also reported that using the on-tool devices reduced their productivity although his may be the effect of using a new tool.

4.3.2 Water suppression

Only the two studies by Akbar-Khanzadeh considered the use of water suppression as an alternative control to on-tool LEV [15, 19]. In both studies water suppression was compared to on-tool LEV. In both cases there was no statistically significant difference in the reductions in exposure to respirable dust.

4.4 CUTTING (CONCRETE, TILES & BRICKS)

A number of studies have been carried out assessing on-tool controls for cutting activities such as cutting concrete blocks and paving slabs, cutting bricks and cutting roofing tiles using hand held saws and stationary chop and cut-off saws. Exposures to respirable dust have been measured at up to 50 mgm^{-3}[20] when using these types of tool. Sheehy *et al*[21] performed a field evaluation of three hand-held masonry saws and a manual tile cutter. One of the saws (Partner) was fitted with a water suppression system fed by a backpack water tank; another (Bosch) was fitted with a ventilated shroud and connected to a vacuum cleaner and a third (Revelation) had an after market dust collection system consisting of an axial fan and a shroud collecting dust in a filter bag. Testing with the Revelation saw was immediately abandoned because in order to fit the dust collection system the blade guard had to be removed which was deemed unsafe by the roofer. The Partner saw was considered unsuitable for use on a roof because of the weight of the backpack and that the water presented a slipping hazard and as such was only tested on the ground. The Bosch saw was also considered unsuitable for use on a roof due to the dragging effect of the exhaust hose and was also only tested on the ground. When using the Partner saw with the water suppression the personal exposure to respirable dust ranged from 4.80 mgm^{-3} to 8.2 mgm^{-3}. When using the Bosch saw the personal exposure to respirable dust was 2.51 mgm^{-3} and when using the manual tile cutter respirable dust exposure never exceeded 0.12 mgm^{-3}. Whilst the manual cutter did not produce significant amounts of dust the roofers felt that it was not suitable for cutting roofing tiles neatly.

Thorpe *et al*[20] conducted a study of controls on three cut-off saws in the construction industry, the controls tested were; water suppression from a pressurised tank, water suppression from mains water and an on-tool LEV system each using a resin bonded blade and diamond tipped blade. Exposures to respirable dust were reduced by 94 %, 96 % and 91 % for the pressurised water, mains water and LEV controls respectively using a diamond tipped saw. For the resin bonded saw, exposures to respirable dust were reduced by 47 %, 97 % and 98 % for pressurised water, mains water and LEV respectively. The authors believed that the poor control reduction for the pressurised water system was caused by the resin bonded blade taking longer to make the cuts and requiring the water tank to be re-pressurised. The mass of RCS collected onto the filters was below the limit of detection for all three 'control on' scenarios making it difficult to accurately measure the reduction in RCS exposure. Additional work was carried out in the laboratory to assess the effect of water volume flow rate on control effectiveness. Respirable dust concentrations were measured using water flow rates of 0.12, 0.20, 0.50 and 1.0 $lmin^{-1}$, the reductions in respirable dust concentration were 55 %, 73 %, 97 % and 98 % respectively. This suggests that when water suppression is used on a hand-held cut-off saw the volume flow rate should be a minimum of 0.50 $lmin^{-1}$.

Croteau[6] assessed the effectiveness of a masonry saw and hand held saw for block and brick cutting. The masonry saw for block cutting produced a 96 % reduction in RCS exposure and a 90 % reduction in respirable dust. The hand held saw for brick cutting produced an 86 % reduction in RCS exposure but no measurements of respirable dust were made. Meeker *et al*[4] measured RCS exposure during block and brick cutting using a hand-held saw fitted with on-tool LEV and a stationary wet saw in the field. When cutting blocks the saw with LEV and wet saw produced reductions in RCS exposure of 96 % and 93 % respectively (0.11 mgm^{-3}, 0.21 mgm^{-3} controlled and 2.83 mgm^{-3} uncontrolled). When brick cutting the reductions in RCS exposure were 91 % for both controls (0.08/0.09 mgm^{-3} controlled and 0.94 mgm^{-3} uncontrolled). Carlo *et al* (2010)[22] performed a laboratory evaluation of an on-tool LEV and a water suppression system for a hand-held masonry saw. The water suppression system reduced exposure to respirable dust by 99 % and the LEV system by 88 %.

Shepherd *et al* (2008)[23] evaluated an on-tool system for a hammer drill, two hood types and two vacuum cleaners were assessed. Exposure to RCS was reduced by 91-98% by the four combinations (0.308 mgm^{-3} uncontrolled, 0.006 – 0.028 mgm^{-3} controlled).

