FUME MINIMISATION GUIDELINES

Welding, Cutting, Brazing and Soldering
INTRODUCTION

1. ABOUT THESE GUIDELINES

These guidelines are based on research supported by the organisations listed at the end of this introduction. The aim of the research was to establish which processes generated fume at levels which would need to be controlled to comply with the requirements of the Hazardous Substances Regulations and to provide advice on the control measures which could be introduced to achieve this. Details of the legislation are summarised in Guideline 1. Guidelines 2 to 16 provide the advice on control measures.

Controlling the level of operators’ exposure to fume is the primary focus of these Guidelines. Depending on the workplace, it may also be necessary to protect personnel, other than operators, from these fumes. As workplaces differ so widely, it has not been possible to develop specific advice for this protection. Some controls, such as local exhaust ventilation or well designed mechanical general ventilation, may protect other staff as well as the operator whereas controls such as personal protective equipment or breathing zone ventilation, such as a fan supplying a cross draft of air for the welder, will not protect staff adjacent to the operation. Some advice on general workshop ventilation is included in Guideline 2.

As with all documents of this nature, the guidelines are dependent on feedback from industry and other interested parties. Suggestions on improvements to these guidelines are welcome and should be addressed to the WTIA.

2. INTENT OF THESE GUIDELINES

The use of these Guidelines cannot guarantee full compliance with the Hazardous Substances Regulations. By following the methodology a workplace will lessen or mitigate the risk of non compliance. Further professional assistance, for example by occupational hygienists or ventilation engineers, may be advisable in those circumstances where the Guidelines may not be entirely applicable or unusual conditions prevail.
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4. ACKNOWLEDGEMENTS

These guidelines have been prepared by the Working Group on Fume, comprising representatives from:

Industry,
Occupational Health and Safety state bodies,
Australian Aluminium Council,
Australian Institute of Steel Construction,
Australian Stainless Steel Development Association,
Australian Workers Union,
Cooperative Research Centre for Materials Welding and Joining,
Copper Development Association of Australia,
Commonwealth Scientific and Industrial Research Organisation,
Nickel Development Institute, and
Welding Technology Institute of Australia.

Guidelines are based on the results of a fume assessment project carried out in 1997 as part of a Research Project of the Cooperative Research Centre for Materials Welding and Joining.

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GUIDELINE 1: HAZARDOUS SUBSTANCES REGULATIONS

1. OBJECTIVE
The objective of the Hazardous Substances Regulations introduced by the States and Territories of Australia is to reduce the risk of adverse health effects for employees exposed to hazardous substances in their day to day workplace activities.

2. HISTORY
The National Occupational Health and Safety Commission (NOHSC) first declared National Model Regulations (NMR) to Control Workplace Hazardous Substances in 1990. Following a period of review, a revised version of the NMR and a National Code of Practice for the Control of Workplace Hazardous Substances were declared in December 1993 and published in March 1994. NOHSC documents are advisory and their application in a particular State or Territory requires legislation to be enacted by that State or Territory. The NOHSC received assurances from the States that, in the interest of uniformity, State regulations would not differ substantially from the NMR.

3. WHAT IS A “HAZARDOUS SUBSTANCE”?
In general a hazardous substance is a substance that has the potential to adversely affect human health. Hazardous substances may
   a) be included in the “List of Designated Hazardous Substances” [NOHSC: 10005 (1994)] or on a list produced by a particular State or Territory,
   b) fit the criteria for a hazardous substance set out in “Approved Criteria for Classifying Hazardous Substances” [NOHSC: 1008 (1994)].

However, employers need only refer to Material Safety Data Sheets (MSDS) for hazardous substances identification.

4. APPLICATION TO WELDING AND ALLIED PROCESSES
Fume is a hazardous substance according to b) above. Certain fume components may also be on the list of hazardous substances in a). Individuals should not be exposed to levels above those given in Exposure Standards for Atmospheric Contaminants in the Occupational Environment (NOHSC: 1003 1995).

5. RESPONSIBILITIES
The state regulations set out the responsibilities of manufacturers, importers, employers and employees. With respect to welding and allied processes the following must be observed:

   **Suppliers must-**
   - Provide Material Safety Data Sheets (MSDS) for substances being supplied for the first time to a particular buyer for use in the workplace.
   - Label substances that are hazardous substances or can be when used.

   **Employers must-**
   - Develop and subsequently maintain a register of all hazardous substances used or produced in the workplace. This may include consumables, welding fume or any other hazardous substances in the workplace.
   - Maintain a collection of MSDS as part of the register. This register must be available for reference by all employees.
   - Ensure a suitable and sufficient assessment is made of the risk to health created by welding fume or other hazardous substances. In most circumstances use of these Fume Minimisation Guidelines will assist in the assessment.
   - Revise the assessment at least every 5 years or if workplace conditions change significantly.
   - Provide training to all employees with the potential for exposure to welding fume.
   - Keep records of training and assessment – assessment reports must be available to employees to whom the assessments relate.
   - Provide health surveillance for employees assessed as being exposed to a significant health risk in the course of their employment duties.
   - Undertake monitoring where the need is indicated in the assessment.
• Ensure that exposure of employees to hazardous substances is prevented or adequately controlled to minimise risk to health. Exposure must not exceed the relevant exposure standards.
• Ensure that engineering controls and safe work practices are effectively maintained.

**Employees** are required to-
• Cooperate with the employer to ensure that activities within the workplace comply with the Hazardous Substances Regulations.
• Report promptly to supervisors/managers any matter that might diminish the employer’s ability to achieve compliance.

### 6. WORKPLACE ASSESSMENTS FOR FUME

The purpose of a workplace assessment is to enable decisions to be made about potential health risks, control measures, training requirements, monitoring and health surveillance. An employer has a duty to ensure a suitable and sufficient assessment is made where there is potential for exposure to hazardous substances. For the purpose of these guidelines the assessment should focus on activity in the workplace and likely exposures (e.g., in operator’s breathing zone). Actions to be undertaken during the assessment include:

- Identify all hazardous substances used or produced in the work being assessed.
- Review the information on the nature of the hazard and precautions for use and safe handling.
- Assess the risk in terms of degree of exposure and potential health effects.

The possible assessment methods include the following:

**Simple and obvious assessments:** These are straightforward assessments where, after reviewing the Material Safety Data Sheets (or equivalent information) for hazardous substances used at work and identifying their method of use, it can be concluded that there is not a significant risk to health. In respect of fume, this could mean that one of the control measures referred to in Guideline 2 and the applicable process guideline is already in place.

**Detailed assessments:** If the assessment is not simple and an appropriate generic assessment is not available, a more detailed risk assessment must be undertaken. This involves obtaining information about the hazardous substances primarily from MSDS sheets and labels, inspecting the workplace, evaluating exposure and evaluating the risk. If the level of exposure cannot be estimated with confidence, atmospheric monitoring by an occupational hygienist or other competent person may be required and the results compared with exposure standards for the substances.

**Generic assessments:** Where a particular hazardous substance(s) is used in the same or similar circumstances in different areas of the same workplace or in different workplaces, the nature of the hazard and the degree of risk may be comparable. In such situations, a single assessment of one representative work situation can be applied to other workplaces. This is the basis of these Welding Fume Minimisation Guidelines. It is the responsibility of the individual employer to ensure that the generic assessment is valid for their workplace. This type of assessment is generally based on information or outcomes from detailed assessments.

Further information on conducting these types of assessments may be found in the Worksafe publication “Guidance Note for the Assessment of Health Risks Arising from the Use of Hazardous Substances in the Workplace” [NOHSC:3017(1994)].

