



# Measurements of the Effectiveness of Dust Control on Cut-off Saws Used in the Construction Industry<sup>1</sup>

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Materials used in the construction industry frequently contain large quantities of silica. When they are cut or shaped with power tools considerable respirable dust can be produced. Three dust control systems for use with cut-off saws have been evaluated on site: wet dust suppression using mains water, the same system using water from a portable water tank, and local exhaust ventilation. The efficiency of water suppression on cut-off saws has been precisely quantified in controlled laboratory conditions by means of measurements with and without dust control. When dust control was used on-site, the mean concentrations of airborne silica were reduced by a factor of between three and seven, the accuracy being limited by the relatively high limit of detection for silica. All controls systems generally reduced respirable dust levels by at least 90%. Although the effectiveness of dust suppression did not depend on blade type, a diamond blade was more effective than a resin-bonded blade with the pressurised water system; cutting a slab with this type of blade could be completed before the water tank required repressurisation. In laboratory tests, the application of water reduced the dust concentration to <4% of its value without control. The method for monitoring the dust concentration was sufficiently sensitive to measure a difference in concentration produced during cutting in different directions. It is important, however, that the pressure in supply reservoirs is properly maintained, that the water is correctly applied and that it is used at the correct rate. If this is done effective dust control can be achieved. Crown Copyright © 1999 Published by Elsevier Science Ltd. All rights reserved.

*Keywords:* construction; wet suppression; silica; respirable dust; saws

## INTRODUCTION

Concern has been expressed for many years about the exposure of construction workers to respirable crystalline silica; a historical account is given by Roznowski (1997). Seaton *et al.* (1987) reviewed the pathological effects of silica, including those of protracted exposure. Particularly important among these is silicosis, a lung fibrosis which may advance to progressive massive fibrosis, at which stage the individual suffers severe respiratory distress. Acute silicosis, due to high exposure to silica over a short period, causes rapidly progressive breathing difficulty and may be fatal within months of onset. In

addition, silicosis can predispose sufferers to other ailments such as tuberculosis; and silica is associated with carcinogenic activity (Guenel and Breum, 1989). Lofgren (1997) found that construction workers were exposed to 0.17–8.3 mg m<sup>-3</sup> of respirable silica during concrete cutting; exposure to levels of more than 1.0 mg m<sup>-3</sup> is considered to cause unacceptable risk of progressive disease (HSE, 1997). Linch (1997) found that 41% of construction workers were exposed to levels of silica exceeding the personal exposure limit. Apart from exposure to respirable silica, construction workers may also be exposed to unacceptably high levels of inhalable dust.

Cut-off saws are used extensively throughout the construction industry, usually without dust control, to cut slabs, edges and other construction products, which can contain substantial concentrations of crystalline silica. In certain conditions of wind

Received 18 November 1998; in final form 10 March 1999.

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<sup>1</sup>Based on a presentation given at the 1998 BOHS Conference, London

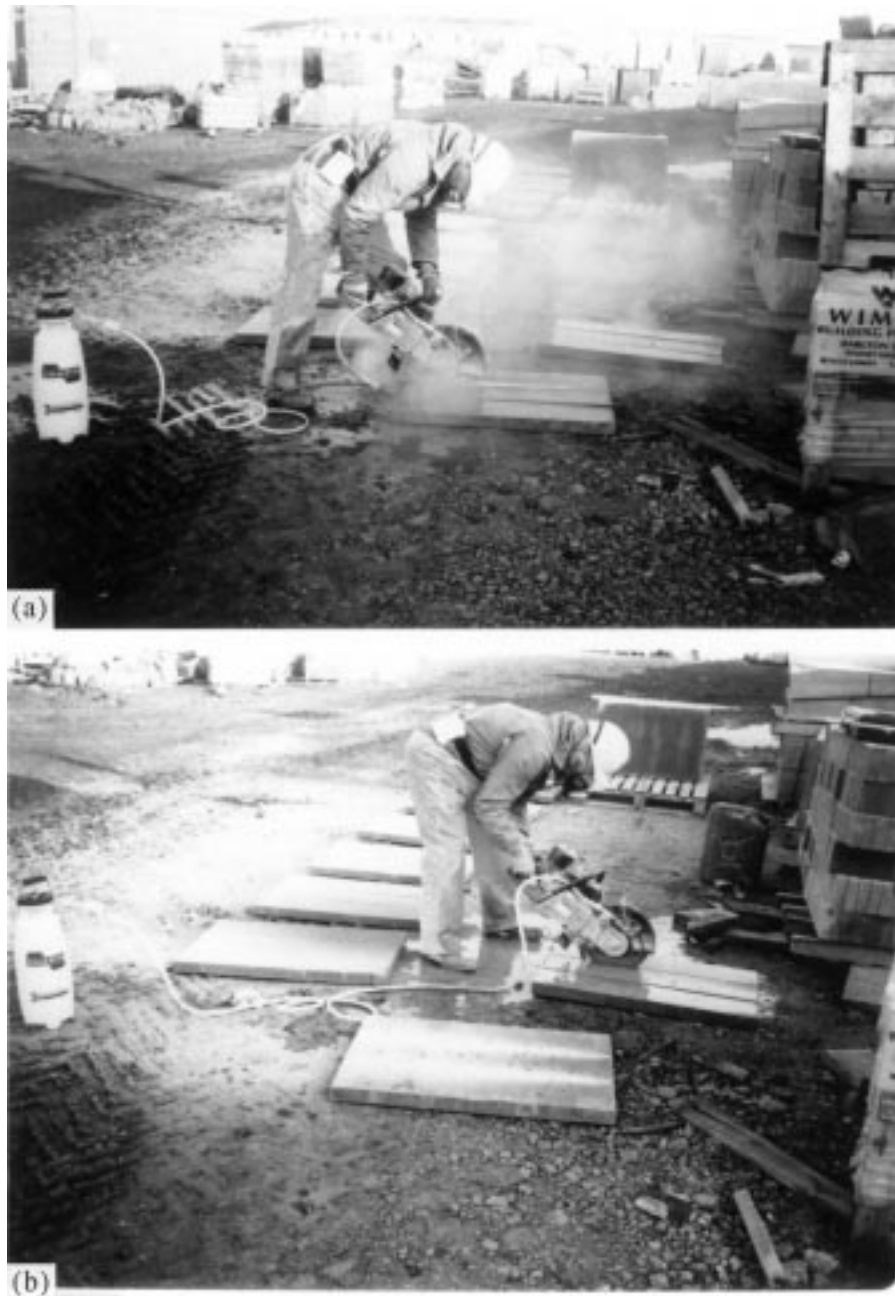


Fig. 1. Slab cutting with mains supply water system. (a) Without control; (b) with control.

speed and direction the operator may be totally engulfed in a cloud of dust.