4.5 OTHER APPLICATIONS

Two articles were found that considered control of dust emissions from sanding internal drywalls comparing the effectiveness of dust control from hand sanding, pole sanding, wet sponge sanding and a ventilated sander. A review article authored by NIOSH[24] states that drywall sanders can be exposed to dust levels in excess of 15 mgm^{-3}, the UK WELs for inhalable and respirable gypsum dust, which is one of the main drywall compound ingredients, are 10 mgm^{-3} and 4 mgm^{-3} respectively[3]. The NIOSH article advises that the use of vacuum sanding tools can reduce exposure by 80-97 %. Young-Corbett *et al* (2009)[25] compared hand sanding to pole sanding (hand sanding with the use of a pole to separate the workers breathing zone from the dust source), wet sponge sanding and vacuum sanding. They found that exposures were reduced by 58 %, 60 % and 88 % respectively.

Potts and Reed (2009, 2010)[26, 27] performed two studies investigating dust emissions from surface drilling. These types of drill are encased in an enclosure called the drill shroud that is extracted. Air is supplied down the drill sleeve which then exits and enters the drill shroud carrying dust with it, the moving air then forms a rolling eddy inside the shroud and dust laden air leaks around the bottom edges despite air being extracted from the shroud. The study investigated the addition of a blocking shelf inside the enclosure to break up the eddy and redirect the air toward the exhaust, this reduced dust concentrations measured outside of the drill shroud by 81 %. The second study investigated the use of compressed air jets to further improve containment of dust-contaminated air inside the drill shroud. The system they designed and tested reduced the concentration of dust outside of the enclosure by 48 – 52 %.

Several articles concerning on-tool controls for woodworking were identified, however none of them contained systematic assessments of effectiveness or measured exposure reductions. Although they were outside of the scope of this literature review HSL have recently carried out two projects assessing the effectiveness of on-tool controls for arc welding and for soldering, which showed that on-gun LEV for these applications could be highly effective. For on-gun welding capture efficiencies were generally greater than 90 % except for when welding in the interface between horizontal/vertical fillets[28]. For soldering, the use of on-tool LEV in the form of a small capturing hood positioned 5 – 10 mm from the soldering iron tip was able to reduce exposure to colophony fume by 100 %.

4.6 VACUUM SOURCES FOR ON-TOOL CONTROLS

The majority of the studies considered in this review tended to concentrate on the hood end of the LEV system and this is a typical approach from an occupational hygiene perspective with the justification that if contaminants do not enter the hood or enclosure then the rest of the system is redundant. However, a majority of the studies conclude that the volume flow rate generated by the LEV system is an important factor in achieving good control. The vacuum source, which would typically be a mobile industrial vacuum cleaner on a construction site, and filtration system are vital in creating and maintaining a sufficient volume flow rate to achieve good control.

Heitbrink and Santalla-Elias studied the effect of filter loading on volume flow rate using four commercially available vacuum cleaners during tuck-pointing operations[12]. They primarily compared two with cyclone type pre-filters to two using traditional bag type pre-filters. The study showed that the vacuum cleaners fitted with cyclone pre-filters suffered virtually no decrease in volume flow rate whilst the two vacuum cleaners with bag pre-filters suffered a decrease in volume flow rate of up to 60 % caused by filter loading. This would mean that vacuums fitted with bag type pre-filters would require more regular filter cleaning or bag replacement to maintain sufficient volume flow rates compared to vacuums with cyclone pre-filters, or be fitted with an automatic ‘back-flush’ system.

There is a European standard, EN 60335-2-69:2009 [29] regarding the use of vacuum cleaners and dust extractors for the collection of hazardous dusts. This standard defines the operating characteristics of L, M and H type vacuum cleaners, these are summarised in Table 4.1 below.

***Table 4.1** Performance characteristics of L, M and H type vacuum cleaners*

Dust Class	*Suitable for hazardous dusts with occupational exposure limits mgm^{-3}*	*Final filter efficiency %*
L	> 1	> 99
M	≥ 0.1	> 99.9
H	< 0.1	> 99.995

