SAFETY NOTES

Solder fume control

The health risk from solder fume in soft soldering is assessed. A possible strategy for instigating control measures is suggested.

It is six years or so since the Centre last published guidance on this subject [1]. In the interim there has been growing concern over the incidence of respiratory sensitisation and other allergic conditions (see "Further reading" at the end of this article). We have had also a number of recent enquiries on the need for measures other than good general ventilation of the workroom. Many industrial concerns and a number of higher education establishments have adopted special control measures for soft soldering.

All of these developments have led us to look again at our earlier advice. An initial risk assessment based on likely rates of solder usage allowed the calculation of release rates (Table 1). These were used to make theoretical estimates of the build-up of concentrations of fume over time. The results suggest that our earlier advice, that local exhaust ventilation (LEV) at the soldering station was unlikely ever to be needed in schools, now has to be re-examined.

Background

Soft soldering is the process whereby conductive connections are made in electrical and electronic circuits. The solder consists normally of a 60/40 alloy of tin and lead together with several cores of flux. The typical percentage by weight of flux is 3%. The relative percentages by weight of the metals are 60% tin and 40% lead. The main constituent of flux is rosin, a natural product, being the residue remaining after the removal of volatiles from exudations of pine trees. Another name for rosin is colophony, after Colophon the ancient Greek name for a coastal region in western Asia Minor. This was famous for its production and supply of rosin. Some fluxes contain modified or synthetic rosin and other synthetic substances.

<table>
<thead>
<tr>
<th>Construction task</th>
<th>Rate of solder usage (g h⁻¹)</th>
<th>Rate of colophony fume production (mg h⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connecting small components to 0.1&quot; stripboard</td>
<td>2.6</td>
<td>75</td>
</tr>
<tr>
<td>Connecting 55/0.1 mm extra flexible leads to 4 mm connectors (banana plugs)</td>
<td>6.5</td>
<td>189</td>
</tr>
</tbody>
</table>

Table 1. Rate of usage of 22 s.w.g. 60/40 tin/lead rosin core solder, 2.9% rosin content, using a 50 W hand iron with 1.6 mm diameter tip. Tip temperature varied between 320°C and 360°C.

During the soldering process the tip of a hand soldering iron may reach a temperature of 350°C. The solder flows to form a joint fillet. Fume and gas are emitted, seen as a vertical plume rising from the tip. This is known as colophony fume. The main component is particulate rather than gaseous. The mean diameter of particulate fume is typically 1.1 μm. Particles are sufficiently small to reach the alveoli, or gas exchange region of the lung. Colophony fume is a known irritant of the eyes, nose and respiratory tract, a respiratory sensitizer causing asthma and is capable of causing allergic contact dermatitis. The specific agent in the fume has not been identified. This risk from exposure to colophony fume is therefore significant. Exposure to lead by inhalation will be minimal because the solder is unlikely to reach a sufficiently high temperature for lead to evaporate. The risks from the toxic effects of lead are insignificant therefore.

The rate of fume emitted depends on many variables such as the nature of the work (Table 1), solder wire diameter, metal/flux ratio, flux composition and solder temperature. The values given are for a constant rate of work by a competent person such as a trained technician or pupil. They allow for intermissions taken to cut and prepare wire between making each solder joint, for positioning components and for other routine tasks typical in constructing a circuit.

The build-up of fume concentration in an enclosed space has been calculated for different rates of ventilation (Fig. 1) (the method should be familiar to readers of our book on making a COSHH risk assessment [2]). The conditions underlying the calculation should be noted. The number of air changes per hour, N, depends on many factors. For any enclosed area the value of N could lie between 0.5 and 10, and vary considerably from one occasion to another. For instance a room with tightly sealed window units might typically have just one air change an hour whereas a room with poorly sealed window units might typically have two air changes an hour. These values vary with weather conditions. Typically the value of N might rise to 4 by opening several windows and a door. It can be seen (Fig. 1) that the occupational exposure standard (OES) short-term limit (15 minute reference period) for the pyrolysis products of rosin core solder of 0.3 mg m⁻³ is liable to be exceeded between 20 minutes and 40 minutes after the commencement of soldering.

The calculation of fume concentration was based on the assumption that there is uniform mixing within the workspace air. By making such an assumption, it was
possible to predict the rate at which incoming fresh air dilutes the fume. If allowance is taken for the vagaries of mixing within the room, fume outwith the plume may concentrate locally to a level up to ten times greater than the uniform mixing value. High concentrations can be expected in the air near to the source - that is in the breathing zone of the solderer. It is therefore likely that the OES levels cannot be met by natural ventilation alone or solely by simple organisational procedures such as limiting the period of work.

