D. Pocock; C J Saunders (Harpur Hill Buxton Derbyshire SK17 9JN):**Visualisation and control of solder fume exposure.** A quantitative assessment of LEV effectiveness

Colophony or Rosin Based Solder Flux Fume is a known cause of occupational asthma and as such exposure to it should be controlled. An effective method of engineering exposure control is to use local exhaust ventilation (LEV) to extract the fume at source. Personal exposure to solder fume was quantitatively measured in the breathing zone of a manikin, these exposures were then compared to those caused by uncontrolled soldering in order to assess five different LEV systems. The five LEV systems tested were a downdraught bench; an extracted bench top enclosure, a mobile capturing hood, an on-tip extraction system and a bench top fume absorber.

It was found that even a moderate amount of soldering when uncontrolled caused exposures over 50 times greater than the 8-hour Workplace Exposure Limit of 0.05 mgm^{-3} and over 30 times greater than the 15-minute Short Term Exposure Limit of 0.15 mgm^{-3}. It was found that all five LEV systems were capable of reducing exposure to zero if used correctly. Each system had distinct advantages and disadvantages that make their use more or less suitable in various situations.

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The main objectives of the project were to quantitatively measure personal and background exposure to colophony fume generated by soldering with rosin flux cored solder. Exposures were measured for uncontrolled soldering and soldering with a variety of engineering local exhaust ventilation (LEV) controls. The engineering controls tested were: a downdraught bench, a mobile capturing hood, an enclosing hood, an air displacement box (or fume absorber) and an on-tip extraction or Low Volume High Velocity (LVHV) system. Then using this data to compare and contrast the available engineering controls and to determine whether it is possible to rank order them. Three soldering scenarios were considered in the project, moderate soldering was 1 s in 20 s, substantial soldering was 1 s in 10 s and extreme soldering was 2 s in every 10 s. The five LEV controls were all tested using the extreme soldering scenario in order to provide the highest emission rate and therefore the most stringent test of the system's ability to control exposure. Rosin based solder flux fume (colophony) has an 8-hour TWA Workplace Exposure Limit (W.E.L) of 0.05 mgm^{-3} and a Short Term Exposure Limit (S.T.E.L) of 0.15 mgm^{-3}. The majority of tests in this study were 15 minutes long allowing direct comparison with the S.T.E.L.

Main Findings

- Soldering produces a narrow but expanding directional rising plume of fume with a high concentration gradient making it a high strength source. The plume of fumes is highly variable and prone to disturbance by ambient air movements.

- Uncontrolled soldering causes high personal exposures in the breathing zone; this can be 20 – 50 times the S.T.E.L dependant on the soldering scenario. This can equate to exposures exceeding the 8-hour TWA W.E.L after only 15 minutes of soldering.

- General ventilation at 5 air changes per hour (ach) per hour was not sufficient to control personal exposures, but was capable of reducing background exposures within the test room.

- Four of the five controls - on-tip extraction, downdraught bench, mobile capturing hood, and the enclosing hood – can all reduce personal exposure to zero if used and maintained correctly.

- The fifth control, the air displacement box or fume absorber was capable of extracting solder fume from the working zone if used correctly, but filtration of the exhausted air was ineffective causing secondary personal exposure by increasing the background concentration of solder fume within the test room.

- Rank ordering the controls was more complex than comparing their quantitative performance reducing exposure and required consideration of their usability, ease of maintenance and adaptability to different processes and tasks.

- Rather than rank ordering the controls it makes more sense to divide them into two groups, the first being the most effective includes the on-tip extraction system, the downdraught bench and the enclosing hood. The second includes the mobile capturing hood and the air displacement box.

- Each control has advantages and disadvantages, these are summarised below.

On-tip extraction

- ✓ Is capable of reducing exposure to zero ✓ The extraction point is always close to the source eliminating the need to reposition the LEV when the soldering position moves ✓ The system is highly adaptable to changes of process and task
- ✓ Requires only a small volume air flow – approximately 1.8 $m^3 h^{-1}$
- × The extra extraction tubing can cause a dragging effect making it slightly harder to use than a standard soldering iron. The presence of the extraction nozzle close to the tip can limit access in situations where space is restricted and may restrict visibility
- × Solder fume tends to condense inside the narrow bore extraction nozzle and tubing causing blockages and restricted flow leading to a loss of control – this means that the system requires regular cleaning to function properly. During this study the system became blocked after approximately 1 – 2 hours of soldering