L-type (Light hazard) vacuum cleaners are suitable for separating dusts with an occupational exposure limit of greater than 1 mgm^{-3}. M-type (Medium hazard) vacuum cleaners are for separating hazardous dusts with an occupational exposure limit of not less than 0.1 mgm^{-3}. H-type (High hazard) vacuum cleaners are for separating dusts with all occupational exposure limits including carcinogenic and pathogenic dusts. At first glance this suggests that both H and M type vacuum cleaners would be suitable for controlling dust emissions from processes creating respirable crystalline silica dust. The 8-hour TWA exposure limit for RCS is 0.1 mgm^{-3} [3], this puts it on the limit between using an M type or H type vacuum cleaner. However, respirable crystalline silica dust is classified by the International Agency for Research on Cancer (IARC) as a group 1 human carcinogen[1]. This classification clouds the issue of which class of vacuum cleaner to use for silica containing materials. BG BAU in Germany conducted a significant body of work in which the capturing efficiency over 100 combinations of power tools fitted with on-tool controls and vacuum cleaners were measured[30]. The main conclusion of this study was that the systems with the most successful dust controls were those that used harmonised systems, i.e. an on-tool control matched to the correct vacuum cleaner, usually one from the same manufacturer. They also found that Class M vacuums tended to be less susceptible to filter loading and thus maintained the correct volume flow rate for longer than compared to class H vacuums. Whilst the filtration efficiency of a class H vacuum is higher this only related to material removed from exhausted air, if the dust-laden air is not captured by the LEV in the first pace the vacuum cleaner filter would remove none of the contaminant dust. This coupled with the fact that class M vacuums are more readily available than class H it would seem sensible to specify that for processes releasing silica containing dusts a **minimum** of a class M vacuum cleaner should be used.

The standard recommends that vacuum cleaners have a low flow warning when the velocity in the largest diameter hose falls below 20 ms^{-1}. If we assume that the mean diameter of the largest hose on an industrial vacuum cleaner is 50 mm this is equivalent to a volume flow rate of 140 m^3h^{-1}. This is comparable to or higher than most of the minimum volume flow rates quoted in the studies reviewed. Two are slightly higher or come close to this value, Collingwood and Heitbrink[10, 11] recommend a minimum volume flow rate of 145 m^3h^{-1} for tuck-pointing operations and Flynn *et al*[31] recommend 43 m^3h^{-1} per inch of grinding wheel for tuck-pointing which would exceed the 140 m^3h^{-1} for anything larger than a 3 ¼" grinding wheel.

Much of the detail of the standard is concerned with the electrical safety of vacuum cleaners; other relevant material concerns the required regular maintenance. Specifically those for H-type vacuum cleaners the internal parts are treated as being contaminated and only opened by trained individuals wearing suitable PPE. The essential (final) filter should be tested for filtration efficiency at least every year.

4.7 DISCUSSION AND CONCLUSIONS

One of the most important factors in achieving good control using any LEV system and on-tool systems in particular is hood design. Many on-tool extraction devices are added as an after thought or retrofitted to existing tools. Whilst this approach can be effective in can detrimentally affect the effective use of the tool by the user and if poorly designed can also reduce control effectiveness. Some modern on-tool controls have been designed as an integral part of the tool and are often positioned so as to maximise the use of any air movement generated by the tool – such as spinning discs of grinders of saws – to intercept the contaminant laden air and to ensure that the extraction does not hinder the effective use of the tool. A good example of this is the evolution of on-tool extraction applied to arc welding torches. The early versions in the 1970s had large and bulky hoods bolted onto existing torches, anecdotally these made the torches heavier and more difficult to use with the dragging effect of the extract duct and also impaired visibility of the work. Modern extracted welding torches have the hood built into the torch and extract ducting integrated as part of the existing hose carrying coolant and the welding wire, this makes the torches considerably more acceptable to operators.

Whilst many factors are important when selecting on-tool controls the two main things to consider are the hood as discussed above and selecting the correct vacuum source to provide and maintain sufficient volume flow rate. As discussed above a system with integrated extraction is preferable to one where a hood has been retrofitted to a tool and vacuum for those systems investigated, cleaners with cyclone type pre-filters are preferable to those with bag type pre-filters. These factors were considered and investigated in detail by the BG-BAU study on on-tool controls[30]. The two main conclusions from this study were that harmonised systems had a higher potential for exposure reduction and that a well-designed hood is critical to achieving adequate dust control. A harmonised system is defined as one where tool, capturing/containing device and vacuum cleaner/extract unit are designed to work together as an integrated system. The work by BG-BAU showed that for much construction related work such as wall chasing/tuck-pointing, concrete grinding, concrete/stone cutting, plaster milling and sanding most on-tool controls were capable of reducing dust exposures below exposure limits, some of their conclusions are given below.

"Most of the tested systems show at least adequate efficiency"

"The essence in future will be to prompt the firms only to use power tool systems recommended and harmonised by the manufacturers"

"An important factor for high efficiency of the seizing [*capture*] element is a hood as closed as possible guiding the exhaust air as optimal[*ly*] as possible. Necessary intakes have to placed in the right positions."

Finally, Flynn *et al* (2003)[31] conducted a review similar to this report, a few of their comments were as follows:

"Exposures to dust and silica during surface grinding of concrete are reduced with both local exhaust ventilation and with wet methods. However, few of the studies provided adequate detail to come to definitive conclusions, and further studies are needed to document the required air flow rates for hoods."

When considering tuck-point grinding:

"Results to date suggest that ventilating the enclosing shroud at a rate of 20 – 25 cfm (34 – 43 m^3h^{-1}) per inch of wheel or blade diameter is required to minimize dust generation."