Under the Control of Substances Hazardous to Health Regulations 1994 (COSHH) the primary duty of an employer is to ensure that exposure to hazardous substances is prevented or, where this is not reasonably practicable, adequately controlled. The toxicity of silica is recognised by the 8 h TWA limit of  $0.1 \text{ mg m}^{-3}$  applied by the ACGIH to quartz, and the TWA limit of  $0.05 \text{ mg m}^{-3}$  applied to cristobalite (ACGIH, 1998; see also Lemen and Hammond, 1992). The MEL for respirable silica

was  $0.4 \text{ mg m}^{-3}$  (BMRC convention at time of work) and is now  $0.3$  (ISO convention); there is a further requirement to reduce airborne exposure so far as is reasonably practicable below that level.

The use of silica-free materials is impractical, but dust control systems are available. These either wet the material to be cut or extract the dust by suction close to its point of production, and both can significantly reduce visible dust emissions during cutting activities. However, manufacturers and suppliers have not produced performance data on the degree of control achieved, and the construction



Fig. 2. Slab cutting with pressurised water tank system. (a) Without control; (b) with control.

industry is reluctant to use them. Part of this reluctance may be due to cost, though there is also a substantial amount of operator resistance, the reasons for which are detailed in the discussion section. The work described in this paper attempts to quantify the benefit of control systems.

#### ON-SITE WORK

Hand held cut-off saws used on construction sites are often powered by small capacity two-stroke combustion engines or by 110 V electric motors.

Normally the saw blades are 305 mm (12 in.) or 230 mm (9 in.) in diameter, and they may be either diamond tip or thermal resin-glass fibre composition. Both types of saw and blade were considered in this survey.

Two dust control systems involving wet dust suppression and one using local exhaust ventilation (LEV) have been examined. The wet systems are similar in principle as they both rely upon water applied to the rotating cutting disc to reduce dust emission. However, one system utilises water provided by a portable pressurised tank as shown in Fig. 2, and the other requires water supplied from



Fig. 3. Slab cutting with LEV system. (a) Without control; (b) with control.

the mains as shown in Fig. 1. The LEV system involves air extraction, and is made more effective by the substantial containment provided by the receptor guard attachment as shown in Fig. 3.

The three systems were assessed independently, between November 1995–January 1996, at three separate sites. Cutting of kerbs and slabs with a silica content ranging between 12–40% was carried out by experienced ground-work sub-contractors. Unfortunately it was not possible to standardise on the material, and the silica content of the materials

cut could not be measured until after the trials. A single operator was employed for each system, to eliminate the effects of variation in work practices, such as operator position. Cutting with and without controls was carried out on the same day to minimise the effects of the variable weather conditions. Cutting time was approx. 15 min, reflecting typical work and exposure patterns within the industry, with and without dust control systems fitted.

Personal protective equipment (PPE) worn by operators during cutting work included particulate res-

Table 1. Respirable dust concentrations measured when cutting with and without a pressurised water tank system<sup>a</sup>

	Respirable dust (mg m <sup>-3</sup> )				Respirable silica (mg m <sup>-3</sup> )			
	Without control		With control		Without control		With control	
	15 min cutting	TWA 8-h	15 min cutting	TWA 8-h	15 min cutting	TWA 8-h	15 min cutting	TWA 8-h
	<i>Diamond blade</i>							
R	11.3	0.2	1.9	0.04	0.9	0.02	< 0.6	< 0.01
L	31.2	0.6	0.6	0.01	3.9	0.07	< 0.6	< 0.01
Mean	21.2	0.4	1.3	0.03	2.4	0.05	< 0.6	< 0.01
	<i>Resin blade</i>							
R	7.9	0.2	4.4	0.08	0.8	0.02	< 0.2	0.01
L	16.1	0.4	8.3	0.14	1.7	0.04	0.4	< 0.01
Mean	12.0	0.3	6.4	0.11	1.3	0.03	< 0.3	< 0.01

<sup>a</sup>The paving slab had a silica content of 20%.

pirators, either FFP3 filtering facepieces or orin-  
nasal respirators with P3 filters, safety glasses/gog-  
gles, ear defenders and head protection. Airborne  
personal sampling for respirable dust was carried  
out as described in MDHS 14 (1997), which is  
believed to give a fair representation of personal ex-  
posure, using Casella cyclone-operated samplers  
with a sampling rate of 1.9 l min<sup>-1</sup> on operators'  
right and left lapels, and all samples were taken in  
duplicate. The mean concentration provided a bet-  
ter estimate of silica dust levels in the operators'  
breathing zone. Both gravimetric analysis and i.r.  
spectrophotometry were carried out on the samples.

#### *Portable tank (wet) system*

This equipment is supplied by a number of plant-  
hire companies and major manufacturers of cut-off  
saws. The system used in the survey consisted of a  
polypropylene bottle containing approx. 8.5 litres of  
water and pressurised by hand. The bottle was con-  
nected by narrow plastic tubing to two brass heads  
attached to the same side of the guard. An on/off  
valve controlled the water supply, which was fil-  
tered to prevent blockage of the heads. These were  
adjustable, and they supplied a fine jet of water to  
the disc face. The saw had a two-stroke engine with  
a capacity of 70 cm<sup>3</sup>, giving a nominal speed of  
5000 rpm. It could be used with a 20 segment  
305 mm diamond blade or a reinforceable silicon  
(medium grain) resin blade.

#### *Mains water (wet) system*

The dust suppression equipment used to put this  
method into effect is essentially the same as the  
tank system, except that the water comes from  
mains supply through a hose, to two water jets  
located on each side of the guard. The saw was dri-  
ven by two-stroke engine with a capacity of 65 cm<sup>3</sup>  
and a nominal speed of 5100 rpm. It could be used  
with a 305 mm diamond blade or a composite resin  
blade of the same size.