Irrespective of the assessment method, **it should be stressed that exposure standards do not represent “no effect” levels for each and every worker. Therefore, the level of exposure should be kept as low as practicable.**
7. ACTIONS FOLLOWING ASSESSMENT

Where assessment indicates a significant health risk decisions have to be made on:

- **Appropriate control measures**: Where prevention of exposure to hazardous material is not practicable, the degree of exposure must be controlled so as to minimise risk to health. If required for welding and allied processes, the controls are listed in these Guidelines.
- **Instituting periodic monitoring**
- **The need for health surveillance**: Includes biological monitoring which can assist in minimising the risk of health from exposure to hazardous substances.
- **Training**: Training shall be provided by the employer to all employees with potential exposure to hazardous substances and should be commensurate with the identified risk.
GUIDELINE 2: FUME CONTROL OPTIONS

1. INTRODUCTION
Some form of fume control is generally required in welding, cutting, brazing and soldering operations, usually in addition to existing general workshop ventilation. The level of control necessary will be determined by:

- The particular process being used.
- The materials being worked with and subsequent pollutants generated.
- The working environment.

The choice of control must be carefully considered and expert advice should be sought if an effective control approach is not obvious.

2. WORKPLACE ENVIRONMENT
In general, the more enclosed the working area, the more likely pollutant levels will exceed exposure standards. Typically, work done outdoors or in an open work space will require only general ventilation to prevent a build up of fumes. Work in a limited work space will usually require local exhaust ventilation, while work in a confined space will require specific respiratory protection and local exhaust. Note however, that in all circumstances the requirement is to prevent all workers being exposed to pollutants in levels above the relevant exposure standards. The welding, brazing or soldering process, the materials being worked with, and other workers must be carefully considered in addition to the work environment.

A definition of various working environments is given below:

2.1 Outdoor/natural ventilation
When working outdoors, natural ventilation is often considered to be a satisfactory form of fume control. This type of air movement is highly variable. On some days there will be hardly any air movement at all, particularly in the workers breathing zone if it is sheltered. Consequently there will be little dilution and dispersion of the pollutants.

2.2 Open work space
An open work space is defined as an area where all of the following apply:
- the average space per worker exceeds 300m² (minimum roof height 3 m).
- free cross-ventilation occurs and fume dispersion is not obstructed by the workpiece, partitions or screens.
- the workplace has adequate general ventilation.
- the operators are able to keep their heads out of the pollutant plume.

2.3 Limited work space
A limited work space is one which does not comply with all the requirements of an open work space, but is not a confined work space.

2.4 Confined work space
A confined work space is one which is not a normal work area and which meets the criteria listed in AS 2865, Safe Work in a Confined Space.

Note that AS 2865 includes specific recommendations on hot work (e.g. welding) in confined spaces.

3. FUME GENERATION
The constituents of the welding fume are generated in one of three ways: from the filler metal and flux, from the parent plate or its contaminants, or from the action of ultraviolet radiation from a welding arc on the surrounding air.

Particulates are produced only in the immediate vicinity of the heat source. They are largely confined to the plume of heated gases which rises from the weld zone. This plume is often visible to an observer, although not to the welder.

The gaseous decomposition products of contaminants remaining on the workpiece are more widely distributed, and are generated from the heated portions of the workpiece.
Ozone is generated in a volume of the atmosphere beyond the arc zone. It is not concentrated in the plume to the same extent as particulates. Most welding processes with a visible arc generate levels of ozone which place the welder at some risk of exceeding the exposure standard unless controls are implemented.

Oxides of nitrogen may also be generated by reactions in the air immediately adjacent to the welding zone. The tests conducted by the Working Group on Fume showed that oxides of nitrogen are unlikely to be generated at levels approaching exposure standards in welding processes. Oxides of nitrogen may be a problem with plasma cutting processes using nitrogen additions to the shielding gas.

4. GENERAL VENTILATION
It is essential that the general ventilation of the workplace is adequate to prevent the accumulation of hazardous substances in the atmosphere. This protects both operators and other workers from exposure to excessive (general fume) levels. It may be preferable to remove fume directly from the source where it is generated, using a ventilated booth or local exhaust ventilation. The latter systems must be designed carefully and used properly to ensure that fume exhaust is adequate.

It may be necessary to consult a ventilation or air conditioning engineer on system design and operation.

5. CONTROL MEASURES
Control measures to minimise worker exposure to hazardous substances should recognise the need to protect both the operator of a particular process, and other workers in the workplace.

Where a process would expose workers beyond the limits given in state regulations, the control method chosen should follow the hierarchy given in Guidance Note For the Assessment Of Health Risks Arising From The Use Of Hazardous Substances In The Workplace [NOHSC 3017: 1994], viz.

- change to a process which produces less fume
- modify the process to produce less fume
- remove all workers from the location of the hazardous fume
- apply engineering control methods. These usually need to be considered separately for each worker in a workplace. They include:-
  - preventing the fume entering the breathing zone by use of a cross draft
  - capturing the fume locally, before it enters the breathing zone
- use personal protective equipment.

Many welding situations will require a combination of these methods.

5.1 Processes producing less fume
Guidelines 4 to 16 indicate the potential of each process to produce fume. The lower fume process must be further evaluated to determine the need for further controls.

5.2 Modification of processes for less fume
- The modification of shielding gas by changing the species in the gas mixture, or their balance, or by introducing reactive components, can be used to reduce fume.
- Because the bulk of fume in arc processes is generated by the energy of the arc, significant reductions in fume generation rates can be obtained by reducing the energy of the arc.

Unfortunately, the size of these effects cannot be reliably predicted from current knowledge, and these fume control methods must be supported by measurements of workers fume exposure.

5.3 Isolate workers from the hazardous fume
Automation of processes allows workers to be remote from the source of all fume components. General ventilation of the workplace must then be adequate to prevent an excessive increase of background levels of fume.
5.4 Engineering control methods

There are two types of control methods:
- breathing zone ventilation where hazardous substances are prevented from entering the operators breathing zone by a cross draft of air
- local exhaust ventilation, where some or most of the hazardous substances are captured at source.

5.4.1 Breathing zone ventilation/mechanical dilution

This control is intended to prevent pollutants entering the operators breathing zone by sweeping them away with a cross draft of air. A minimum cross draft away from the operators breathing zone of 0.5m/s will ensure protection against particulate and ozone. A pedestal fan is generally adequate for this purpose.

All workers in the workplace must be positioned to avoid fume from other operators, and an adequate level of general ventilation must be provided. Inexpensive instruments for the measurement of air velocity are available from suppliers of fume extractors, air conditioning and laboratory equipment.

5.4.2 Local exhaust ventilation

Local exhaust ventilation (LEV) captures fume at its source before it enters the operators breathing zone or the workshop atmosphere. LEV should be positioned to capture the plume in which the particulates are concentrated.

A minimum capture velocity of 0.5m/s, measured at the fume source is required for protection of the welder from particulate and ozone generated near the arc.

High air velocities at the fume extractor lead to greater efficiency of capture of fumes. Most gas shielded welding processes can tolerate air velocities around the weld zone of about 2 m/s. Where adequate welds cannot be made due to disturbance of the gas shield by fume extraction, the shielding gas flow rate may be increased, or the process may be changed, or the welder may be supplied with personal protective equipment (PPE).

Exhaust fume from LEV equipment should be adequately filtered, including for ozone, if it is to be discharged into the workplace. If it is to be discharged outside the workplace, the relevant environmental regulations should be followed, and it should be isolated from any air intake to the workplace.

Ozone generated between the arc and the operators breathing zone may require additional control measures.