And cutting:

"The use of wet methods and LEV provide significant reductions in exposures for cutting operations using either fixed or hand held masonry saws."

And in conclusion:

"…, it is clear that technology is currently available to provide dramatic reductions in exposure."

Regarding the first comment from Flynn, since 2003 a number of studies have been completed that demonstrate that on-tool LEV applied to surface grinders is capable of producing significant reductions in exposure to respirable dusts. Some of the studies investigated the effect of volume flow rate upon control effectiveness. A minimum volume flow rate of 50 m^3h^{-1} (30 cfm) is required to maintain a capture efficiency greater than 90 % and a flow rate of 80 – 100 m^3h^{-1} would be recommended to allow for some decrease in volume flow rate caused by filter loading in the vacuum source.

Having reviewed a large quantity of literature on the subject it seems clear that on-tool controls exist that are capable of reducing exposure to respirable dusts including silica by greater than 90 % for construction activities such as mortar removal, concrete grinding and finishing, block, tile and brick cutting and sanding. However, in the case of silica because the activities concerned produce high quantities of respirable dust and the need to reduce exposure as far below the challenging exposure limit it may still be necessary to combine on-tool controls with supplementary RPE. The exposure reductions provided by on-tool controls may remove the need for full-face air fed respirators in favour of half face filtering masks with lower assigned protection factors, although it should be noted that protection level is only one factor in selecting RPE. Proper training in the use of tools fitted with controls is vital as it may be necessary to alter methods of working in order to maximise the effectiveness of controls.

In those studies where water suppression as an on-tool exposure control was studied it was found to be effective and where it was compared to on-tool LEV there was often no significant difference in control effectiveness. There are some concerns using about using water suppression in some applications. For instance in roofing activities the use of water suppression would pose a significant slip risk on a roof and there are quality control issues with the slurry staining roofing tiles. There are also some issues regarding electrical safety and the use of water suppression, however for some applications there are pneumatic or electrically isolated tools available.

It seems clear that without some form of exposure control, exposure to respirable dusts caused by these construction activities is excessive. The majority of studies in this review measured task-based exposure rather than full shift exposure and as many construction workers are likely to vary their activities during the working day further studies measuring full shift exposures whilst using on-tool controls would be beneficial in further assessing their capabilities.

4.8 AVAILABILITY OF ON-TOOL CONTROLS IN THE UK: AS OF NOVEMBER 2011

A wide range of hand-held power tools fitted with on-tool extraction is available for sale and for hire in the UK. These include mitre saws, cut-off saws, table saws, hand-held circular saws, surface grinders, angle grinders, wall chasers, drills, hand-held sanders and floor and wall sanders. An internet search was undertaken of the types and availability of on-tool extraction devices in the UK. This was performed using internet search engines using combinations of the following search terms:

Power tools, extraction, on-tool, dust control, dust extract, industrial vacuum cleaners, hire

Not all tools in any of the ranges available were fitted with a capturing hood and extraction take-off port but most manufacturers offered at least some models with dust control fitted. Tools fitted with extraction and dust control devices were available to purchase either directly from the manufacturers or via retailers. Most tools fitted with on-tool controls were also available to hire.

Most companies offering power tools also offered a number of vacuum cleaners/extraction units. The majority of vacuum cleaners were of unspecified dust classes on websites, more information was usually available if the company was contacted directly. Vacuum cleaner manufacturers tended to be those who specify dust class. L and M class vacuum cleaners were widely available, H class vacuums were available but from a limited number of suppliers which tended to be companies specialising in extraction.

5. REFERENCES

1. IARC, *IARC Monograph on the Evaluation of Carcinogenic Risks to Humans: Volume 68 - Silica, Some Silicates, Coal Dust and Para-Aramid Fibrils*, ed. IARC. Vol. 68. 1997. 506.

2. Nij. E.T., Hilhorst.S., Spee. T., Spierings. J., Steffens. F., Lumens. M., Heederik. D., *Dust Control Measures in the Construction Industry.* Ann. Occup. Hyg., 2003. **47**(3): p. 211-218.

3. HSE, *EH40/2005 Workplace exposure limits*. 2nd ed, ed. H. Books. 2011: HSE Books. 74.

4. Meeker. J.D., Cooper.M.R., Lefkowicz. D., Susi. P., *Engineering Control Technologies to Reduce Occupational Silica Exposures in Masonry Cutrting and Tuckpointing.* Public Health Reports, 2009. **124**(1): p. 101 - 111.

5. Heitbrink. W.A., *In-depth Survey Report: Control Technology for Crystalline Silica Exposures in Construction: Exposures and Preliminary Control Evaluation*, in *In-depth Survey Reports*, C. NIOSH, Editor. 2000, NIOSH: Cincinnati. p. 21.