#### *LEV system*

LEV is a well established technique, but the sys-  
tem used in our tests took a sophisticated form. It  
was specifically designed for the saw, and takes into  
account whether the user is left- or right-handed.  
More importantly, it adjusts to the depth of the cut  
by means of an inner sleeve contained with the  
guard, which can be adjusted to ensure maximum  
containment during cutting. Alternative systems are  
“add-on” guard attachments, which often provide  
only limited enclosure. The system tested was driven  
by a 2400 W electric motor with a nominal speed of  
6500 rpm. It was used with either a diamond blade  
of diameter 230 mm or a composite resin blade of  
the same diameter. The dust extraction was pro-  
vided by a vacuum cleaner, the filter grade of which  
was not known.

#### *Method*

The portable pressurised water tank system was  
used first with a diamond blade to cut paving slabs  
600 × 900 mm, ten cuts in all giving a total cut  
length of 9 m. This was followed by cuts on similar  
slabs using a resin blade, three full cuts and a frac-  
tion, in all giving a total length of 3.15 m. The silica  
content of the slab cut was 20%.

The mains water system was used with a dia-  
mond blade to cut paving slabs 600 × 900 mm,  
twelve cuts giving a total length of 10.8 m, plus a  
single kerb 250 × 125 × 900 mm, to give a total cut  
length of approx. 12 m. A second set of tests using  
a resin blade was applied to similar paving slabs,  
with five cuts followed by one cut on a similar kerb  
giving a total cut length of approx. 5.7 m. The silica  
content of the paving slabs was 40%.

The LEV system was used to cut 600 × 900 mm  
paving slabs with a diamond blade, twelve cuts in  
all giving a total length of 10.8 m. This was fol-  
lowed by similar slabs cut with a resin blade three  
cuts in all giving a total cut length of 2.7 m. The  
silica content of these paving slabs was only 12%.

Table 2. Respirable dust concentrations measured during cutting with and without mains water dust suppression<sup>a</sup>

	Respirable dust (mg m <sup>-3</sup> )				Respirable silica (mg m <sup>-3</sup> )			
	Without control		With control		Without control		With control	
	15 min cutting	TWA 8-h	15 min cutting	TWA 8-h	15 min cutting	TWA 8-h	15 min cutting	TWA 8-h
	<i>Diamond blade</i>							
R	14.8	0.5	0.3	0.02	1.7	0.06	< 0.4	< 0.01
L	14.1	0.5	0.8	< 0.01	1.4	0.04	< 0.4	< 0.01
Mean	14.4	0.5	0.6	0.01	1.6	0.05	< 0.4	< 0.01
	<i>Resin blade</i>							
R	58.1	1.7	1.0	0.14	5.2	0.16	< 0.3	< 0.01
L	57.6	1.7	2.84	0.01	4.4	0.13	< 0.3	< 0.01
Mean	58.0	1.7	1.9	0.08	4.8	0.15	< 0.3	< 0.01

<sup>a</sup>The paving slab had a silica content of 40%.

### Results

The results shown in Tables 1–3 are based on a cutting time of approx. 15 min. The figures were calculated from the time of each cut, but the 8-h TWAs were calculated from the actual time/volume of sampling. For this reason there may appear to be discrepancies between the two sets of values.

The major factors affecting dust exposure are the operator's technique and posture during cutting, and the speed and direction of the wind. The results show differences resulting from sampler locations, i.e. left or right shoulder (cf. Vaughan *et al.*, 1990). The mean levels measured provide information on typical dust concentrations likely to occur during this type of work.

The mean concentrations of silica show reduction by a factor of 3 to 7 when dust control was used on-site, the accuracy being limited by the relatively high limit of detection for silica. However, the three control systems generally reduced respirable dust levels to less than one tenth. For example, use of the control measures reduced mean respirable dust concentrations from 21.2 to 1.3 mg m<sup>-3</sup>, 14.4 to 0.6 mg m<sup>-3</sup> and 8.0 to 0.7 mg m<sup>-3</sup>, with the diamond blade and the pressure tank system, mains water and air extraction respectively. Levels were

reduced from 12.0 to 6.4 mg m<sup>-3</sup> (the poor control here was due to loss of pressure in the water tank, as described below), 58.0 to 1.9 mg m<sup>-3</sup> and 13.3 to 0.2 mg m<sup>-3</sup> respectively when resin blades were used.

Although the effectiveness of dust suppression did not depend on blade type, a diamond blade was more effective with the pressurised water system overall, because its use enabled a slab to be cut in approximately one minute using a single pressurisation of the tank, whereas when the resin disc was used the tank needed to be re-pressurised a number of times during cutting.

### LABORATORY TESTS

On-site tests provide realistic data but they are susceptible to variation as a result of external forces such as wind speed and direction, which are outside the control of the experimenter. This means that results are not sufficiently accurate to enable subtle distinctions of the sort needed for optimisation, or for discrimination between alternative systems to be made. Accurate data require laboratory experiments, which can be carried out in conditions where external effects can be controlled.

Table 3. Respirable dust concentrations measured when cutting with and without LEV system<sup>a</sup>

	Respirable dust (mg m <sup>-3</sup> )				Respirable silica (mg m <sup>-3</sup> )			
	Without control		With control		Without control		With control	
	15 min cutting	TWA 8-h	15 min cutting	TWA 8-h	15 min cutting	TWA 8-h	15 min cutting	TWA 8-h
	<i>Diamond blade</i>							
R	7.0	0.2	1.4	0.03	< 0.4	< 0.01	< 0.50	< 0.01
L	8.9	0.2	< 0.1	< 0.01	0.6	0.02	< 0.50	< 0.01
Mean	8.0	0.2	0.7	0.02	< 0.5	0.01	< 0.50	< 0.01
	<i>Resin blade</i>							
R	13.5	0.5	0.3	0.01	1.0	0.04	< 0.34	< 0.01
L	13.0	0.5	0.1	< 0.01	0.4	0.01	< 0.35	< 0.01
Mean	13.3	0.5	0.2	< 0.01	0.7	0.03	< 0.35	< 0.01

<sup>a</sup>The paving slab had a silica content of 12%.