<table>
<thead>
<tr>
<th>EXTRATION TYPE</th>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stand alone hoods</td>
<td>• long capture distance so does not interfere with worker</td>
<td>• has to be moved around in line with the work, and as a result may not always be used</td>
</tr>
<tr>
<td>(e.g. articulated arms, or magnetic hose kits)</td>
<td>• high flow design so will capture/extract high fume concentrations</td>
<td>• generally has a higher cost per worker</td>
</tr>
<tr>
<td>On tool (e.g. fume extraction welding torch,</td>
<td>• automatically used whenever work is done</td>
<td>• adds weight to the tool / handpiece, and reduces flexibility</td>
</tr>
<tr>
<td>or on-tip soldering extraction)</td>
<td>• high pressure/low flow design uses small diameter hoses, with easier design/installation requirements</td>
<td>• may not capture all fume (e.g. fume off sparks, residual fume when welding/soldering finished)</td>
</tr>
<tr>
<td></td>
<td>• generally has a lower cost per worker</td>
<td>• requires careful set up to capture fume without stripping away shielding gases and regular service to maintain performance</td>
</tr>
<tr>
<td>In-bench/fixed (e.g. downdraft or slot benches, solder fume enclosure systems)</td>
<td>• automatically used whenever work is done</td>
<td>• reduced flexibility</td>
</tr>
<tr>
<td></td>
<td>• combines work top/bench with extraction system</td>
<td>• only suitable for work on smaller items</td>
</tr>
<tr>
<td></td>
<td>• suitable for high velocity fume applications such as oxy-cutting</td>
<td>• generally has a higher cost per worker</td>
</tr>
<tr>
<td>Overhead canopy hoods</td>
<td>• low cost</td>
<td>• rising fume generally travels straight through the workers breathing zone</td>
</tr>
</tbody>
</table>
5.5 **PPE control methods**

Various styles of respirators are available. When deciding on respirators as a control method, consideration must be given to fellow workers who may also be exposed to fume, and any effect on equipment maintenance or performance caused by the fume. Care must also be taken regarding hygiene, maintenance and correct facial fit. Respirators must filter both particulates and ozone.

There are two basic types of respirator: air purifying or air supplied. Refer to AS1715, Selection, Use and Maintenance of Respiratory Protection Devices, for more details.

<table>
<thead>
<tr>
<th>TYPE</th>
<th>STYLE</th>
<th>FEATURES/APPLICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Purifying</td>
<td>Disposable</td>
<td>Lightweight, maintenance free.</td>
</tr>
<tr>
<td></td>
<td>Maintainable</td>
<td>Suitable for more prolonged use, though with the same protection factor as disposables. Various replaceable filter cartridges available to suit particular pollutants.</td>
</tr>
<tr>
<td></td>
<td>Powered air purifying respirators (PAPR)</td>
<td>Battery powered units which draw air through replaceable filters. Higher protection factor. Can be worn for long periods as they have no breathing resistance, and deliver a constant flow of air to the wearers face. Incorporated in the actual welding helmet or visor.</td>
</tr>
<tr>
<td>Air Supplied</td>
<td>Air line</td>
<td>Breathable air supplied from a compressor through an airline system. Requires a filter/regulator unit to control/clean the air. Incorporated in the actual welding helmet.</td>
</tr>
<tr>
<td></td>
<td>Self contained breathing apparatus (SCBA).</td>
<td>Air supplied from a back pack tank, for situations where airline systems are not possible.</td>
</tr>
</tbody>
</table>

5.6 **Relative cost and availability**

An indication of the relative cost and availability of the various control measures is provided below.
<table>
<thead>
<tr>
<th>Welder Protection Options</th>
<th>Low end</th>
<th>High end</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Air movement</strong></td>
<td>Unfiltered</td>
<td>800</td>
<td>Blower only</td>
</tr>
<tr>
<td></td>
<td>Filtered</td>
<td>2,700</td>
<td>Extractor and arm (1.0m)</td>
</tr>
<tr>
<td><strong>Stand alone hoods</strong></td>
<td>Unfiltered</td>
<td>2,900</td>
<td>Extractor and arm (1.0m)</td>
</tr>
<tr>
<td><strong>Fume arm extraction</strong></td>
<td>Filtered</td>
<td>2,900</td>
<td>Extractor and arm (1.0m)</td>
</tr>
<tr>
<td><strong>On tool</strong></td>
<td>Filtered</td>
<td>2,400</td>
<td>Extractor and attachment</td>
</tr>
<tr>
<td><strong>On-gun extraction</strong></td>
<td>Filtered</td>
<td>2,400</td>
<td>Extractor and attachment</td>
</tr>
<tr>
<td><strong>In-bench fixed</strong></td>
<td>Filtered</td>
<td>5,000</td>
<td>Un-ducted</td>
</tr>
<tr>
<td><strong>Downdraft benches</strong></td>
<td>Filtered</td>
<td>3,100</td>
<td>Ducted</td>
</tr>
<tr>
<td><strong>Overhead canopy hood</strong></td>
<td>Filtered</td>
<td>5,600</td>
<td>Un-ducted</td>
</tr>
<tr>
<td><strong>Extraction hood</strong></td>
<td>Filtered</td>
<td>3,100</td>
<td>Ducted</td>
</tr>
<tr>
<td><strong>Disposable P2 Respirator</strong></td>
<td></td>
<td>3.20</td>
<td></td>
</tr>
<tr>
<td><strong>Half face Respirator</strong></td>
<td></td>
<td>40</td>
<td>Mask</td>
</tr>
<tr>
<td></td>
<td></td>
<td>90</td>
<td>Mask</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P2 Filters Cartridge</td>
<td>13 17</td>
</tr>
<tr>
<td><strong>Powered Air Purifying Respirator (PAPR)</strong></td>
<td></td>
<td>900</td>
<td>1,800</td>
</tr>
<tr>
<td><strong>Air line respirator</strong></td>
<td></td>
<td>600</td>
<td>1,200</td>
</tr>
</tbody>
</table>

Availability: All alternatives are readily available in Australia. They are either locally made or imported. They can be purchased direct from the local manufacturer or their distributors and agents. eg Industrial and welding product suppliers or safety products distributors, etc.

Most stand-alone products require no special installation procedures other than the need to ensure sufficient power is available. Some ducted units may require the need of a mechanical services contractor or other skilled tradesman. Design of more elaborate systems can usually be supplied by the manufacturer, mechanical services contractor or a skilled engineer. It is not unusual for the manufacturer or their local agent to perform this task as part of the service.
GUIDELINE 3: MATERIALS

1. INTRODUCTION
The potential hazards associated with base materials and consumables are detailed in material safety data sheets (MSDS) which are available from the supplier. This guideline gives a general indication of the effect of the material on fume hazard and may be helpful in situations where MSDS are not available for example in the case of coatings.

2. TYPES OF FUME
The materials found in fume consist of:
- **Particulates**
  - metal and metal oxides, lead from paint
  - inorganic fluxes yielding halide salts
- **Gases and liquids**
  - added and photo-oxidant gases
  - from coatings, paints and solvents, which can generate gases such as phosgene
  - fluxes from colophony or rosin which can give rise to hydrocarbons, formaldehyde, hydrochloric acid, benzene, styrene, acetone and other chemicals
  - inorganic fluxes yielding halide acids

3. SOURCES OF FUME
Materials present in fumes may come from the following sources:
- Consumable – most of the metal fume comes from the consumable
- Surface coatings or surface preparations
- Gases which are added - such as carbon dioxide, argon, helium
- Gases formed by electric arcs - such as ozone and oxides of nitrogen
- Parent metal

It is necessary to consider all these sources to determine the materials in your fume.

4. EXPOSURE STANDARDS
The ratio of substances in fume is not equal to the ratio of the input sources. Some elements, which are more volatile than iron, can appear in greater quantity in the fume.

The exposure standard for welding fume is 5mg/m$^3$, although some individual component metals (e.g. chromium VI in stainless steel) have lower limits which should be observed. In non-ventilated laboratory tests, most welding processes result in a breathing zone concentration greater than the exposure standard. The exposure standard for ozone is 0.1 ppm and in similar non-ventilated trials, this level was commonly exceeded. The exposure standard for solder flux (pyrolised rosin as formaldehyde) is 0.1mg/m$^3$. It is usual for this concentration to be exceeded in poorly or non-ventilated workshops.