6. Croteau. G.A., Guffey.S.E., Flanagan. M.E., Seixas. N.S., *The Effect of Local Exhaust Ventilation Controls on Dust Exposures During Concrete Cutting and Grinding Activities.* AIHA Journal, 2002. **63**(4): p. 458-467.

7. Nash. N.T., Williams.D.R., *Occupational Exposure to Crystalline Silica During Tuckpointing and the Use of Engineering Controls.* Applied Occupational and Environmental Hygiene, 2000. **15**(1): p. 8-10.

8. Heitbrink. W.A., Bennett.J.S., *Control Technology for Crystalline Silica Exposures in Construction: Exposures and Preliminary Control Evaluation at a Restoration Preservation Masonry Construction Site*, in *In Depth Survey Report*, C. NIOSH, Editor. 2000, NIOSH: Cincinnati. p. 14.

9. Shojiro. Y., Susi.P., McClean. M., Flynn. M., *Assessment of Silica Exposures and Engineering Controls During Tuckpointing.* Applied Occupational and Environmental Hygiene, 2003. **18**(12): p. 977-984.

10. Heitbrink. W., Bennett.J., *A Numerical and Exerimental Investigation of Crytalline Silica Exposure Control During Tuckpointing.* Journal of Occupational and Environmental Hygiene, 2006. **3**(7): p. 366-378.

11. Collingwood. S., Heitbrink.W.A., *Field Evaluation of an Engineering Control for Respirable Crystalline Silica Exposures During Mortar Removal.* Journal of Occupational and Environmental Hygiene, 2007. **4**(11): p. 875-887.

12. Heitbrink.W.A., Santalla-Elias.J., *The effect of debris accumulation on and filter resistance to airflow for four commercially available vacuum cleaners.* Journal of Occupational and Environmental Hygiene, 2009. **6**(6): p. 374-384.

13. Flanagan. M.E., Seixas.N., Majar. M., Camp. J., Morgan. M., *Silica Dust Exposures During Selected Construction Activities.* AIHA Journal, 2003. **64**(3): p. 319-328.

14. Ojima. J., *Efficiency of a Tool Mounted LEV System for Controlling Dust Exposures During Metal Grinding Operations.* Industrial Health, 2007. **45**: p. 817-819.

15. Akbar-Khanzadeh. F., Milz.S.A., Wagner. C.D., Bisesi. M.S., Ames. A.L., Khuder. S., Susi. P., Akbar-Khanzadeh. M., *Effectiveness of Dust Control Methods for Crytalloine Silica and Respirable Suspended Particulate Matter Exposure During Manual Concrete Surface Grinding.* Journal of Occupational and Environmental Hygiene, 2010. **7**(12): p. 700-711.

16. Echt. A., Sieber.W.K., *Control of Silica Exposure from Hand Tools in Construction: Grinding Concrete.* Applied Occupational and Environmental Hygiene, 2002. **17**(7): p. 457-461.

17. Shepherd. S., Woskie.S.R., *Case Study to Identify Barriers and Incentives to Implementing an Engineering Control for Concrete Grinding Dust.* Journal of Construction Engineering and Management, 2010. **136**(11): p. 1238-1248.

18. Akbar-Khanzadeh. F., Brillhart.R.L., *Respirable Crystalline Silica Dust Exposure During Concrete Finishing (Grinding) Using Hand-held Grinders in the Construction Industry.* Ann. Occup. Hyg., 2002. **46**(3): p. 341-346.

19. Akbar-Khanzadeh. F., Milz.S.A., Ames. A., Susi. P.P., Bisesi. M., Khuder. S.A., Akbar-Khanzadeh. M., *Crystalline Silica Dust and Respirable Particulate Matter During Indoor Concrete Grinding - Wet Grinding and Ventilated Grinding Compared with Conventional Grinding.* Journal of Occupational and Environmental Hygiene, 2007. **4**(10): p. 770-779.

20. Thorpe. A., Ritchie.S.A., Gibson. M.J., Brown. R.C., *Measurement of the Effectiveness of Dust Control on Cut-off Saws Used in the Construction Industry.* Ann. Occup. Hyg., 1999. **43**(7): p. 443-456.

21. Sheehy. J.W., Garcia.A., Echt. A., *In-Depth Survey Report of a Demonstration and Evaluation of Roofing Tile Saws and Cutters Controlling Respirable and Crystalline Silica Dust*, in *In-depth Survey Reports*, C. NIOSH, Editor. 2006, NIOSH: Cincinnati. p. 21.