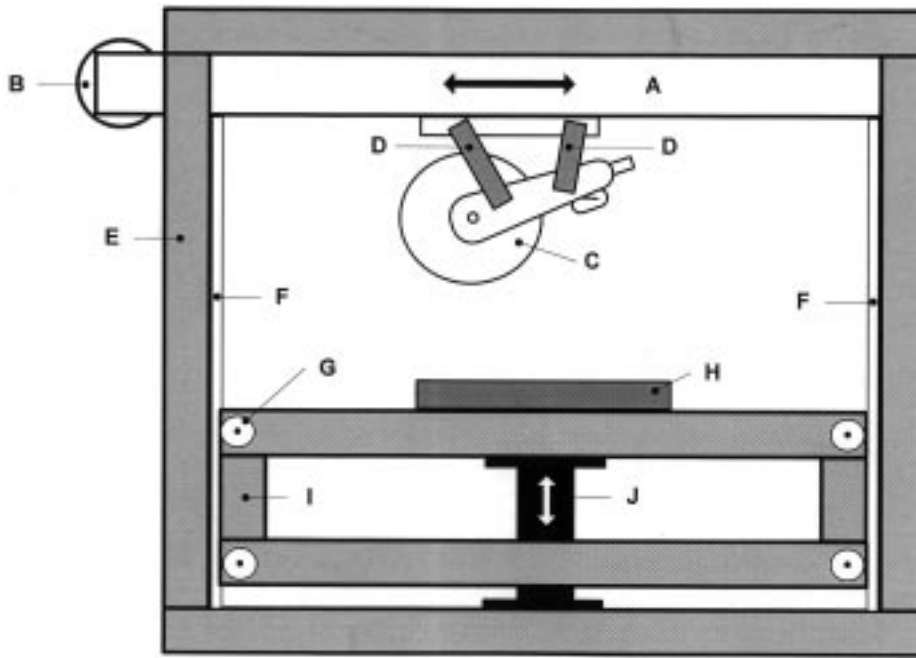


Fig. 4. Apparatus used to carry out sawing of paving slabs in a repeatable manner.

A cut-off saw with provision for the application of water to suppress dust production was sought for the tests. Petrol-driven saws had the provision but indoor tests were not possible because of the production of carbon monoxide during use. The electrically-powered saws examined did not have the provision, but a compressed air-driven saw was available with an optional water feed kit comprising two nozzles which are fitted either side of the blade onto the saw hood, along with a hand-driven water pump and an 8 litre capacity tank. Laboratory tests were carried out on this saw, which was powered by a petrol-driven compressor, which stood outside the laboratory.

Precise measurements required that the saw be tested at a constant cut speed, and that the resultant airborne dust concentration be measured in a steady state air flow (Regnier *et al.*, 1988). The dust concentration will depend on this flow rate, which may not be typical of conditions of use, and so absolute values have no real meaning. However, the constancy of the conditions means that relative values are extremely reliable, and therefore the effectiveness of control systems can be specified accurately by this means. A test rig previously used to test hand sanders (Thorpe and Brown, 1994) inside a large recirculating dust tunnel (Blackford and Heighington, 1986) was used. The apparatus, shown schematically in Fig. 4, comprises an inner (I) and an outer framework (E) made from strong modular sections of extruded aluminium. The material to be cut (H) is mounted on top of the inner frame. This frame can be raised or lowered by an electrically operated telescopic pillar (J), and the

height can be set using a limit switch. A linear module (A) with a movable platform driven by a dc motor (B) is attached underneath the top of the outer frame. A single control box regulates the speed and direction of the linear module, and a switch connected to the moving platform controls the direction of movement.

The saw, fitted with a diamond tipped blade (C), was securely attached directly to the platform using four separate brackets (D), necessary because of the saw's complex shape. It was fixed, as shown in Fig. 5, at an angle similar to that observed during a site visit and illustrated in the instruction manual, and the blade was held vertical throughout the tests. The rate of water supply to the saw was monitored by two floating ball type liquid flow indicators with ranges of 0.07–0.55 and 0.2–2 l min<sup>-1</sup>, along with a liquid flow sensor with ranges of 0.05–1.5 and 0.2–9 l min<sup>-1</sup>, both attached to the side of the tunnel. The output of the latter meter consists of pulses at

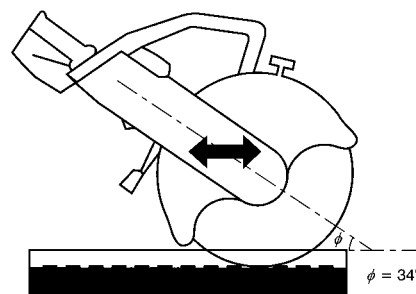


Fig. 5. Schematic diagram of cut-off saw indicating the angle of cut.

Table 4. Dust concentration measured during cutting with various rates of application of water in laboratory tests<sup>a</sup>

Rate of water flow to saw blade (l min <sup>-1</sup> )	Average depth of cut (mm)	Gravimetric dust concentration (mg m <sup>-3</sup> )	HAM dust concentration (mg m <sup>-3</sup> )	% Reduction in dust concentration (gravimetric results)	% Reduction in dust concentration (HAM results)
None	10.0	183.8	34.6		
0.12	7.3	83.1	21.7	54.8	37.3
0.2	9.5	49.0	11.5	73.3	66.8
0.5	9.5	6.12	0.62	96.7	98.2
1.0	10.2	3.93	0.49	97.9	98.6

<sup>a</sup>The water was supplied by the hand pump. The flow dropped continuously with time during the test, and the dust concentrations given are a mean of all the results.

a frequency proportional to the liquid flow rate, and the flow can be logged remotely. Water was applied to the saw, either from the hand pump supplied with the system or from an electric pump, which provided a uniform supply.

The mean dust concentration inside the tunnel was measured with a gravimetric sampler consisting of an open faced sampling head containing a 47 mm diameter high efficiency glass fibre filter, and a Rotheroe and Mitchell high volume pump. The variation of dust concentration with time was measured with a Hand-held Aerosol Monitor (HAM), a direct reading instrument. This instrument is calibrated with Arizona road dust with particle sizes in the respirable range, i.e.  $\leq 7 \mu\text{m}$  in diameter, and so can only be used to make comparative measurements with other types of dust. The two sampling instruments were placed alongside each other in the centre of the tunnel, approx. 3 m downstream of the test rig. The output from the HAM was connected to a data logger module manufactured by Digitron Ltd which plugs into a Psion series 2 organiser.

In order to ensure safe use, the saw's compressed air supply was first passed through a mains operated solenoid valve, interfaced with magnetic contact switches on the doors of the tunnel so that if the doors were opened the power would be cut. Water settling on the floor of the tunnel produces a slip hazard, and so drip trays were placed in the vicinity of the saw and downstream, and an area of carborundum-impregnated non-slip floor covering was securely attached to the floor of the tunnel just downstream of the drip tray. During the tests the operators wore polyurethane rubber or soft rubber soled shoes to ensure a good grip. The paving slabs inside an enclosed space are dangerous to handle, especially when they are partly cut through, and so a small fork lift was used to transport the slabs to the tunnel and to put them on and off the platform of the test rig.