5. CONSUMABLES
- Consumables generally contain metals and also various elements, which assist the process and protect the weld from the atmosphere.
- Brazing fluxes contain mixtures of potassium bifluorides and borates. Fluorosilicates, boron, sodium aluminium fluoride and sodium fluoride may be present in specific formulations. Aggressive soldering fluxes contain inorganic salts often with hydrochloric acid as well as fluorides and fluoroborates, orthophosphoric acid and glycerin. Less aggressive solder fluxes contain organic compounds which decompose at soldering temperatures. They may contain hydrazine monohydrobromide, lactic acid, glutamic acid, hydrochloric acid and wetting agents. Non corrosive fluxes, typically used in electronic applications, are based on rosin in water or solvent and may contain halide or organic acid activator additions. Colophony is rosin.
- Submerged arc welding gives off minimal fume, but care needs to be taken to avoid dust when handling the flux.

Remember to refer to the MSDS, which is available from your consumable supplier.

6. COATINGS
Metals can be coated with plastics, polyurethane, epoxy materials, paint or other metals. Common examples include primers with rust preventatives, galvanised steel and chrome plating. Particular care must be taken for cadmium coatings, which are highly toxic. If it is not possible to identify the coating, fume control must be employed.

For welding, a 20-25mm band should be removed prior to welding. For flame cutting, this band should be 50-100mm.
1. **Metallic coatings**: galvanising (zinc), sprayed coatings (aluminium, zinc and others), electroplating (chromium with copper and nickel underlays, cadmium, zinc or tin) are common.

2. **Paints**: give off a complex mixture. Lead, zinc, chromium, cadmium and other metals may arise from pigments and resins.

3. **Plastics**: give off a complex mixture. Ammonia, hydrochloric acid, carbon dioxide, cyanides can arise. These can be irritant, corrosive, asphyxiating and toxic.

7. **SURFACE PREPARATIONS**
Chlorinated hydrocarbons like trichloroethylene, perchloroethylene, trichloroethane, acetone and freons are used as degreasing agents. Do not breathe vapours of these agents. Chlorinated hydrocarbons and freons, under certain conditions, can decompose to form phosgene, which is highly toxic. Care must be taken to dry the surface before welding.

8. **MAJOR CLASSES OF METALS**

* **Mild steel may contain**
  - iron, carbon, manganese, silicon, aluminium
  - Occasionally nickel, chromium, molybdenum, niobium, vanadium, boron

* **Stainless steels may contain**
  - iron, chromium and nickel
  - Occasionally molybdenum, manganese, titanium and other elements

* **Aluminium may contain**:
  - aluminium, silicon, iron, copper, manganese, chromium, zinc, titanium
  - Occasionally gallium, vanadium and/or boron in wrought alloys
  - Occasionally tin and/or lead in cast alloys

* **Copper, bronze and brass alloys may contain**
  - copper, zinc, nickel, aluminium, tin, lead, silicon, iron
  - Occasionally manganese, tellurium, sulphur, chromium, cadmium, beryllium, silver, cobalt

The specific quantities of additions will vary with the grade of material selected. The relevant industry associations listed in the introduction to these guidelines should be contacted for further information if required.
List of Atmospheric Contaminants, Worksafe Australia’s Exposure Standards, and the medical effects.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Type</th>
<th>Type</th>
<th>TWA</th>
<th>STEL</th>
<th>Carcinogen Category</th>
<th>Medical Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>Fume</td>
<td>Al</td>
<td>5</td>
<td>2</td>
<td></td>
<td>Respiratory irritant</td>
</tr>
<tr>
<td>Barium</td>
<td>Sol. compounds</td>
<td>Ba</td>
<td>0.5</td>
<td>2</td>
<td></td>
<td>Respiratory tract and skin irritant, benign pneumoconiosis with heavy exposure</td>
</tr>
<tr>
<td>Beryllium</td>
<td>&amp; compounds</td>
<td>Be</td>
<td>0.002</td>
<td>2</td>
<td></td>
<td>Very toxic, damages respiratory tract, quick acting, carcinogenic</td>
</tr>
<tr>
<td>Boron oxide</td>
<td></td>
<td></td>
<td>10</td>
<td>2</td>
<td></td>
<td>Eye and respiratory irritant</td>
</tr>
<tr>
<td>Cadmium</td>
<td>&amp; compounds</td>
<td>Cd</td>
<td>0.01</td>
<td>2</td>
<td></td>
<td>Very toxic; lung and kidney damage. Quick acting, may be fatal</td>
</tr>
<tr>
<td>Calcium Oxide</td>
<td>Fume</td>
<td>CaO</td>
<td>2</td>
<td>2</td>
<td></td>
<td>Irritant of eyes, mucous membranes and skin</td>
</tr>
<tr>
<td>Chromium</td>
<td>Compounds</td>
<td>Cr(II)&amp;(III)</td>
<td>0.5</td>
<td>1</td>
<td></td>
<td>Toxic, damages respiratory tract, corrosive to skin</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cr(VI)</td>
<td>0.05</td>
<td></td>
<td></td>
<td>Carcinogenic</td>
</tr>
<tr>
<td>Cobalt</td>
<td>Metal dust &amp; fume</td>
<td>Co</td>
<td>0.05</td>
<td>2</td>
<td></td>
<td>Irritant, fibrosis of the lung, sensitizer</td>
</tr>
<tr>
<td>Copper</td>
<td>Fume</td>
<td>Cu</td>
<td>0.2</td>
<td>2</td>
<td></td>
<td>Metal fume fever</td>
</tr>
<tr>
<td>Fluorides</td>
<td></td>
<td>F</td>
<td>2.5</td>
<td>2</td>
<td></td>
<td>Irritant of eyes, mucous membranes, skin and lungs</td>
</tr>
<tr>
<td>Iron Oxide</td>
<td>Fume</td>
<td>Fe₂O₃</td>
<td>5</td>
<td>1</td>
<td></td>
<td>Siderosis (no long term effects)</td>
</tr>
<tr>
<td>Lead</td>
<td>Fume</td>
<td>Pb</td>
<td>0.15</td>
<td>1</td>
<td></td>
<td>Affects the nervous system, digestive system, and mental capacity</td>
</tr>
<tr>
<td>Magnesium Oxide</td>
<td>Fume</td>
<td>MgO</td>
<td>10</td>
<td>2</td>
<td></td>
<td>Irritant, metal fume fever</td>
</tr>
<tr>
<td>Manganese</td>
<td>Fume</td>
<td>Mn</td>
<td>1</td>
<td>3</td>
<td></td>
<td>Toxic, tiredness, pneumonia, psychotic behaviour</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>Sol. Compounds</td>
<td>Mo</td>
<td>5</td>
<td>1</td>
<td></td>
<td>Irritant</td>
</tr>
<tr>
<td></td>
<td>Insol. Compounds</td>
<td></td>
<td>10</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nickel</td>
<td>Metal</td>
<td>Ni</td>
<td>1</td>
<td>1</td>
<td></td>
<td>Metal fume fever, possible carcinogen</td>
</tr>
<tr>
<td></td>
<td>Sol. compounds</td>
<td></td>
<td>0.1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen Dioxide</td>
<td></td>
<td>NO₂</td>
<td>3</td>
<td>1</td>
<td></td>
<td>Irritant</td>
</tr>
<tr>
<td>Ozone</td>
<td></td>
<td>O₃</td>
<td>0.1</td>
<td>1</td>
<td>Peak Limitation</td>
<td>Irritant of the respiratory tract and lungs.</td>
</tr>
<tr>
<td>Phosphoric acid</td>
<td></td>
<td>H₃PO₄</td>
<td>3</td>
<td>1</td>
<td></td>
<td>Mild irritant of the eyes, upper respiratory tract and skin.</td>
</tr>
<tr>
<td>Potassium Hydroxide</td>
<td></td>
<td>KOH</td>
<td>2</td>
<td>1</td>
<td>Peak Limitation</td>
<td>Severe irritant of eyes, mucous membrane, and skin</td>
</tr>
<tr>
<td>Selenium</td>
<td>Compounds</td>
<td>Se</td>
<td>0.2</td>
<td>1</td>
<td></td>
<td>Irritant of eyes, mucous membranes and skin. Central nervous system effects with chronic exposure.</td>
</tr>
<tr>
<td>Silica</td>
<td>Respirable dust</td>
<td>SiO₂</td>
<td>2</td>
<td>1</td>
<td></td>
<td>Fever, similar to metal fume fever</td>
</tr>
<tr>
<td>Sodium Hydroxide</td>
<td></td>
<td>NaOH</td>
<td>2</td>
<td>1</td>
<td>Peak Limitation</td>
<td>Severe irritant of eyes, mucous membrane, and skin</td>
</tr>
<tr>
<td>Tin</td>
<td>Oxide &amp; inorganic compounds</td>
<td>Sn</td>
<td>2</td>
<td>1</td>
<td>Peak Limitation</td>
<td>Stannosis, a rare benign pneumoconiosis</td>
</tr>
<tr>
<td>Titanium Dioxide</td>
<td></td>
<td>TiO₂</td>
<td>10</td>
<td>2</td>
<td></td>
<td>Mild respiratory irritant</td>
</tr>
<tr>
<td>Vanadium Pentoxide</td>
<td>Respirable dust &amp; fume</td>
<td>V₂O₅</td>
<td>0.05</td>
<td>1</td>
<td></td>
<td>May cause tremor and depression of central nervous system</td>
</tr>
<tr>
<td>Zinc Oxide</td>
<td>Fume</td>
<td>ZnO</td>
<td>5</td>
<td>10</td>
<td></td>
<td>Metal fume fever, bronchitis</td>
</tr>
<tr>
<td>General Fume</td>
<td></td>
<td></td>
<td>5</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Metal fume fever** - The fumes of several metals and their oxides can give rise to metal fume fever. Fever, nausea, cough, shivering, headache, muscle ache, shortness of breath and general malaise may occur. The condition may start a few hours after the end of the working day, and last a day or so. The fever subsides spontaneously and no chronic effects result.