Health effects

A causal link has been established between exposure to colophony fume and respiratory sensitisation. This can come about after repeated or prolonged exposure. Inhalation of the peak concentrations of fume is thought to be particularly hazardous because it may be one important factor in initiating sensitisation. All persons are at risk of becoming sensitised. However sensitisation is unpredictable. Only some individuals at risk will become sensitised. Atopic persons (those with a history of childhood eczema or asthma, etc.) may be at greater risk.

The prevalence of asthma associated with occupational exposure to colophony may be as high as 21%. (For a fuller description of sensitisers and allergenic substances see our book on making a COSHH risk assessment [3].)

Initial symptoms of harm include rhinitis (runny or stuffy nose), irritation of the eyes, irritation of the upper respiratory tract (sore throat), or bronchospasm (difficulty in breathing). If exposure continues, the person may become sensitised, the symptoms being rhinitis or asthma, characterised by periodic bouts of wheezing, chest tightness and breathlessness resulting from constriction of airways.

Once a person is sensitised, allergic symptoms can recur on any re-exposure to colophony fume, even to very low levels. Asthma attacks may also be triggered by other things, such as tobacco smoke, cold air and exercise. They may also be caused by exposure to colophony substitutes such as modified or synthetic rosin.

Exposure of skin to rosin or colophony fume may cause a rash to form. Repeated exposure may cause the skin to become sensitised, thus developing into allergic contact dermatitis.
Assessment

The COSHH Regulations require that exposure to substances hazardous to health should be prevented or, where this is not reasonably practicable, should be controlled. As soldering is a process that schools find necessary to undertake - for curricular and technical reasons - it would be operationally impossible to prohibit. Control measures are therefore required which are aimed at preventing sensitisation. There are no means of finding out which persons are predisposed to being sensitised. Therefore all soldering operations should be controlled so as to minimize exposures to solder fume.

Measurement of fume concentration is difficult and complex. As a guide to where good standards of engineering control have been established, HSE advise that the concentration of particulate solder fume should not exceed 0.2 mg m⁻³ over the sampling period.

Calculations (Fig. 1) indicate just how readily the OES levels and guideline for the pyrolysis products of rosin can be exceeded. However it should be appreciated that OES levels apply to occupational situations and are primarily concerned with healthy adults who may be exposed over the large part of a working life. They cannot necessarily be applied to children or to persons in poor health in schools. Indeed there is no recognised approach to setting acceptable indoor concentrations of pollutants for these groups.

More than 3 million persons in the UK have asthma. Between 10% and 15% of school children have asthma and 80% of children with asthma will continue to have it in adult life.

Taking aboard these issues, schools must ensure that children, and staff also, are not unnecessarily exposed to solder fume. The pool of persons suffering from asthma should not be increased because of any additional hazards encountered in school. It becomes necessary therefore to develop health and safety management strategies to deal

<table>
<thead>
<tr>
<th>Solder type</th>
<th>Suitability or purpose</th>
<th>Flux</th>
<th>Supplier</th>
<th>Relative cost</th>
<th>Test results</th>
<th>Fine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multicore 362 flux cored 60/40 solder wire</td>
<td>General soldering</td>
<td>Natural rosin 2.9% with halide activation</td>
<td>Farnell 419-345, RS 555-235</td>
<td>1.0</td>
<td>5</td>
<td>5</td>
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<tr>
<td>Multicore X38B low residue solid flux cored 60/40 solder wire</td>
<td>Repair operations</td>
<td>Modified rosin 1% Acid activators Halide free</td>
<td>Farnell 289-826, RS 685-033</td>
<td>1.2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Multicore X39B low residue solid flux cored 60/40 solder wire</td>
<td>Repair operations</td>
<td>Modified rosin 1% Acid activators Halide free</td>
<td>Farnell 289-863</td>
<td>1.2</td>
<td>3-4</td>
<td>5</td>
</tr>
<tr>
<td>Multicore X32C low residue flux cored 60/40 solder wire</td>
<td>General soldering with low fuming</td>
<td>Modified rosin 0.67% Halide free</td>
<td>Farnell 419-515</td>
<td>1.2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Multicore X42B low residue activated flux cored 60/40 solder wire</td>
<td>General soldering with low fuming Halide activator improves solderability to dirty surfaces</td>
<td>Modified rosin 0.45% Halide activator</td>
<td>Farnell 419-527, RS 567-531</td>
<td>1.2</td>
<td>4</td>
<td>4-5</td>
</tr>
<tr>
<td>Multicore Crystal 400 no clean clear residue flux cored 60/40 solder wire</td>
<td>General soldering</td>
<td>Modified rosin 3.4% Halide free</td>
<td>Farnell 609-985, Hawnt D622R 400</td>
<td>1.2</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Multicore Hydro-X flux cored 60/40 solder wire</td>
<td>Water-washing procedures to avoid using CFCs Unsuitable for schools</td>
<td>Citric acid-type</td>
<td>RS 185-0115</td>
<td>1.0</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 2. Comparison of low rosin, modified rosin or rosin-free fluxes with natural rosin-based flux (first row). Test results indicate relative solderability with 22 SWG solder wire on unused components. The coarse test consisted of connecting a component with relatively large thermal inertia (DIL socket, 0.25 W resistors and 30 AWG wire) to stripboard. The fine test consisted of connecting parts with low thermal inertia (2A bridge rectifier) to stripboard. The relative scale should be interpreted as follows:

5 = performs as if using natural rosin-based flux
4 = performs slightly less well than if using natural rosin-based flux
3 = performs markedly less well than if using natural rosin-based flux
2 = very difficult to work with, time consuming, solder not flowing properly
1 = impossible to work with
with exposure to allergens and sensitisers - of which solder fume is a significant example. All that can be suggested here is a general range of possible controls. It is a matter for educational employers and each establishment to assess risks in specific situations and to put the instigation of control measures into an overall set of priorities for action.

**Suggested control measures**

**Substitution**: Substitution of natural rosin with synthetic or modified rosins has been developed as one control to attempt to reduce the risk of sensitisation to solder fume. Often, but not always, synthetic or modified rosin concentrations will be lower than that of natural rosin in conventional soft solders. However there is evidence that modified rosins play a major role in contact allergy and may even have a stronger sensitising potency than natural rosin. We are not aware of any evidence that modified rosins are less potent. Reliance on substitution should not therefore be used as the sole control measure, although substitution itself may reduce the overall level of risk.

Solders with modified rosins are generally less easy to work with than is solder with natural rosin. Soldering to components with a large amount of thermal inertia, or with dirty legs, or to tarnished copper track, may be difficult. A comparative review (Table 2) shows the relative difficulty. In order of preference with respect to ease of use, the following types of solder wire containing modified rosin flux are recommended, all products of Multicore: Crystal 400, X42B, X39B. Our recommendations are tentative because of the cautionary remarks already made.

The percentage by weight composition of rosin in Multicore X42B flux cored solder wire is only 0.45%, six times lower than traditional solder wire containing natural rosin, such as Multicore 362. Fume concentrations can be reduced sixfold by substituting X42B for 362 flux cored solder.

**Local exhaust ventilation (LEV)**: In view of the knowledge we now have about how potent a sensitiser colophony is, and having made estimates of likely fume concentrations, we have reviewed the advice given some years ago [1]. We are now of the opinion that local exhaust ventilation has to be seriously considered for soldering operations in schools and further education. LEV may provide the only effective way of removing colophony fume from the breathing zone and preventing persons, whether persons soldering or others in the vicinity, from exposure. Information on LEV can be found at the end of the article.

**Natural ventilation**: This cannot be relied upon to remove or to sufficiently dilute colophony fume from school workplaces. In order for natural ventilation to be considered to be an adequate control measure in itself, the place would need to have about eight complete air changes an hour together with effective air mixing and the following administrative controls: one soldering iron per 80 m$^3$ of space, a limitation of the hours spent soldering to two hours, and a prohibition on persons with asthma entering the workspace. By substituting X42B solder, which contains only 0.45% rosin by weight, for solder with natural rosin, a higher iron density of one per 15 m$^3$ of space could be attained. However since this type of general ventilation simply does not exist in school work areas - except possibly by mishap - control measures based solely or mainly on natural ventilation probably cannot be relied upon. In work areas with LEV, natural ventilation is used as a secondary form of control. Typically this might be achieved by opening several windows and a door. The provision of an air extraction fan to ventilate the room is also recommended.

**Personal protective equipment (PPE)**: Although colophony is a skin irritant it is unlikely that gloves would be needed to prevent exposure because the period of risk is likely to be low and because the plume rises. Also, the use of gloves leads to loss of manipulative sensitivity. It may increase the risks of burns or other physical injuries as well as making the work itself difficult.

**Health surveillance**: Because of a growing awareness of problems with sensitisation and allergy, many employers have put systems in place to identify those thought to be at particular risk. In this present context persons at risk can be categorized as children and employees, the second group comprising technicians and teachers who solder, and teachers who supervise classes where pupils are soldering.

In any effective scheme, new employees and existing employees at the onset of their health surveillance programme are initially screened using a short health questionnaire and also, possibly, spirometry if that were advised by an occupational physician contracted to give advice by the EA. Persons reporting active eczema or bronchial asthma are directed not to work with known respiratory sensitisers and these would include solder fume. Existing employees are screened annually by way of a simple health questionnaire. Any employee at risk who develops signs of asthma or allergic dermatitis is instructed to report such symptoms to the employer for investigation.

A school's guidance system should identify, record and inform teachers - in confidence if need be - of those pupils who have active eczema, asthma or other history of respiratory problems. Pupils with active eczema or asthma should not undertake soldering operations without the advice of the school health service or family doctor. If LEV has not been provided, asthmatic pupils should be asked to inform the teacher if neighbourhood exposure to a soldering process upsets their chest.