22. Carlo. R.V., Sheehy.J., Feng. H.A., Sieber. W.K., *Laboratory Evaluation to Reduce RCS Dust When Cutting Concrete Roofing Tiles Using a Masonry Saw.* Journal of Occupational and Environmental Hygiene, 2010. **7**(4): p. 245-251.

23. Shepherd. S., Woskie.S.R., Holcroft. C., Ellenbecker. M., *Reducing Silica and Dust Exposures in Construction During the Use of Powered Concrete Cutting Hand Tools: Efficacy of LEV on Hammer Drills.* Journal of Occupational and Environmental Hygiene, 201*. **6**(1): p. 42-51.

24. NIOSH, C., *Hazard Controls of Drywall Sanding Dust Exposures.* Applied Occupational and Environmental Hygiene, 2000. **15**(11): p. 820-821.

25. Young-Corbett. D.E., Nussbaum.M.A., *Dust Control Efficiency of Drywall Sanding Tools.* Journal of Occupational and Environmental Hygiene, 2009. **6**(7): p. 385-389.

26. Potts. J.D., Reed.W.R. *Horizontal Air Blocking Shelf Reduces Dust Leakage From Surface Drill Shroud*. in *SME Annual Meeting and Exhibit*. 2009: Society for Mining, Metalurgy and Exploration Inc.

27. Reed.W.R., Potts.J.D., *Improved Drill Shroud Capture of Respirable Dust Utilizing Air Nozzles Beneath the Drill Deck*, in *Tanscript Society Minerals Metal Exploration*. 2010. p. 10-15.

28. Pocock, D., Saunders, C.J., Carter, G., *Effective control of gas shielded arc welding fume RR683*, in *HSE Research Report*. 2009.

29. BSI, *BS EN 60335-2-69 2009 Household and similar electrical appliances - Safety - Part 2-69: Particular requirements for wet and dry vacuum cleaners, including power-brush, for commercial use*. 2009, BSI. p. 29 - 40.

30. Kluger. N, Kraus.J.W.-K., Musanke. U, *Evaluation of Dust Emission Properties for Hand Operated Power Tools and Devices for Use in Work on Mineral Materials*, B. BAU, Editor. 2006, BG BAU: Berlin. p. 131.

31. Flynn. M.R., Susi.P., *Engineering Controls for Selected Silica and Dust Exposures in the Construction Industry - A Review.* Applied Occupational and Environmental Hygiene, 2003. **18**(4): p. 268-277.

6. APPENDIX I – ON-TOOL CONTROLS USED IN STUDIES REVIEWED

Tools with controls used in reviewed papers

Tool	Make	Model	Task	Paper
Grinder	Metabo[1]	W7-115 Quick 10000 rpm		Workplace Solutions: Control of Hazardous Dust When Grinding Concrete; NIOSH
Grinder	Metabo	11025		
Grinder	Bosch[2]	1347A		
Grinder	Milwaukee[3]	6153-20		
Grinder shroud	Pearl[4]	Vacugaurd		
Grinder shroud	Transmatic[5]	Dustcontrol		
Grinder Shroud	Sawtec[6]	Full-dust shroud		
Grinder shroud	Sawtec	Cut (edging) shroud		
Tuckpointing grinder	Bosch	Dust Director 1775E		Workplace Solutions: Control of Hazardous Dust During Tuckpointing; NIOSH
Roofing saw	Bosch	1364 Hand held electric saw	Tile cutting	In-depth survey report of a demonstration and evaluation of roofing tile saws and cutters controlling respirable and crystalline silica dust., 317-11a Sheehy, Garcia, Echt,
Roofing saw	Partner	Gasoline powered saw	Tile cutting	
Roofing saw	Revelation		Tile cutting	
Roofing saw	Bronco	Water backpack saw	Tile cutting	
Tile saw	Hytile	Manual tile cutter	Tile cutting	
Grinder	Matabo[7]	Tuckpointing grinder	Tuck-pointing	In-depth survey report ECTB 247-12 Heitbrink W.A February 2000
Grinder	Sawtec	Hiltzx DC500b	Tuck-pointing	

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[1] Metowerke GmbH; Nurtingen, Germany
[2] Robert Bosch GmbH; Stuttgart, Germany
[3] Milwaukee Electric Tool Corp.; Brookfield, Wisconsin, USA
[4] Pearl Abrasive Co.; Commerce, CA, USA
[5] Transmatic Inc.; Wilmington, NC, USA
[6] Sawtec; Oklahoma City, OK, USA
[7] Matabo Vollwellenen, Germany