**Other health effects** - Certain alloying elements may result in further health complication.
GUIDELINE 4: MANUAL METAL ARC WELDING (MMAW)

An employer has a duty to ensure that a suitable and sufficient assessment is made where there is potential for exposure to hazardous substances. It should be noted that in tests conducted under still air conditions, breathing zone fume from MMAW usually exceeds the recommended levels (see Figure 1). No special measures may be necessary to protect the operator provided clean air movement is greater than 0.5 m/s across the welders breathing zone (see Figure 2). Accumulation of fumes in the workshop must be prevented by general ventilation.

Have satisfactory results been obtained from a simple and obvious assessment? (see guideline 1)

Yes

Document the results of the assessment. Ensure controls identified to minimise exposure are maintained. Reassess if conditions change or every 5 years whichever is shorter. See Guideline 1 for further details.

No

Have satisfactory results been obtained from a detailed workplace assessment? (see guideline 1)

Yes

No

Some form of fume control is required. See Guidelines 2 and 3 for further details.

Steps To Reduce The Effect Of Fumes And Gases

• Process Alternatives
  1) Consider using GMAW, FCAW, SAW or GTAW as these processes may be mechanised and/or on gun fume extraction is available. Higher capital costs are often offset by higher productivity.

• Process Modifications
  1) Arrange welding to reduce welders exposure as shown in Figure 3. This also reduces fatigue and back problems.
Figure 1. MMAW fume production at the breathing zone under still air conditions compared to the regulations (not to scale).

Figure 2. Preferred and non–preferred direction of cross draft for breathing zone ventilation.

Figure 3. The welder's head should not enter the visible fume plume.
GUIDEline 5: Gas Metal Arc Welding (GMAW)

An employer has a duty to ensure that a suitable and sufficient assessment is made where there is potential for exposure to hazardous substances. It should be noted that in tests conducted under still air conditions, breathing zone fume from GMAW usually exceeds the recommended levels (see Figure 1). No special measures may be necessary to protect the operator provided clean air movement is greater than 0.5 m/s across the welders breathing zone (see Figure 2). Accumulation of fumes in the workshop must be prevented by general ventilation.

Have satisfactory results been obtained from a simple and obvious assessment? (see guideline 1)

Yes
- Document the results of the assessment. Ensure controls identified to minimise exposure are maintained. Reassess if conditions change or every 5 years whichever is shorter. See Guideline 1 for further details.

No

Have satisfactory results been obtained from a detailed workplace assessment? (see guideline 1)

Yes

No

Some form of fume control is required. See Guidelines 2 and 3 for further details.

Steps To Reduce The Effect Of Fume And Gases

- **Process Alternatives**
  2) Consider using SAW for flat position seams in heavier material. Higher capital costs are often offset by higher productivity.

- **Process Modifications**
  2) Arrange welding to reduce welders exposure as shown in Figure 3. This also reduces fatigue and back problems.
  3) Consider using alternative shielding gases (Argon/Helium mixtures reduce ozone and, for steel, Argon/CO₂ may reduce particulate).
  4) Mechanize the process using simple tractors, turntables or robots.
Australian Exposure Standard

Particulate /mg.m$^3$

Australian Exposure Standard

Ozone /ppm

Figure 1. GMAW fume production at the breathing zone under still air conditions compared to the regulations (not to scale).

Figure 2. Preferred and non-preferred direction of cross draft for breathing zone ventilation.

Figure 3. The welder’s head should not enter the visible fume plume.
GUIDELINE 6: GAS TUNGSTEN ARC WELDING (GTAW)

An employer has a duty to ensure that a suitable and sufficient assessment is made where there is potential for exposure to hazardous substances. It should be noted that in tests conducted under still air conditions, breathing zone fume from GTAW usually exceeds the recommended levels (see Figure 1). No special measures may be necessary to protect the operator provided clean air movement is greater than 0.5 m/s across the welders breathing zone (see Figure 2). Accumulation of fumes in the workshop must be prevented by general ventilation.

Have satisfactory results been obtained from a simple and obvious assessment? (see guideline 1)

Yes
Document the results of the assessment. Ensure controls identified to minimise exposure are maintained. Reassess if conditions change or every 5 years whichever is shorter. See Guideline 1 for further details.

No

Have satisfactory results been obtained from a detailed workplace assessment? (see guideline 1)

Yes

No

Some form of fume control is required. See Guidelines 2 and 3 for further details.

Steps To Reduce The Effect Of Fumes And Gases

- **Process Alternatives**
  3) Laser and electron beam welding may be viable but higher capital costs must be offset by higher productivity.

- **Process Modifications**
  5) Arrange welding to reduce welders exposure as shown in Figure 3. This also reduces fatigue and back problems.
  6) Consider using alternative shielding gases (Argon/Helium mixtures reduce ozone in aluminium welding and Argon/Hydrogen may be used to reduce ozone levels with austenitic stainless steel).
  7) Mechanise or automate the process.
Figure 1. GTAW fume production at the breathing zone under still air conditions compared to the regulations (not to scale).

Figure 2. Preferred and non-preferred direction of cross draft for breathing zone ventilation.

Figure 3. The welder’s head should not enter the visible fume plume.
GUIDELINE 7: FLUX CORED ARC WELDING (FCAW)

An employer has a duty to ensure that a suitable and sufficient assessment is made where there is potential for exposure to hazardous substances. It should be noted that in tests conducted under still air conditions, breathing zone fume from FCAW usually exceeds the recommended levels (see Figure 1). No special measures may be necessary to protect the operator provided clean air movement is greater than 0.5 m/s across the welders breathing zone (see Figure 2). Due to the high levels of fume generated, there is a greater likelihood of co-workers exposure exceeding the relevant exposure standards unless good general ventilation is implemented. Particular care should be taken with self shielded hardfacing wires which are normally expected to be used outdoors.

Steps To Reduce The Effect Of Fumes And Gases

- **Process Alternatives**
  4) Consider using SAW or GMAW for flat position seams in heavier material and for hardfacing. Higher capital costs are often offset by higher productivity.