#### Method

The saw was designed to operate at a pressure of 7 bar and an air consumption of 2–2.4 m<sup>3</sup> min<sup>-1</sup>. Its rotational speed, measured with a stroboscope,

was adjusted to the specified value of 5100 rpm. The air flow through the tunnel was set to 1 m s<sup>-1</sup> and the speed at which the saw moves, its cutting speed, was adjusted to about 0.6 m min<sup>-1</sup>.

Cuts were made on 600 × 600 × 48 mm paving slabs placed onto a wooden platform between two wooden stops and fastened on top of the inner frame of the test rig using G clamps, with the cut depth set to approx. 10 mm. At the end of each cut the slab was moved along 2 cm using a length of wooden dowel inserted through the side of the tunnel, so that a new cut could be made in the opposite direction. In practice cuts are normally made with the saw moving away from the operator, but it was easier to return the saw to its original position cutting than not, and it will be seen below that an interesting result emerged from this exercise.

After nine cuts the linear module, saw, logger and sampling pump were switched off. The gravimetric sampling filter was removed and weighed, and the logged data were transferred to a computer spreadsheet program. The drip trays were emptied if necessary. After each test the average cut depth was determined from measurements at four positions along each cut.

When the effects of water on dust suppression were investigated, the water tank was pumped up to maximum pressure, usually with about 26 pump actions, at which a safety valve would begin to open. The initial flow was then set to either 1 or 2 l min<sup>-1</sup> and the decrease in flow rate with time was measured. This was then repeated with an initial tank pressure of approximately half the maximum.

#### Results

The results of all the tests are shown in Table 4 and Figs. 6–8. Dust concentrations are calculated from measurements made during the cutting cycles and not the time between cuts, and are normalised to a standard 10 mm cut depth. The HAM measurements were normalised with respect to the gravimetric results using pooled results from all of the experiments.

When no water was applied to the saw blade the dust concentration was 184 mg m<sup>-3</sup> measured gravimetrically, the normalised HAM result being

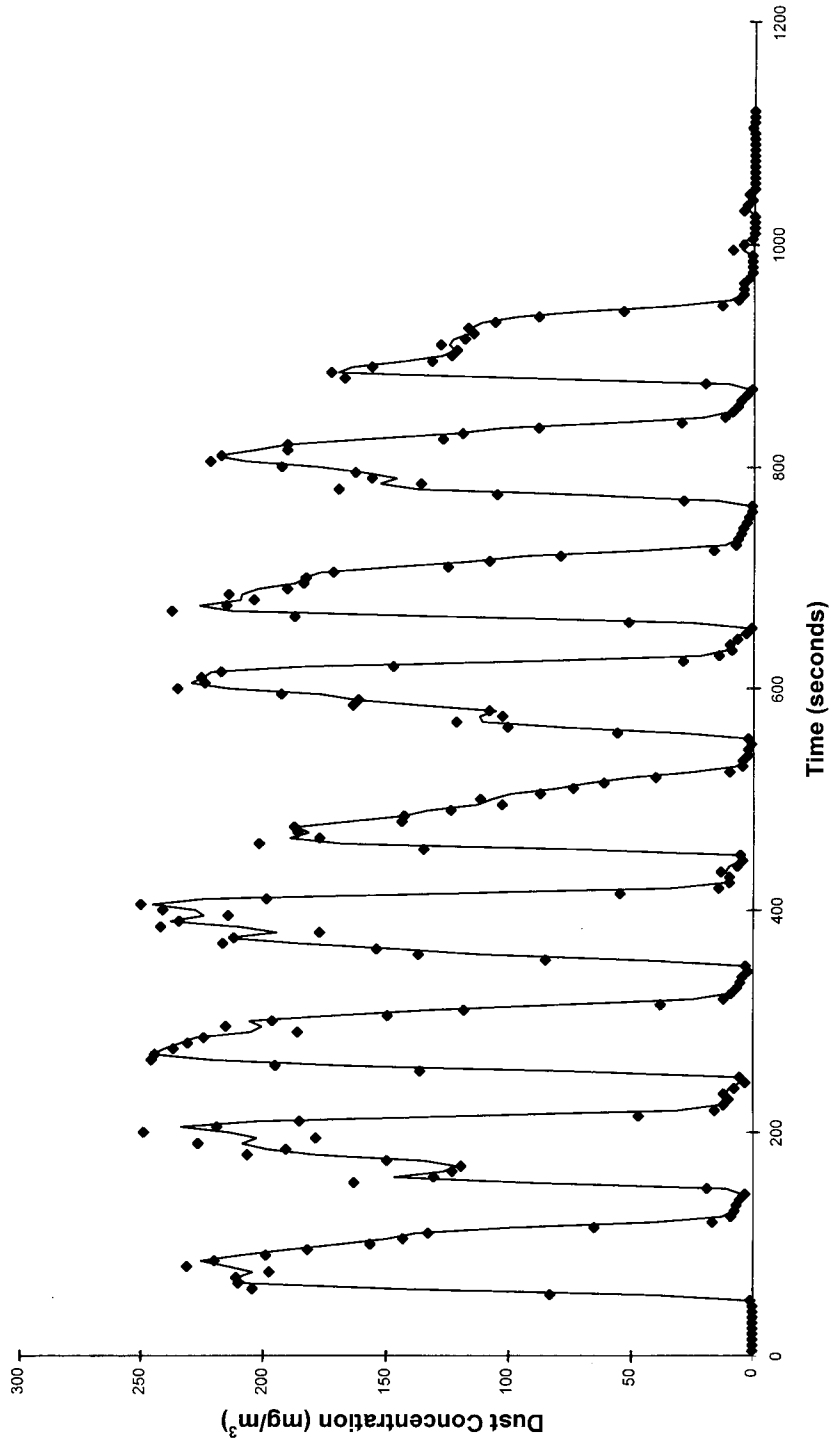


Fig. 6. Temporal variation of dust concentration during laboratory experiments without water dust suppression. (The cuts are indicated by peaks. The first cut is in the forward direction; subsequent cuts alternate in direction).