Downdraught bench

- ✓ Is capable of reducing exposure to zero
- ✓ Because the surface of the bench is extracted the effective capturing zone encompasses the whole working area
- ✓ It is easy to use, does not require any repositioning of the extract when moving soldering position
- × Requires a large volume air flow – approximately 575 $m^3 h^{-1}$ at maximum flow
- × The size of objects that can be soldered is limited as blockages of more than 50 % of the extracted surface can compromise control

× It is unclear how the bench would perform when soldering objects that form cavities shielded from the downward flow of air such as the inside of televisions or tower PCs

Enclosing hood ☙ Is capable of reducing exposure to zero ☙ It is highly resistant to disturbing draughts such as people moving around or the close

presence of a cooling fan ☙ Provides a physical barrier between the source and the worker's breathing zone ☙ Requires a relatively small volume air flow – the enclosure maintained complete control
of the fume emission operating at 40 $m^3 h^{-1}$

☙ Enclosures are ideally suited to production line work where identical or similar sized objects will be soldered

× Enclosures are more difficult to use where objects of various sizes and shapes are encountered as they are only capable of controlling emissions that occur within the enclosed volume

Mobile capturing hood

☙ Is capable of reducing exposure to zero if positioned correctly

× Has a relatively small effective capturing zone which means that it needs to be repositioned when the soldering position moves to keep it within the working zone and maintain control

× The model of mobile arm tested is difficult to move and reposition although other more flexible versions are available

× If the hood is not positioned close enough to the source fume escapes capture and high exposures can occur

Air displacement box

☙ It is simple and easy to use

× Whilst it is capable of capturing fumes at source and preventing direct exposure, the filtration in the unit tested was ineffective. The exhausted air contained a high concentration of particulate phase fume, that, in the relatively small test room used
(46.7 m^3), caused the background concentration to increase rapidly, which in turn caused exposure that exceeded the S.T.E.L.

× The integral filter in the unit is an activated carbon porous foam, which is very porous meaning that much of the fume passed straight through, unabsorbed

× The air displacement box works on the same principle as the mobile capturing hood, which means it has a relatively small effective capturing zone. If the source is outside of this zone then control is ineffective and exposure occurs

× The air displacement box tested would not be suitable for use where extensive and prolonged soldering will take place, such as a production line

Recommendations

Of the five controls tested the enclosing hood, the downdraught bench and the on-tip extraction system are the most effective. Each has advantages and disadvantages in various situations and careful consideration of the processes and tasks to be controlled is required to select between the three.

The mobile capturing hood is capable of controlling exposure if used correctly, but like all capturing hoods requires repositioning if the source moves in order to keep it within the effective capturing zone. This means that the potential for worker misuse leading to exposure to solder fume is high, for this reason it should be considered secondary to the other forms of control in the opinion of the author.

Whilst it is capable of capturing solder fume the air displacement box does not adequately filter the exhaust causing background exposure, for this reason the air displacement box should not be considered suitable for use in industrial production.

Due to concerns over exposure to lead, the soldering industry has moved toward the use of lead free solders; these tend to be a tin/copper alloy. In order to compensate for the removal of lead another flux substance has to be used to aid the flow of the solder. One of the most commonly used fluxes is rosin or colophony. When heated, rosin creates fumes (known as Rosin Based Solder Flux Fume - RBSFF). This fume is composed of two fractions, the particulate fraction contains rosin sublimates and thermal decomposition products, which are predominantly a mixture of diterpentine acids, this fraction makes up approximately 90 % of the total fume. The remaining gaseous phase of the fume is composed of low molecular weight organic compounds including acetone, methyl alcohol, aliphatic aldehydes and other hydrocarbons.
RBSFF is a known cause of occupational asthma[1, 2], it is also a cause of contact dermatitis[3]. Colophony is a hazardous substance and has a workplace exposure limit (W.E.L) of 0.05 mgm-3 over an 8-hour reference period and a short-term exposure limit (S.T.E.L) of 0.15 mgm-3 over a 15-minute reference period[4]. Furthermore, as a known asthmagen it is necessary to reduce exposure to solder fume as far below the W.E.L as is reasonably practicable as stated in Control of Substances Hazardous to Health (COSHH) Reg 7.7(c)(ii)[5]. Exposure should be reduced by following the principles of good control given in COSHH Schedule 2a[5].
This research project was initiated by the Health and Safety Executive (HSE) to visualise the emission of colophony fume by hand soldering, produce a series of training aids and then quantitatively measure the effectiveness of a variety of LEV controls. The project was to be completed in two phases. This project was to quantitatively measure the effectiveness of the different controls by measuring a baseline exposure for uncontrolled soldering and compare this with exposure whilst controls were employed and to the workplace exposure limit (W.E.L). The results from phase 2 are detailed in this report.