- **Process Modifications**
  8) Arrange welding to reduce welders exposure as shown in Figure 3. This also reduces fatigue and back problems.
  9) Consider using alternative shielding gases (Argon/Helium mixtures reduce ozone and Argon/CO$_2$ may reduce particulate fume).
  10) Mechanize the process using simple tractors, turntables or robots.

<table>
<thead>
<tr>
<th align="left">Have satisfactory results been obtained from a simple and obvious assessment? (see guideline 1)</th>
<th align="left">Yes</th>
</tr>
</thead>
<tbody>
<tr>
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<td align="left"></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th align="left">Have satisfactory results been obtained from a detailed workplace assessment? (see guideline 1)</th>
<th align="left">Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td align="left">No</td>
<td align="left"></td>
</tr>
</tbody>
</table>

**Some form of fume control is required.**
See Guidelines 2 and 3 for further details.

Document the results of the assessment. Ensure controls identified to minimise exposure are maintained. Reassess if conditions change or every 5 years whichever is shorter. See Guideline 1 for further details.
Figure 1. FCAW fume production at the breathing zone under still air conditions compared to the regulations (not to scale).

Figure 2. Preferred and non–preferred direction of cross draft for breathing zone ventilation.

Figure 3. The welder’s head should not enter the visible fume plume.
GUIDELINE 8: HARDFACING

An employer has a duty to ensure that a suitable and sufficient assessment is made where there is potential for exposure to hazardous substances. It should be noted that in tests conducted under still air conditions, fume from FCAW hardfacing operations usually exceeds the recommended levels (see Figure 1). No special measures may be necessary to protect the operator provided clean air movement is greater than 0.5 m/s across the welders breathing zone (see Figure 2). Due to the high levels of fume generated, there is a greater likelihood of co-workers exposure exceeding the relevant exposure standards unless good general ventilation is implemented.

Hardfacing consumables are often highly alloyed and fumes may contain significant levels of manganese and chromium. See Guideline 3 for relevant exposure standards.

Have satisfactory results been obtained from a simple and obvious assessment? (see guideline 1)

No

Have satisfactory results been obtained from a detailed workplace assessment? (see guideline 1)

No

Some form of fume control is required. See Guidelines 2 and 3 for further details

Yes

Document the results of the assessment. Ensure controls identified to minimise exposure are maintained. Reassess if conditions change or every 5 years whichever is shorter. See Guideline 1 for further details.

Steps To Reduce The Effect Of Fumes And Gases

- **Process Alternatives**
  5) Consider using wearplate or alternate processes such as submerged arc surfacing. Gas Metal Arc and Gas Tungsten Arc surfacing both produce less fume than "open arc" processes.

- **Process Modifications**
  11) Arrange welding to reduce welders exposure as shown in Figure 3. This also reduces fatigue and back problems.
  12) Mechanise the process using simple tractors, turntables or robots.
Figure 1. Hardfacing fume production at the breathing zone under still air conditions compared to the regulations (not to scale).

Figure 2. Preferred and non–preferred direction of cross draft for breathing zone ventilation.

Figure 3. The welder’s head should not enter the visible fume plume.
GUIDELINE 9: PLASMA CUTTING

An employer has a duty to ensure that a suitable and sufficient assessment is made where there is potential for exposure to hazardous substances. It should be noted that in tests conducted under still air conditions, breathing zone fume from plasma cutting usually exceeds the recommended levels (see Figure 1). No special measures may be necessary to protect the operator provided clean air movement is greater than 0.5 m/s across the operators breathing zone (see Figure 2). Accumulation of fumes in the workshop must be prevented by general ventilation. Oxides of nitrogen may be a problem with plasma cutting processes using nitrogen additions to the shielding gas.

Have satisfactory results been obtained from a simple and obvious assessment? (see guideline 1)

Yes

Document the results of the assessment. Ensure controls identified to minimise exposure are maintained. Reassess if conditions change or every 5 years whichever is shorter. See Guideline 1 for further details.

No

Have satisfactory results been obtained from a detailed workplace assessment? (see guideline 1)

Yes

No

Some form of fume control is required. See Guidelines 2 and 3 for further details

Steps To Reduce The Effect Of Fumes And Gases

- **Process Alternatives**

  6) Consider guillotining, laser cutting, mechanical cutting or water jet cutting.

- **Process Modifications**

  13) Arrange cutting to reduce operators exposure as shown in Figure 3. This also reduces fatigue and back problems.

  14) Plasma cutting is easily mechanised and readily automated.

**Note:**
Automatic cutting processes (water table or travelling head) are beyond the scope of this guideline. Please consult the manufacturer for safe use of automated plasma cutting equipment.
Figure 1. Plasma cutting fume production at the breathing zone under still air conditions compared to the regulations.

Figure 2. Preferred and non–preferred direction of cross draft for breathing zone ventilation.

Figure 3. The operator’s head should not enter the visible fume plume.
GUIDELINE 10: OXY-FUEL CUTTING

An employer has a duty to ensure that a suitable and sufficient assessment is made where there is potential for exposure to hazardous substances. It should be noted that in tests conducted under still air conditions, breathing zone fume from oxy-fuel cutting usually exceeds the recommended levels (see Figure 1). No special measures may be necessary to protect the operator provided clean air movement is greater than 0.5 m/s across the operators breathing zone. Accumulation of fumes in the workshop must be prevented by general ventilation.

Steps To Reduce The Effect Of Fumes And Gases

• Process Alternatives
  7) Consider guillotining, plasma cutting, mechanical cutting or water jet cutting.

• Process Modifications
  15) Arrange cutting to reduce operators exposure as shown in Figure 3. This also reduces fatigue and back problems.
  16) Oxy-fuel cutting is easily mechanised and readily automated. Guide wheels are available for manual cutting torches.
Figure 1. Oxy-fuel cutting fume production at the breathing zone under still air conditions compared to the regulations.

Figure 2. Preferred and non-preferred direction of cross draft for breathing zone ventilation.

Figure 3. The welder’s head should not enter the visible fume plume.
GUIDELINE 11: LOW FUME LEVEL PROCESSES

Low Fume Processes:

- Submerged arc welding (SAW)
- Electroslag welding
- Water jet cutting
- Resistance welding eg. spot, seam and projection welding
- High frequency induction welding
- Friction welding
- Ultrasonic welding
- Semi automatic stud welding

Materials:

All materials known not to contain beryllium or cadmium as an alloying element or as a coating, and not contaminated with solvents, oil or grease. See Guideline 3.

Explanation:

Atmospheric contaminants are generated only in small quantities by these processes, because either:

- The arc region is protected by a heavy slag blanket, which filters out metallic fume and prevents the formation of significant gaseous fume (ozone and oxides of nitrogen) by ultraviolet radiation from the arc (SAW welding), or
- The process does not use an arc (all the other processes in the list).

In addition, all of these processes are automatic or semiautomatic, and do not require the operator to be close to the work.

<table>
<thead>
<tr>
<th>Is Fume Control Required?</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All fume levels were well below Australian Exposure Standards.</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Are there any exceptions?</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accumulation of fumes in the workshop must be prevented by general ventilation. See Guideline 2.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>For materials containing beryllium or cadmium, or contaminated with solvents, oil or grease see Guideline 3.</strong></td>
<td></td>
</tr>
</tbody>
</table>
GUIDELINE 12: BRAZING AND SOLDERING – PLUMBING INDUSTRY

SCOPE
Covers the brazing and soldering of copper and brass tube for plumbing, drainage, gas fitting, air conditioning, refrigeration, fire and mechanical services.

MATERIALS
Brass and copper tube made from phosphorus deoxidised copper, high residual phosphorus alloy C12200 and 70/30DR arsenical brass alloy C26130 (alloy 259).

Covers solder and silver brazing alloys which comply with Joint Australian/New Zealand Plumbing Code AS/NZS3500 1.2 Water Supply. Soft solder must be "lead free", i.e. containing not more than 0.1% lead. Silver brazing alloys must be "cadmium free", i.e. containing not more than 0.05% cadmium and a minimum of 1.8% silver.