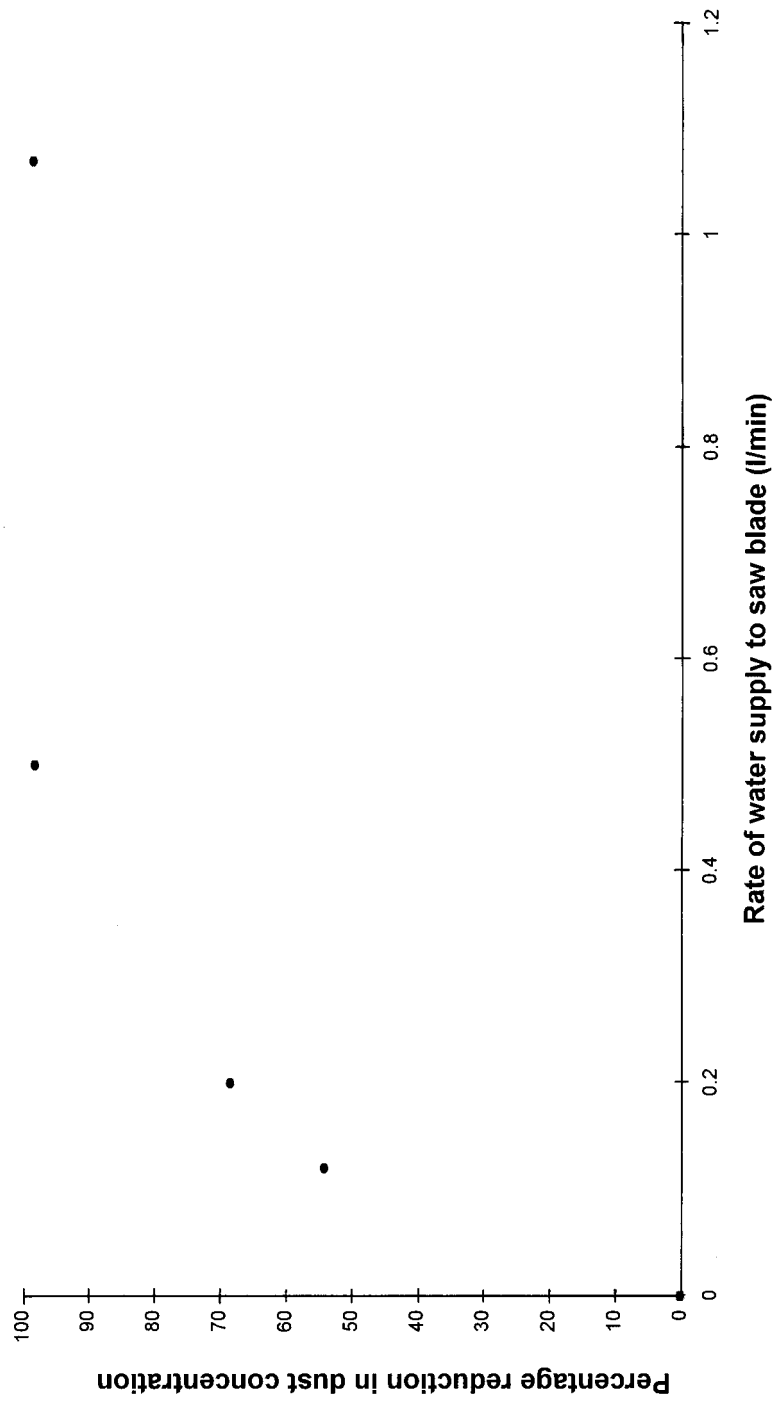


Fig. 7. Reduction of airborne dust during cutting as a function of flow rate of applied water.

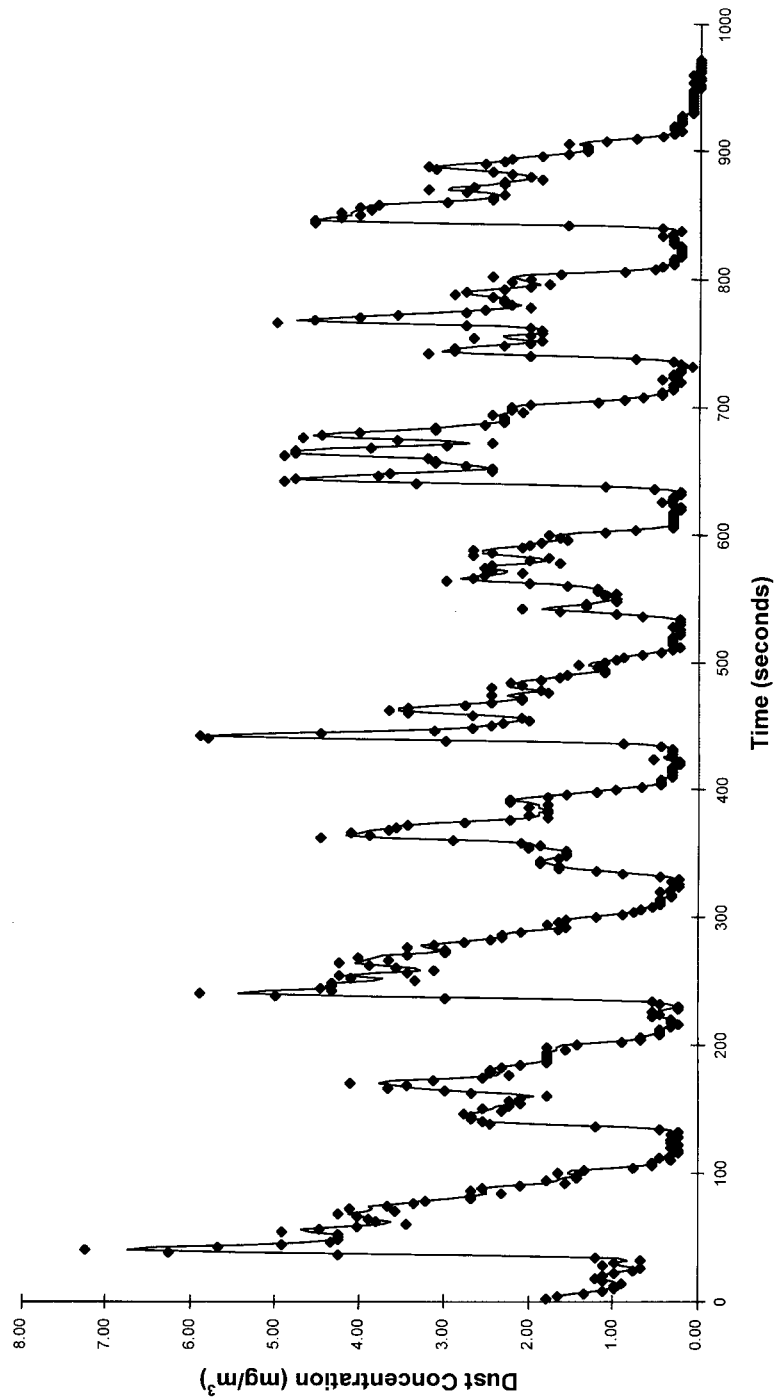


Fig. 8. Temporal variation of dust concentration during laboratory measurements with water supplied using an electric pump to supply water at  $0.5 \text{ l min}^{-1}$ . (The cuts are indicated by peaks. The first cut is in the forward direction; subsequent cuts alternate in direction).