Masonry saw	EDCO[8]	EDCO GMS 10	Brick cutting	In-depth study report EPHB 247-18 Heitbrink. W.A., Watkins. D.S.,
Right angle grinder	Metabo	11025	Tuck Pointing	
Mortar rake and shroud	American Tool Company[9]		Tuck Pointing	
Angle Grinder	Milwaukee	6153-20	Tuck Pointing	
Grinder shroud	Zantech Inc[10]		Tuck Pointing	
Grinder Shroud	Dustcontrol[11]		Tuck Pointing	
Grinder Shroud	Workshop made		Tuck Pointing	
Floor standing 20" disc sander	Fireline[12]		Sanding and polishing of refractory ceramic fibre parts	In depth study report EPHB 246-11a. Dunn. K.H., Shulman. S.A., Cecala. A.B.
Homemade LEV for above	Fireline		Sanding and polishing of refractory ceramic fibre parts	
Grinder	Metabo	W7-115 Quick	Concrete surface grinding	In-depth surver report EPHB 247-15c Echt. A., Sieber. W.K., Also reported in Echt. A., Sieber. W.K., Control of silica exposure from hand tools in construction: App. Occ. Env. Hyg **17**(7), pp 457-461, 2002
Grinder	Bosch	1347A	Concrete surface grinding	
Grinder shroud	Pearl Abrasive	Vacu-Guard	Concrete surface grinding	
Vacuum cleaner	Dustcontrol	DC 2700C	Vacuum source for above	
Rotary hammer drill	Bosch[13]	11221 DVS 7/8" SDS-plus 6.9 amp	Drilling and concrete finishing	Shepherd. S., Woskie. S.R., Holcroft. C., Ellenbecker. M. (2008): Reducing silica dust exposures in Construction….
Ring hood for drill	Bosch	Part No. 1618190009	Drilling and finishing concrete	
Bellows hood for drill	Tiger-Vac[14]	Bellows hood	Drilling and finising concrete	
Vacuum cleaner	Porter-Cable[15]	#7812	Vacuum source	

[8] *Equipment Development Company, Frederick, Maryland, USA*
[9] *Ameican Tool Company, Lincoln, Nebraska, USA*
[10] *Zantech Inc. Wayne, New Jersey, USA*
[11] *Dustcontrol. Wilmington, Delaware, USA*
[12] *Fireline Inc. Youngstown, Ohio, USA*
[13] *S-B Power Tool Co., Chicago Ill, USA*
[14] *Plattsburgh NY, USA*
[15] *Porter-Cable, Jackson, Tennessee*

Vacuum cleaner	Dustcontrol[11]	#DC3700C	Vacuum source	
Grinder	Makita[16]	17.5" GA7001L	Wet-Concrete surface grinding	Akbar-Khanzadeh et al Crystalline silica dust and RPM during indoor concrete grinding J.Occ.Env.Hyg
Grinder	Black and Decker[17]	4.5" 2750G	Concrete surface grinding	
Grinder	Hilti[18]	6" DG 150	LEV-concrete surface grinding	
Vacuum cleaner	Hilti	VCD 50L	Vacuum source for above	
Grinder	Metabo	5" diamond blade with shroud	Tuckpointing	Yasui. S., Susi. P., McClean. M, Flynn. M., Assessment of Silica Exposure and Engineering Controls During Tuckpointing: App. Occ. Env. Hyg, **18**, p. 977-984, (2003)
Vacuum	Industrial Contractors' Supplies[19]	Dust Director High Power Vacuum	Vacuum source for above	
Angle Grinder	Dewalt	Tungsten Carbide tipped mortar ra ke[20]	Tuckpointing	
Vacuum	Rigid?	Wet and dry 8 gallon shopvac	Vacuum source for above	
Disc sander	Oliver	Model 30	Wood sanding	Hampl. V., Johnston. O.E., (1991): Control of wood dust from disc sanders, App. Occ. Env. Hyg. **6**(11), pp. 938-944
Abrasive cutting tool	Bosch	1364 12 Inch cutter with all-purpose diamond blade	Block and brick cutting	Meeker. J.D., et al (2009) Engineering control technologies to reduce occupational silica exposures in masonry cutting and tuckpointing. Public Health Reports, 2009 Supplement Volume 124 pp 101 – 111
Dust extraction guard for above	Bosch	Model 1605510215		
Vacuum source for above	Bosch	3931 Airsweep (HEPA)		

[16] *Makita, Anjo, Japan*
[17] *Black & Decker, Towson, Maryland, USA*
[18] *Hilti, Schaan, Liechtenstein*
[19] *Industrial Contractors' Supplies, North Huntingdon, PA, USA*
[20] *Joran Bor, Randers, Denmark*