OVERVIEW
This guideline is based on a two stage research program.

Initial testing was performed by Bakkham Pty Ltd in conjunction with the CDAA. It involved copper/copper, copper/brass, brass/brass, copper/gunmetal in a range of common pipe and fitting sizes, eg. DN15 to DN100. 2% silver solder, 15% silver solder and Aquasafe soft solder (99% tin) were used and where fluxes were required Eziweld, Laco, Yorkshire and Tenacity brands were employed. Further tests were done by CSIRO in conjunction with CRC, WTIA and CDAA using heavy wall large diameter pipe to represent the worst case scenario. Tube sizes were: AS1432 Copper: DN150 Type B (152.40x2.03mm); AS3795 Brass DN100 type D (101.60x1.22mm). All work was conducted at waist level in an enclosed booth 2m x 2m with open top and minimum air movements. Operators kept their head out of the visible plume and samples were taken from the breathing zone for periods over 30 minutes (see Figure 1).

RESULTS

<table>
<thead>
<tr>
<th>Is Fume Control Required?</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>All fume levels were well below Australian Exposure Standards. (see Figure 2)</td>
<td></td>
</tr>
<tr>
<td>Are there any exceptions?</td>
<td>Yes</td>
</tr>
<tr>
<td>For totally closed workspace refer to AS 2865 “Safe Working in a Confined Space”</td>
<td></td>
</tr>
</tbody>
</table>
Figure 1. The operator’s head should not enter the visible fume plume.

Figure 2. Plumbing fume production and analysis at the breathing zone as a percentage of Australian Exposure Standard limits.
GUIDELINE 13: SOFT SOLDERING – ELECTRICAL/ELECTRONIC INDUSTRY

MELTING RANGE (TYPICAL 60Sn 40Pb) 183-190°C

An employer has a duty to ensure that a suitable and sufficient assessment is made where there is potential for exposure to hazardous substances. For non routine repair activities, no special measures may be necessary to protect the operator provided clean air movement is greater than 0.5 m/s across the operators breathing zone. In normal soldering operations a risk assessment is likely to find that there is no significant risk of lead absorption, but control measures must be in place to limit exposure to all flux fumes.

Have satisfactory results been obtained from a simple and obvious assessment? (see guideline 1)

Yes

Document the results of the assessment. Ensure controls identified to minimise exposure are maintained. Reassess if conditions change or every 5 years whichever is shorter. See Guideline 1 for further details.

No

Have satisfactory results been obtained from a detailed workplace assessment? (see guideline 1)

Yes

No

Are process alternatives an option?

Yes

Consider mechanical joining.

No

Some form of fume control is required. See Guidelines 2 and 3 for further details.

Notes:
1. For bench work local exhaust extraction to remove fume before reaching the breathing zone is recommended using tip extraction on soldering irons or articulated arm/suction tube extraction from the workplace. Mobile extraction units or respirators can be used for maintenance (eg. wave solder bath) and field work.
2. Mechanical ventilation should be backed up with complete filtration of fume particulate and gases to avoid recirculation of pollutants into the work environment. Typically a three stage system is used comprising of coarse filter to remove down to 95% of 1 μm, then a high efficiency particle air filter to remove 99.997% of 0.3 μm followed by a gas filter eg. activated carbon.
<table>
<thead>
<tr>
<th>Process</th>
<th>Typical Application</th>
<th>Typical Solders</th>
<th>Typical Fluxes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand soldering iron</td>
<td>General assembly</td>
<td>63/37, 60/40 Sn Pb</td>
<td>Rosin (colophony) with or without halide activator.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50Sn/48.5 Pb/1.5 Cu</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>62 Sn/36Pb/2 Ag</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(low MPt)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plain or flux cored wire</td>
<td></td>
</tr>
<tr>
<td>Wave soldering</td>
<td>PCB plug in devices</td>
<td>63/37,60/40 Sn Pb</td>
<td>Rosin in solvent or “no clean” modified rosin with</td>
</tr>
<tr>
<td></td>
<td></td>
<td>62/36/2Ag (board separately fluxed)</td>
<td>halide free/carboxylic acid activator</td>
</tr>
<tr>
<td>Reflow soldering</td>
<td>PCB surface mount</td>
<td>60Sn/40 Pb solder cream incorporating</td>
<td>“No clean” modified rosin. Halide free activator.</td>
</tr>
<tr>
<td></td>
<td>devices</td>
<td>flux. Screen printed. Reflowed under</td>
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<tr>
<td></td>
<td></td>
<td>inert atmosphere.</td>
<td></td>
</tr>
</tbody>
</table>

**FUME SPECIES**

**Solder**

Metal oxide fumes are usually less than the relevant Australian Exposure Standards at soldering temperature. Lead is poorly absorbed by intact skin but is absorbed if swallowed from dirty hands giving various chronic health effects.

**Rosin Flux**

Formaldehyde, abietic acid, isopropyl alcohol, benzene, toluene, hydrochloric or hydrobromic acid from amine/halide activator. Water soluble resin free fluxes containing phosphorus hexate give hexanoic acid fumes.

**HEALTH EFFECTS**

**Solder Fume**

Headache, nausea, strong respiratory irritation, occupational asthma, adverse lung function.
GUIDELINE 14: GENERAL SOFT SOLDERING

An employer has a duty to ensure that a suitable and sufficient assessment is made where there is potential for exposure to hazardous substances.

For intermittent maintenance work, no special measures may be necessary to protect the operator. For continuous production work, clean air movement exceeding 0.5 m/s across the operators breathing zone may be required. Accumulation of fumes in the workshop must be prevented by general ventilation. Solders containing zinc, cadmium or indium are not covered by this guideline. See Guideline 15. If using flux cored wire containing rosin (colophony) see Guideline 13.

Have satisfactory results been obtained from a simple and obvious assessment? (see guideline 1)

Yes: Document the results of the assessment. Ensure controls identified to minimise exposure are maintained. Reassess if conditions change or every 5 years whichever is shorter. See Guideline 1 for further details.

No: Have satisfactory results been obtained from a detailed workplace assessment? (see guideline 1)

Yes: Investigate alternative solders and/or fluxes.

No: Are process alternatives an option?

Yes: Investigate pretinned components with oven baking, automated or mechanised methods and indirect heating in factory production situations.

No: Are process modifications an option?

Yes: Investigate pretinned components with oven baking, automated or mechanised methods and indirect heating in factory production situations.

No: Some form of fume control is required. See Guidelines 2 and 3 for further details.

Notes:
1. For some production operations one of the types of local exhaust may be required.
2. Under normal circumstances it should be possible to satisfy the regulatory requirements by process and work practice modifications. Known exceptions are still air, confined spaces (see AS 2865 “Safe Working in a Confined Space”) or where particular hazards are identified in Material Safety Data Sheets.
SCOPE

Covers soft soldering in such industrial activities as electro-mechanical assembly, radiator manufacture and repair, battery manufacture, tool and die repair, also arts and crafts.

Materials

Solders

Most commonly, lead/tin solders from 95/5 to 50/50 (melting range 300–315°C to 183–212°C) also lead/silver, lead/silver/tin solders for high temperature strength and corrosion resistance (eg. in electric motors) melting range 296–370°C. Also 96/4 tin/silver for stainless steel and jewellery with good wetting (melting range 220-240°C).

Fluxes

Inorganic, corrosive, general purpose fluxes most commonly contain zinc chloride and ammonium chloride with hydrochloric acid activator but other halide salts and acids, including fluorides, are found in some fluxes. Organic fluxes cover a variety of organic acids also hydrazine hydro bromide, aniline hydrochloride and phosphate which decompose at soldering temperatures. Vehicles range from water to various organic carriers and wetting agents. It is clearly important to consult the manufacturers MSDS for the flux used.