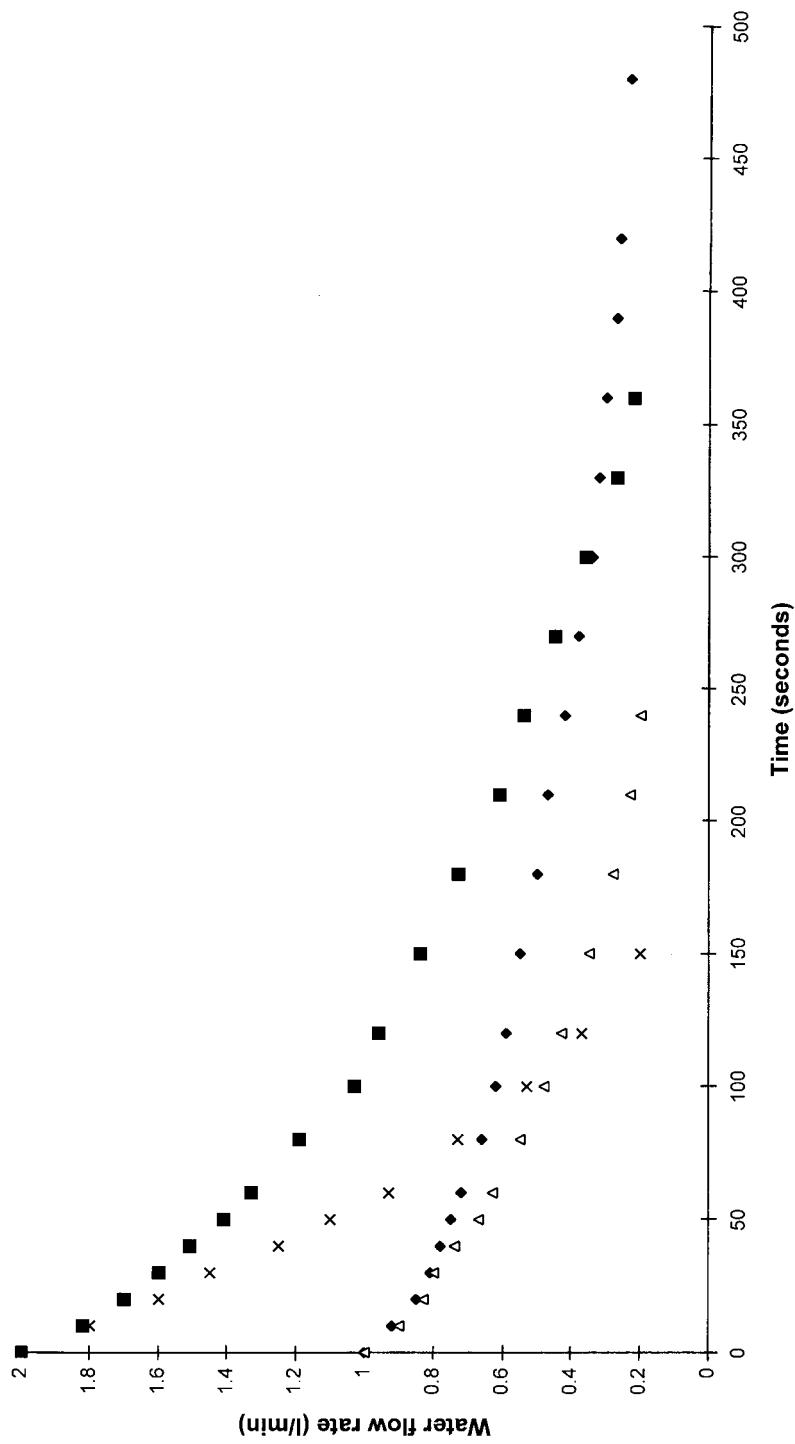


Fig. 9. Decrease of water supply rate with time when hand pump is used: (1) 26 pumps, 1 l min<sup>-1</sup> initial flow; (2) 26 pumps, 2 l min<sup>-1</sup> initial flow; (3) 12 pumps, 1 l min<sup>-1</sup> initial flow; (4) 12 pumps, 2 l min<sup>-1</sup> initial flow.

154.4 mg m<sup>-3</sup>. Figure 6 shows that the levels of dust produced in this instance did not vary with the direction of cut.

When the test was repeated with water supplied by the hand pump, at an average flow rate of 0.12 l min<sup>-1</sup> and an initial flow rate of 0.2 l min<sup>-1</sup>, the concentration was reduced by 55%. Water at a constant flow rate of 0.2 l min<sup>-1</sup>, supplied by the electric pump, resulted in a 73% drop in concentration, to 49 mg m<sup>-3</sup>, though this is still high. However, increasing the flow rate to 0.5 l min<sup>-1</sup> had a dramatic effect, reducing the dust concentration by about 97%, to 6.12 mg m<sup>-3</sup> measured gravimetrically, the normalised HAM result being 2.64 mg m<sup>-3</sup>. These results are summarised in Fig. 7, and indicate that further increase in water flow to 1 l min<sup>-1</sup> does not cause further significant reduction. Figure 8 shows that when water dust suppression was used, the levels of dust were higher on the forward stroke, i.e. with the saw blade spinning in the direction of a wheel moving along the cut, by between 55 and 70%. The reason for this is not known, but the effect was repeatable.