Wet masonry saw	Felker[21]	Mason Mate II 14" diamond blade	Block cutting	
Wet masonry saw	Target[22]	Portasaw PS1141S		
Tuckpopint grinder	Bosch	1775E 5"	Mortar removal	
Grinder shroud	Bosch	TG500 and vacuum adaptor VAC002	Same vacuum source as above	
Grinder	Metabo[23]	WE14-125 Plus	Mortar removal	
Grinder shroud	Industrial Contractors Supplies[24]	Dust Director Shroud	LEV hood for above	
Angle grinder	Metabo[1]	W7-115 Quick	Concrete grinding	Akbar-Khanzadeh et al. Effectiveness of dust control methods for crystalline silica and respirable suspended particulate matter exposure during manual concrete surface grinding
Angle grinder	Metabo[1]	WE14-150 Quick	Concrete grinding	
Angle grinder	Metabo[1]	W23-180	Concrete grinding	
Concrete grinder	Eibenstock[25]	EBS 1801 with integral dust shroud	Concrete grinding	
Vacuum	Dustcontrol[11]	DC 2800c cyclone HEPA	Vacuum for above tools	
Vacuum	Eibenstock[25]	Eibenstock 1500	Vacuum for above tools	
Vacuum	Shop-vac[26]	85L575	Vacuum for above tools	
Powered dry wall sander	Porter Cable[27]	Model 7800	Dry wall sanding	Young-Corbett. D.E., et al Dust Control Effectiveness of Drywall Sanding Tools
Angle Grinder	Porter Cable	F1509 FR	Tuck pointing	Croteau. G.A., et al, The effect of lev controls on dust exposures during concrete
Flat Grinder	Porter Cable	LD 1509 FR	Surface grinding	
Masonry Saw	EDCO	GMS-10	Block and brick cutting	

[21] *Felker Products Inc., Olathe, Kansas*
[22] *Target (Now Husqvarna)., Olathe, Kansas*
[23] *Metabo Corp., West Chester, PA*
[24] *Industrial Contractors Supplies Inc. Huntingdon, PA*
[25] *Elekrowerkzeuge GmbH, Eibenstock, Germany*
[26] *Shop-vac Corporation., Williamsport, PA*
[27] *Porter Cable Inc., Cleveland, Ohio*

Hand-held saw	Partner	K650 Active	Block cutting	cutting and grinding activities. AIHA Journal **63**(4): pp 458-467
Vacuum	Dust Control[28]	3700c	Vacuum source for above tools	
Surface grinder	Hitachi Koki[29]	G10SM2	Surface metal grinding	Ojima. J., Efficiency of a tool mounted LEV system for controlling dust exposure during metal grinding operations. Industrial Health, **45** pp. 817-819
Dust collector	Hitachi Koki	R30Y3	Vacuum source for above	
Grinder	Flex[30]	LD 1509 FR	Concrete surface grinding	Croteau et al The efficacy of LEV for controlling dust exposures during concrete surface grinding. Ann. Occ. Hyg. **48**(6) p. 509-518, 2004
Grinder	Metabo	WE 9-125 Quick	Concrete surface grinding	
Grinder shroud	Flex	Rigid rubber shroud	Concrete surface grinding	
Grinder shroud	Sawtec[31]	Polyurethane shroud	Concrete surface grinding	
Grinder shroud	Sawtec	Cut-shroud[32]	Concrete surface grinding	
Vacuum	Dust Control	2700C	Vacuum for above	
Masonry saw	EDCO[33]	GMS-14	Tile cutting	Carlo. R.V., et al Laboratory evaluation to reduce RCS dust when cutting concrete roofing tiles using a masonry saw. J. Occ. Env. Hyg. **7**(4) p 245-251, 2010
Dust hood	EDCO	40320	Tile cutting	

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[28] *Dust Control, Norsburg, Sweden*
[29] *Hitachi Koki Co. Ltd., Japan*
[30] *Flex, Steinheim, Germany*
[31] *Sawtec, Costa Mesa, California*
[32] *Modified by cutting section off of front of shroud*
[33] *EDCO Inc., Frederick, Md*

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On-tool controls to reduce exposure to respirable dusts in the construction industry

A review

Many processes in the construction industry create large quantities of dust; often materials used in construction contain silica. If the dust emissions from these processes are not controlled they can cause exposures that exceed UK workplace exposure limits and consequently lead to occupational diseases such as cancer, silicosis, chronic obstructive pulmonary disease and asthma. A common way to control these hazards is to apply local exhaust ventilation (LEV). However, construction sites tend be temporary workplaces, which makes the application of traditional LEV difficult. One solution is to affix LEV to the tool being used or to use another mobile form of on-tool control such as water suppression.

The objective of this project was to conduct a review of the literature on the subject of the effectiveness of on-tool controls and to summarise this information for HSE. The main findings were that:

- On-tool LEV is capable of reducing exposures by 90% or more.
- Important factors in achieving this reduction is hood design and choice of vacuum extraction source.
- Even with exposure reductions of 90 %, on-tool controls never completely eliminated exposure. This may mean that the use of supplementary respiratory protective equipment (RPE) is required, especially where materials contained silica.

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