Processes

Heating methods include soldering iron, torch flame, hot dip, induction, resistance, furnace (of assemblies) and infra red.

HEALTH EFFECTS

Metal Fume

Solder alloys containing lead give off negligible lead fume unless overheated (>450°C). Lead is very harmful if absorbed into the body but is not readily absorbed through intact skin. Avoid eating, drinking or smoking in work area and attend to personal hygiene to avoid lead entering by mouth.
Note: In radiator repair shops high blood lead levels are not uncommon due to the absence of local exhaust ventilation and poor hygiene practices.

Flux Fume

Consult relevant MSDS. Exposure to halides is highly irritating to eyes, skin and respiratory tract while chronic exposure to zinc halides can cause lung damage. Ammonium chloride is usually a mild irritant but repeated exposure can lead to occupational asthma. By comparison hydrogen fluoride, bromide and chloride have peak limitation exposure standards. These must not be exceeded even instantaneously.
GUIDE 15: GENERAL INDUSTRIAL BRAZING

An employer has a duty to ensure that a suitable and sufficient assessment is made where there is potential for exposure to hazardous substances. For intermittent work, not involving cadmium, indium or lithium, no special measures may be necessary to protect the operator provided clean air movement is greater than 0.5 m/s across the operators breathing zone. Accumulation of fumes in the workshop must be prevented by general ventilation.

Have satisfactory results been obtained from a simple and obvious assessment? (see guideline 1)
Yes
Document the results of the assessment. Ensure controls identified to minimise exposure are maintained. Reassess if conditions change or every 5 years whichever is shorter. See Guideline 1 for further details.

No
Have satisfactory results been obtained from a detailed workplace assessment? (see guideline 1)
Yes
Replace cadmium containing brazing alloys with equivalent silver-copper-zinc-tin (or nickel) alloys, or “phos copper”. Check for higher zinc oxide fume if substitute alloy has higher zinc content or melting range.

No
Are process alternatives an option?
Yes
Investigate possible automation, preplaced filler, induction or controlled atmosphere brazing.

No
Are process modifications an option?
Yes

No
Some form of fume control is required. See Guidelines 2 and 3 for further details.

Notes:
1. Ventilation by local exhaust will usually be required. In cases where cadmium, indium or lithium fume occurs, personal respiratory protection will also be necessary.
2. Under normal circumstances it should be possible to satisfy the regulatory requirements by process and work practice modifications. Known exceptions are still air, confined spaces (see AS 2865 “Safe Working in a Confined Space”) or where particular hazards are identified in Material Safety Data Sheets.
SCOPE

Covers capillary brazing of iron, copper, nickel and precious metal alloys, indeed all alloys of appropriate melting point that can be successfully fluxed or prevented from oxidation by controlled atmosphere or vacuum furnace heating including dissimilar metals, cemented carbides etc.

Materials

Filler Metals

Filler metals most commonly used fall into one of two broad classes:

1. **Low Temperature Brazing Alloys (melting range 600-850°C)** which include silver solders. These are silver/copper alloys commonly with significant amounts of zinc and cadmium (or tin and nickel) and sometimes manganese for use with certain nickel alloys, stainless steel and cemented carbides. Also included are copper alloys with high phosphorus and usually some silver for self-fluxing brazing of copper (“phos copper”).

2. **High temperature brazing alloys (melting range 890-1085°C)**. These include most commercial grades of copper, some brass and bronzes alloyed with silver and copper alloys with small additions of boron, nickel, manganese and silicon usually for protective atmosphere furnace brazing of steel and carbides. Also a few specialist alloys such as 82/18 gold/nickel for high temperature oxidation resistance are used.

Fluxes

The common silver brazing fluxes are complex mixtures of potassium fluoroborates, bi-fluorides and borates, sometimes with small amounts of potassium hydroxide and chloride. For prolonged heating of steels, particularly stainless and for materials rich in chromium carbide, fluorosilicates and boron are included whilst for aluminium bronzes, sodium aluminium fluoride/sodium fluoride handle the aluminium oxide.

Processes

Torch (with hand fed rod or preplaced filler), automated with gas/air burners, induction and furnace (controlled atmosphere or vacuum) all with preplaced filler and resistance (spot brazing).

HEALTH EFFECTS

Metal Fume

When present, zinc, cadmium and sometimes lithium or indium oxides are the main metal fume constituents. Cadmium is a very toxic metal whose fume in high concentrations causes a range of chest and lung problems which can be fatal. Long term low concentration exposure can affect sense of smell, weight loss and induce emphysema, pulmonary fibrosis, kidney damage and possibly cancer. Using proper heating techniques, fluxing and avoiding overheating, manual torch brazing can give metal and oxide fume from brazing alloy constituents (other than cadmium and zinc) that are low enough to be discounted as health hazards. Excessive exposure to zinc oxide can cause metal fume fever.

Flux Fume

Commonly contain hydrogen fluoride and boron trifluoride also sodium aluminium fluoride and sodium fluoride in some formulations. Dusts of boric acid, potassium hydroxide, potassium chloride and potassium tetraborate can arise dependent on flux type. Toxic and corrosive if swallowed, these fumes (particularly halides) irritate eyes, skin and respiratory tract. Long term exposure to fluoride dusts and vapours can give fluoride poisoning (fluorosis).
GUIDELINE 16: HIGH TEMPERATURE BRAZE WELDING

(APPROXIMATE MELTING POINTS 890-900°C)

An employer has a duty to ensure that a suitable and sufficient assessment is made where there is potential for exposure to hazardous substances. For intermittent maintenance work, no special measures may be necessary. For continuous work, clean air movement greater than 0.5 m/s across the operators breathing zone may be required. Accumulation of fumes in the workshop must be prevented by general ventilation.

Have satisfactory results been obtained from a simple and obvious assessment? (see guideline 1)

Yes

Document the results of the assessment. Ensure controls identified to minimise exposure are maintained. Reassess if conditions change or every 5 years whichever is shorter. See Guideline 1 for further details.

No

Have satisfactory results been obtained from a detailed workplace assessment? (see guideline 1)

Yes

Furnace brazing with controlled atmosphere may be a production alternative.

No

Are process alternatives an option?

Yes

No

Some form of fume control is required. See Guidelines 2 and 3 for further details.

Notes:
1. Ventilation by local exhaust will usually be required. For work performed in a limited or crowded space, supplementary respiratory protection may be needed.
2. Under normal circumstances it should be possible to satisfy the regulatory requirements by process and work practice modifications. Known exceptions are still air, confined spaces (see AS 2865 “Safe Working in a Confined Space”) or where particular hazards are identified in Material Safety Data Sheets.
SCOPE

<table>
<thead>
<tr>
<th>Process</th>
<th>Typical Application</th>
<th>Typical Filler Metal (rod)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Braze Welding</td>
<td>Maintenance brazing of cast iron and steel.</td>
<td>Manganese bronze (AS1167, RCuZn-C)</td>
</tr>
<tr>
<td>Gas (Braze and Fusion) Welding</td>
<td>Braze welding of mild steel for low stress applications and welding of high melting point brass and bronze alloys.</td>
<td>Tobin bronze (AS1167, RCuZn-A)</td>
</tr>
</tbody>
</table>

Fluxes either as rod coating or separately applied, are typically boric acid/sodium metaborate mixtures but some eg. those used for tinning dirty cast iron also contain alkali fluorides.

FUME SPECIES

Filler metal (rod)
Copper, copper oxide, zinc oxide, tin oxide (negligible).

Flux
Boric acid dust, sodium metaborate.

HEALTH EFFECTS

Metal Fume
Prolonged exposure can cause irritation to eyes and nose, and/or metal fume fever. Tin oxide has low toxicity.

Flux Fume
High temperature boric acid fluxes are not significantly absorbed through intact skin or mucosa. With fluorides present, fumes are highly irritating to respiratory tract. Over exposure can cause nose bleeds and fluorosis (fluorine poisoning).

Figure 1. The welder’s head should not enter the visible fume plume.