The water flow produced using the hand pump is illustrated in Fig. 9. An 8 litre capacity tank should be capable of supplying water at a flow rate of 0.5 l min<sup>-1</sup> for 16 min. However, even the initial pressure inside the tank at its maximum, the minimum adequate flow of 0.5 l min<sup>-1</sup> can be sustained only for just over 4 min. The flow is not constant and the initial flows of 2 or 1 l min<sup>-1</sup> result in waste of water without any improvement in dust suppression.

The flow of water to each nozzle was observed to be uneven to an extent that depended on the rate of water flow. At total flows of <1 l min<sup>-1</sup> the water failed to reach the far nozzle, which was supplied by a length of tube that passed over the saw hood. Smaller diameter nozzles operating at a higher pressure would probably resolve this problem, since the resistance to flow introduced by the nozzles would dominate, reducing the effect of the resistance of any connecting tubes. The manufacturers recommended that a "trickle" of water would be sufficient to control dust levels, but they could not quantify this (private communication). Since there is no water flow indicator supplied with the kit the operator would have no idea whether the flow rate is higher than the 0.5 l min<sup>-1</sup> required to give good dust suppression, other than by observing the dust generated.

## DISCUSSION

The survey shows that failure to use engineering control measures can expose operators to levels of up to 5.0 mg m<sup>-3</sup> crystalline silica. However, the use of any of the three systems by trained workers can significantly reduce exposure. In general short-

term exposures can be reduced to below the MEL of 0.4 mg m<sup>-3</sup>, and eight hour TWA exposures can be reduced to less than 0.01 mg m<sup>-3</sup>.

The hand-operated water pump sold by the manufacturers of the saw was capable of supplying water at a rate sufficient to provide good dust suppression for only around 4 min on a single pressurisation. This is more of a problem with resin blades because these cut more slowly.

From the studies in the laboratory, effective dust suppression required a flow of 0.5 l min<sup>-1</sup> of water to the blade. Higher flow rates result in minimal further improvement, but at flow rates below 0.2 l min<sup>-1</sup> dust suppression was poor. Water flow was not equal through the two nozzles and it stopped altogether through one at total flow rates below 1 l min<sup>-1</sup>. Adjustment of the nozzle and guard position affects wetting efficiency. Some systems examined but not tested have nozzles either side of the guard as opposed to the system used in this survey. It is claimed that a fine spray system provides a more efficient wetting mechanism than a jet. This could be disputed, but further investigation would be useful.

The operator was not usually diligent in re-pressurising the tank, and so after a minute or two of cutting there were significant levels of visible dust. A second worker pumping the tank during cutting would correct this, but had obvious labour costs/time implications. The mains water system has the advantage of a continuous supply of water, which is more reliable and which reduces operator involvement. However a nearby mains water supply is needed, and so the system is less flexible than the portable tank arrangement.

The wet systems have several minor disadvantages. The line of a cut is usually marked with chalk, which can easily be washed off by the applied water. An alternative is the use of a carbon brush producing an indelible line. In addition a significant amount of slurry can be produced, particularly at the fixed location required for the mains water system, and this makes the use of waterproof PPE necessary.

Possible improvements would follow from a closer specification of the critical water flow rate required for adequate dust suppression. If the rate is too low dust suppression is inadequate. If it is too high the water tank empties too quickly. The design and position of the water nozzle could be investigated, along with alternative methods of water supply such as gravity feed or using the saw's source of power. Some method of water flow monitor/detector would be useful. If the pressure inside the tank drops below that needed to give adequate water flow a pressure switch could be used to activate an alarm.

The LEV system was equally effective for both types of disc but the makers do not recommend the

composite resin blade because of the possibility of sparks entering the vacuum system. The blade used was 230 mm in diameter, whereas a 305 mm blade is more common with saws powered by petrol engines. The smaller blade required the operator, who was relatively tall, to bend a little lower during cutting activities.

Whatever is the outcome of experimental investigation, dust suppression should be used whenever possible during the cutting of building materials. The substantial reduction in exposure will be reflected in the reduction of risk, and there is a legal obligation to reduce exposure so far as is reasonably possible. The three systems assessed, which in general are of similar efficacy, vary substantially in cost. The mains water supply system is cheapest, incurring virtually no additional cost. The pressurised tank system may add 10% to the cost of a saw and diamond blade but brings the advantage of portability. An LEV system that provides a similar degree of control to wetting can double the cost of a saw and diamond blade. Although the saw is portable a generator is required for both the vacuum cleaner and the saw (a small generator can be transported on a wheel-barrow) and so it is more cumbersome than the portable wet tank system. However, LEV does not produce spray or sludge and may be particularly suitable for certain types of indoor work. The costs should be viewed in the context of reducing the risk of ill health, in particular silicosis, to operators. Because the control systems are of similar efficacy, the choice should reflect the requirement of the job.

The use of engineering control systems does not remove the need for the production of building products with low crystalline silica content. There is a relationship between airborne silica levels and silica content of the products cut. Paving slabs with 12% silica content gave rise to barely more than 0.4 mg m<sup>-3</sup> of silica dust averaged over 15 min, whereas respirable silica levels were significantly higher when products with 20–40% silica content were cut. Information regarding silica content of building products that are likely to require cutting should be readily available on-site.

### CONCLUSIONS

Without control cut-off saws produce levels of respirable silica that are unacceptably high. Both LEV and the proper application of water can reduce levels significantly and for this reason the use of control systems should be encouraged.

If a wet system is used it is important that attention be directed at the flow rate since when this is inadequate dust control is ineffective.

The laboratory method, in which dust concen-

tration is measured during steady state conditions, with the saw contained in a tunnel with a controlled constant airflow, enables the efficiency of dust control methods to be rigorously quantified. Similar methods could be applied to other tools used in stoneworking or construction.

There is significant scope for improvement of the dust control systems on cut-off saws.

*Acknowledgements*—We would like to thank the staff of Wimpey Homes Holdings Ltd, for using the saws and wearing the dust samplers during the site testing, and the representative of the building firm who arranged a site visit for HSL staff. We would like to thank Andreas Stihl Ltd for providing the mains water dust control system, Tool and Plant Services (Edinburgh) for providing the portable tank system, and Hilti (Great Britain) for providing the LEV system. We are also grateful to our colleagues in HSE's Field Operations Division, particularly Mrs A. Whitehead, Dr M. Piney and Mrs K. Parkinson for advice, the staff of the Field Scientific Support Unit, Edinburgh, for the gravimetric analysis of samples, and Mr P.A. Roberts of the Health and Safety Laboratory, for help with the laboratory experiments.

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