**Information, instruction and training**: Exposure to colophony fume can cause irritation to the eyes, the lungs, or the skin. Allergy to colophony appears as asthma, or as dermatitis. Persons at risk need to be informed of these symptoms, of the control measures provided and be told to use them. If training is required, this should be given.
**Provisional controls:** At present it is uncommon for schools to make use of LEV to capture solder fume. Since LEV is expensive the priority for its provision will have to be examined against a number of other pressing needs for improvements in health and safety. It can be presumed that there will be a delay before it is installed. Interim steps to minimize exposure and risk of harm thus need to be taken. These might include combinations of any of the following:

- curtailing soldering operations to the necessary minimum;
- using solder wire with a relatively low percentage of rosin in the flux, such as Multicore X42B flux, but which is relatively easy to work with;
- limiting the number of solder stations per unit volume of work space, for example but only as a rough guide:
  - one solder station per 80 m$^3$ if using natural rosin based flux, or
  - one solder station per 15 m$^3$ if using X42B flux cored solder wire;
- minimizing the period spent soldering by any one person and limiting it to about 1 hour a day;
- not using a work area which has poor natural or forced ventilation;
- opening windows and doors;
- ventilating the work area with an air extraction fan provided that the source of fume is between the person soldering and the extraction fan;
- using a fume cupboard;
- checking by means of a bright lamp and Tyndall effect that the draught does not blow solder fume into the breathing zone of either the person soldering or other persons nearby;
- instructing persons not to directly breathe in fumes from the solder plume;
- not allowing persons with asthma or acute eczema into the work area (see Health surveillance).

**Local exhaust ventilation**

There is a statutory requirement to maintain LEV in good working order. Maintenance includes inspection and testing. The filters in systems returning filtered air to the workplace atmosphere need to be replaced as per the manufacturers' directions. Of the many different types of LEV, the following may find application in schools:

**Soldering iron with tip extraction:** A small nozzle fitted very close to the tip of the iron is linked via flexible tubing to an exhaust fan (Fig. 2). The fumes are then either expelled from the building, or are removed by being drawn through a filter of activated charcoal. This system would seem to be the most effective arrangement for removing colophony fume. It can be very effective at capturing fume and it operates continuously. Not only does it remove fumes during soldering, it also operates whilst the iron is at rest. It may not be necessary to buy special irons with fume extraction tips because conversion kits are available. There are systems for connecting several irons to the one pump and exhaust or filtration unit. Multiples of 2, 5, 10, 15, or 30 irons may be so connected. Several benches in a classroom could be piped up to the one pump. Since some pumps and filtration units
are transportable, several rooms could have fixed installation piping, being serviced by the one pump taken from room to room on demand. The noise level from such a pump can range from 50 dB to 65 dB depending on type. If the pump is to be sited in a classroom, select one that does not exceed about 58 dB.

The main disadvantage of tip extraction is that fume tends to be deposited within the narrow bore sections of the tubing, which are therefore prone to blockage. This can and should be overcome by routine preventive maintenance. Another problem for schools, as affects other fixed installation services, is that this type of LEV would be prone to vandalism. The obstruction to line of sight caused by the tip and inertia of the tubing are not generally thought to be over-troublesome.

**Portable extraction units with fume absorbers:** These consist of a box comprising a fan and filter. Those with a captor hood (Fig. 3) which draw in fume largely by natural convection would seem to be more effective than fume displacement units (Fig. 4). The circuit being soldered must be positioned carefully so as to ensure that fume is captured. The zone of effective capture may be quite small and may vary with draughts. Solder fume generated outwith this zone is unlikely to be captured. Some captor hood units include illumination. This helps to direct where the work should be positioned.

Another disadvantage is that these units may not be able to capture fume from a soldering iron in its rest position. Ideally both the workpiece and soldering iron stand should be sited together in positions where fume is effectively collected. The noise from the fan should not exceed about 58 dB.

**LEV buying advice**

At the time of writing, the Centre has begun formal testing of this type of LEV system. It would seem that tip extraction is effective, but would be expensive to install in several rooms. A 10-station system including conversion kits for irons costs around £2000. Portable extraction units with captor hoods would therefore seem to be the better buy. Although not as effective in capturing fume, they can be bought in small numbers to provide LEV in any location. Since soldering is a relatively infrequent occupation for most persons in school, this type of LEV may provide adequate protection to those at risk. Two portable fume displacement units are reviewed overleaf. One was found to be quite ineffectual. The other was reasonably effective.

**References**

2. Calculation of the level of contaminants in the general atmosphere of the workroom or laboratory, Appendix 6, Preparing COSHH risk assessments for project work in schools, SSERC, 1991.